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Thesis Title:

Using Augmented Reality to Improve Learning in BODY COMBAT Classes

MSc Research & Development Project Report

MSc Computing

Department of Computing

Supervisor: Dr Mark Liptrott

**2016/17**

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…………………………………………………………………………………………………………….

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Paul Hill

For my dear friend, Callum Westbrook, taken unexpectedly and far too young, and for my Grandfather James Nugent who remains my everlasting inspiration, and guiding force.

“I don’t pretend we have all the answers. But the questions are certainly worth thinking about.”

Arthur C. Clarke

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Using Augmented Reality to Improve Learning in BODY COMBAT Classes

**Abstract**

Augmented reality is an emerging technology which has a wide range of practical applications. Current commercial applications of the technology can be found in the form of games that use augmented reality to provide a unique and enjoyable experience to the player. The current research explores the state of the art of the technology and its applicability for learning BODY COMBAT, specifically for self-learning in BODY COMBAT.

The research finds that the single most relevant limitation of the technology is perhaps the limitation of the precision in movement recognition; this is found to impact on the player strategy, and when applied to self-learning in BODY COMBAT, to limit the accuracy of the moves learnt. However, the potential for improvement and positive contribution of the use of the technology is found to be enormous.

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**Chapter 1 – Introduction**

* 1. **Background**

One of the important tasks in learning body combat is for the student to master new postures and motions. This can be a very challenging task and students would need significant amounts of practise as well attention from the teacher to learn. However, not everyone has the access and convenience of constantly being coached by a professional teacher in the field. This leads to the interest in finding more effective ways of self-learning that can be self-paced, and done at the time and place that is convenient to the student.

**1.2 Rationale**

Videos have long been used as a guide for self-paced learning. However, the development of motion tracking technology such as the Microsoft Kinect, and other technology such as augmented reality has opened up the potential of what has become possible in terms of the development of new learning support technology that could support self-learning much more effectively than ever before. This research examines how augmented reality can be used to develop new learning support technology for body combat.

**1.3 Aims and Objectives**

The aim of the research is to identify how augmented reality can improve technology that supports self-learning in body combat classes. The objectives of the research can be identified as:

1. To investigate the state of the art in augmented reality
2. To investigate how self-learning in body combat can be improved
3. To identify the manner in which augmented reality can be used to improve self-learning in body combat

**1.4 Scope**

The research will examine the state of the art technology in the subject areas of augmented reality and motion tracking in order to establish the boundaries of what is practically possible and propose potential solutions that could be implemented to support self-learning more effectively. The research will be comprised of secondary research, in line with the aim of the research to explore the boundaries of what is possible with the state of the art technology today.

**1.5 Overview of the Work**

This work will be presented over five chapters. This first chapter presented an overview of the research subject area and the research aims and objectives. The next chapter will present a review of current literature on the subject area. Chapter three will discuss the research methods and methodologies and chapter four will bring together the results of the research and discuss the implications of the research findings. It will also present the proposed solutions that could better support self-learning on body combat. Chapter five wraps up the research with the overall conclusions and identification of further areas for research.

**Chapter 2 - Literature Review**

**2.1 BODY COMBAT**

In this modern era where people have developed increasingly sedentary lifestyles, and obesity has become an endemic problem in the Western world (Hoverd, 2005) the importance of physical movement to general well-being is increasingly being recognised. Although more and more people are becoming glued to the screen, there is also increasing awareness of the concept of quality of life, and the importance of modifying individual habits to contribute to a better quality of life. One of the most common habits that people tend to improve is to increase the amount of exercise undertaken; this can improve the quality of life by increasing cardiorespiratory capacity, promoting weight loss, increasing the muscular mass etc. In general, increased physical activity is accepted to promote general well-being as well weight loss.

This increased emphasis on physical activity as a planned activity has led to the growth of the fitness industry. This includes the growth in the number of facilities offering physical activities such as sports, and general physical exercise such as gyms, as well as physical fitness trainers. LeisureDB (2017) reports that gyms in the UK have achieved a penetration rate of 14.9% - one in every 7 people are members of a gym, totalling to more than 9.7 million members. There has been a 4.6% increase in the number of fitness facilities in 2017, 5.1% in the number of members and 6.3% in market value. This scenario is set to grow with the fitness industry poised to hit several milestones in the next few months, such as the market value reaching £5 billion and penetration rate surpassing 15%.

Some physical activities have been franchised, such as Body Pump, Body Combat, RPM, Body Step, Body Balances, Spinning, Jump Fit, etc. While there is a lack of scientific studies in these fields, a better understanding of the acute and chronic physiologic effects of such activities is much needed. In order to do this however there is a need to collect some physiologic variables, such as as heart frequency (HF), subjective effort perception (SEP), oxygen consumption (VO2) and energy cost, during the execution of these activities.

BODYCOMBAT is a fitness franchise where users are trained to punch and kick their way into fitness; in one session alone users are expected to lose up to 740 calories. It is a martial arts inspired workout, with no contact and no complex moves to master. It is a very energetic workout that allows the participants to release stress, and get fit and strong fast. The workout can be adjusted to suit the individual’s levels of fitness. Instructors can show the options that are available for individuals to work at their own level. Hastings (2015) explains that core training is a component of fitness training that cannot be ignored; a strong core is vital to whole body health, and gives the individual stability, helps with balance and assists with injury prevention. He suggests that BODYCOMBAT is a more effective method of improving core strength than even crunches. Research by Dr. Gottschall at Penn State suggests that BODYCOMBAT workouts had greater muscle activation levels from specific moves, than the crunch. In fact, in every comparison it was found that muscle activation levels where a lot higher in the BODYCOMBAT moves such as jabs, kicks and high knees than they were in crunches. Overall it was suggested that one class of BODYCOMBAT was equivalent to 1700 crunches. It is suggested that the BODYCOMBAT is an effective core workout because if conducts reactive core training. Reactive core training is said to be what happens when the body’s muscle wiring and natural reflexes are exploited by doing movements that force the core muscles to automatically respond as they’re meant to. Jabs and kicks are typical examples of reactive core training that unlocks the individual’s functional core strength.

Currently, Les Mills offers on demand BODY COMBAT classes, which are basically videos which are made available online. The learners can choose the levels that are suitable for them and build a workout routine that suits them the best. This on demand facility allows all levels of learners to build their confidence in the sport in the comfort and privacy of their home. There is a huge variety of online workouts that are offered by the company to ensure that almost everyone will be able to choose the type of workout that fits their own personal goals – whether it is improving cardio, strength, intensity, training, core toning, flexibility, etc. The popularity of these on demand videos suggest that there is scope for further expansion. The current research therefore seeks to examine in greater depth the feasibility, benefits and drawbacks of implementing an AR supported BODY COMBAT program that can provide enhanced benefits to the learners. This would almost certainly take the form of a packaged workout, where the learners can learn individually or in groups, at a time and location of their choosing. The self-learning therefore would take place in small, digestible chunks.

**2.2 Self-learning in Sports and Fitness**

Anderson et al (2013) explain that mastering new postures and motions is a crucial component of many physical activities such as dancing, martial arts and sports. This is also the case in BODYCOMBAT, where the kicks and punches have to be executed properly in order to obtain the most benefit and also not to injure oneself. However, as with everything else, the mastery and the benefits are realised only when the effort to learn is put in; users need to learn these motor skills and this can be difficult, and time consuming. It also tends to be a repetitive activity, which means users can lose concentration quickly. As with BODYCOMBAT, in order to facilitate learning, the activities are often structured in the form of a class where an instructor leads a group through a set of activities. However, practical considerations will mean that there would be people who prefer self-paced learning in a more private setting for convenience or choice, either as the primary form of learning or to supplement the coaching received at a purpose-built centre. This is where technology comes to the fore as an enabler. Users can practise along to online videos. However, the use of videos for self-paced learning has a major drawback in that it does not afford for feedback to be given to the user, nor does it capture 3D movement information, or offer personalized motivation. However, Anderson et al (ibid) point out that substantial research has highlighted the fact that the amount of deliberate practise has the greatest effect on learning; furthermore, the availability and modality of feedback can greatly impact skill acquisition. Therefore, it is clear that there is a significant scope for the contribution of a technology based system which can provide users with feedback on their practise.

Mueller (2011) puts forward the Exertion Framework (shown in fig. 2.1 below) which illustrates how technology can be used to create more engaging exertion experiences that is mediated by technology. Their hypothesis is that more engaging experiences will lead to increased physical investment, and health benefits will follow naturally as a consequence of the increased physical investment. The Exertion Framework is described in terms of the Four Lenses for Exertion Interactions. This framework describes the contextual factors arising from users’ interactions with the environment as well as the social factors arising from the users’ interactions with the other individuals in the game or learning environment. The framework seeks to explain bodily interaction with non-keyboard controlled devices. It is suggested that the “four lens view” provides a framework with a suitable level of detail and abstraction to analyse new systems that work with the human body. The four lenses are defined as:

1. The Responding Body
2. The Moving Body
3. The Sensing Body
4. The Relating Body

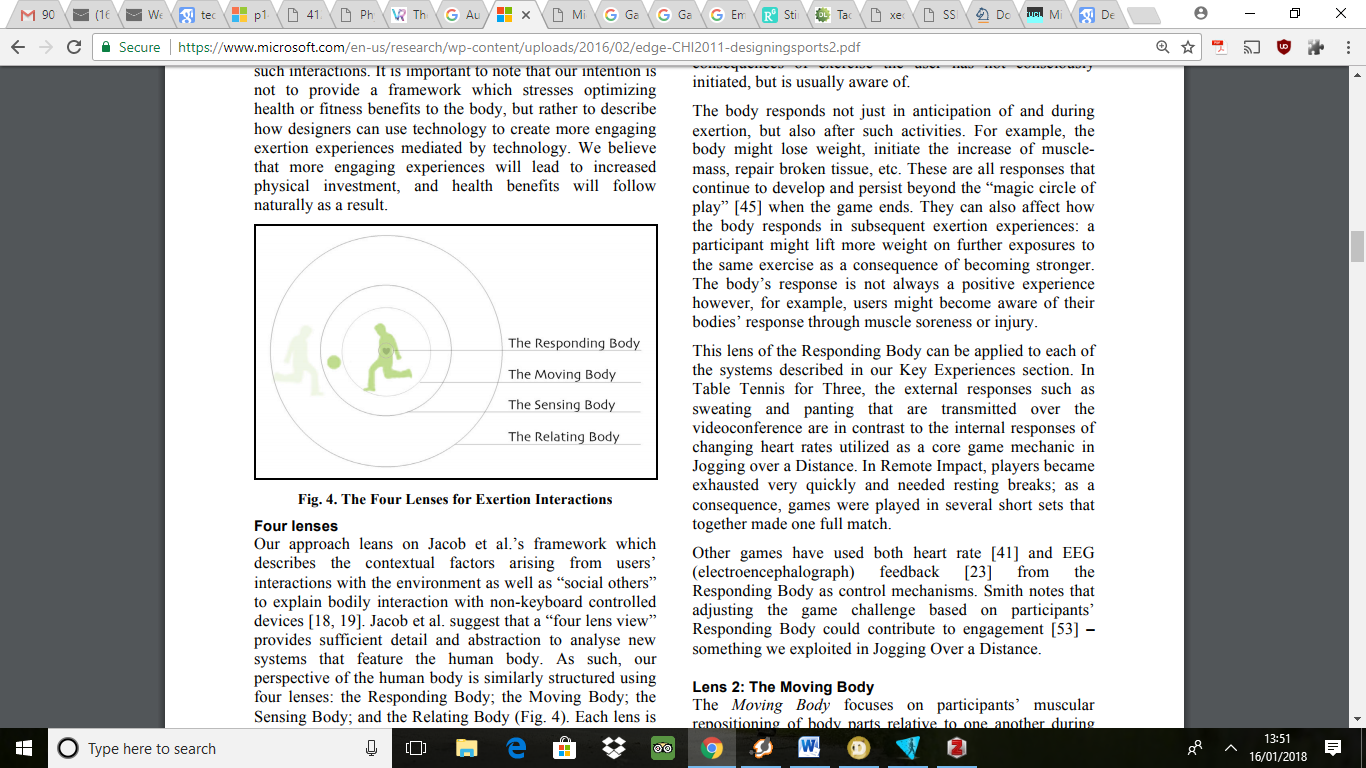


Fig. 2.1 – The Four Lenses in the Exertion Framework

Mueller (2011) explains that each lens is inspired by van Manen’s phenomenological approach to the analysis of “lived” experience. This lived experience is described in terms of four different dimensions, namely corporeality, temporality, spatiality and relationality. The lenses can overlap.

**Lens 1: The Responding Body**

The Responding Body is at the core of the framework. This is a view of the body from the inside, or how the internal state of the body changes over time as a result of the exertion. Physical activities that take part in the outer layers requires this core later to give a physiological response.

The Responding Body emphasizes how both corporeality and temporality, or the body and change, are at the core of people’s experiences of the activities that generate exertion. The human frame reacts to physical activity in a way that keeps stability, or “homeostasis”. The body undergoes internal changes physiologically, for example the person’s heart rate generally will increase with increased activity; the breathing becomes faster because the body needs more oxygen, and sweating takes place. Those are effects of exercise the person has not consciously initiated, however is typically susceptible to. The body responds no longer just in anticipation of and at some stage in exertion; it also responds long after the physical exertion is completed. For instance, the body might shed fat or weight, initiate the increase of muscle mass, repair broken tissue, and so forth. Those are all responses that continue to broaden and persist beyond the “magic circle of play” long after the game has ended. They also can have an effect on how the body responds in subsequent exertion experiences: a player might exert greater force on similar movements, or identical workouts on account of becoming stronger. The body’s reaction is not always a fantastic experience but, for instance, the individuals could possibly become aware of their bodies’ reaction via muscle discomfort or harm.

***Lens 2: The Moving Body***

The Moving Body focuses on how the individuals move their physical bodies using their muscles relative to other opponents or players while they are engaging in the physical activity. Temporality and spatiality are combined in the Moving Body, as the physical movement causes the body to respond in some way. The converse is however not true, in that the body that is responding may not necessarily be moving, as we recall that the body responds long after the physical activity has stopped. This lens highlights certain movement related characteristics such as depth, arising from the momentum of the weight moving, continuousness where movement exhibits preparatory and follow-through phases) and finally variety of human movement. The amount of space, weight, period and continuousness are useful between supplying each constraint then resources for designing user exertion experiences. Prior research concerning movement and measure has helped to pick out these expressive characteristics.

The Moving Body also highlights the kinaesthetic sense, or proprioception, an area that has been underexplored among human computer interface scholars. The kinaesthetic experience governs users’ awareness about the function over physique components. This is called “bodily intelligence”, a feeling that allows humans to react intuitively besides base in imitation of assume about each single movement.

**Lens 3 – The Sensing Body**

The Sensing Body describes how the body senses and experiences the arena within the world of sports activities. Many popular games involve bodily gadgets, which useful resource in shaping the exertion pastime. Artefacts variety from fundamental equipment which includes balls to very specialised equipment (e.g. bicycles). The bodily and technological surroundings also shapes the activity – gambling in a massive stadium is not the identical as gambling in the park, neither is going for walks in a park similar to going for walks on a treadmill. The Sensing body therefore aims to provide a contextual attitude, highlighting the frame and its interactions with the arena. This angle differentiates Exertion video games from traditional sports activities in that the sector of Exertion video games includes each physical and virtual items and areas.

In terms of BODY COMBAT and martial arts in general, it is clear that there is a need for high precision movement recognition because of the richness of movements that will take place in the activity. For example, in golf, there is only the swing movement and the tangent in which the ball moves; the force with which the ball is hit, etc. However, in BODY COMBAT, every part of the body moves with different force. A kick and a punch can be landed at the same time; the momentum of the body influences the amount of force that a kick or a punch has. The tangential force is also influenced by the momentum of the body. Hence the person’s height and weight are also a relevant factor when calculating risk and injury. Body to body interactions are very complex to anticipate, especially when there are two or more individuals involved in the activity. Hence this is one area in which employing AR (to support the sensing body) could be a very complex task.

**Lens 4 – The Relating Body**

The outer layer of the Relating body encompasses the methods in which our bodies and those relate to each other through digital generation. Such social interactions are tremendously numerous, mediated by extensive type of roles which includes co-gamers, warring parties and audiences and joint exertion can make well defined positive contributions to social consequences. A social view of exertion also enables us to apprehend the barriers and motivators for exercising. Research centred on bodily activity participation have showed that “social interactions” are among the maximum common motives for humans being physically active. The potential to preserve current relationships whilst also being capable of developing new social networks are two of the key positive results of taking part in physical activity with other people. The principle of social facilitation suggests that in social settings sportsmen and women will enhance their athletic performance and that athletes will exhibit a higher tolerance to pain when exercise is done with other people.

**2.3 Augmented Reality (AR) and Motion Tracking**

Augmented reality is a term that is generally used to describe the class of display technologies that are capable of overlaying alphanumeric, symbolic or graphical information with the user’s view of the real world. These enhanced pieces of information would be aligned, correlated and stabilised in a spatially and contextually intelligent manner. The earliest versions of augmented reality were perhaps the HUD (heads up display) on aircraft where information is projected onto the display. Augmented reality today has however come out of the defence applications and into commercially available products. Some of the devices today that provide augmented reality include optical see through glasses, video see through glasses, handheld/mobile AR devices, etc. In optical see through displays, the user views the real world by looking directly through monocular or binocular optical elements such as holographic wave guides or other systems that allows graphic, video and other symbols to be overlaid on the real-world surroundings. With video see through devices, the real world is first captured using video cameras mounted on the front of the display, then combined with computer generated display and presented to the user (Aukstakalnis, 2016). Kipper and Rampolla (2012) explain that the key difference between augmented reality and virtual reality is that virtual reality creates a synthetic world for the user to experience whereas augmented reality supplements reality. Three main characteristics define AR, that it combines real and virtual information; that it is interactive in real time, and operates and is used in a 3D environment.

There are however a number of challenges associated with getting AR to work as desired. Two of the biggest challenges in AR according to Kipper and Rampolla (2012) is object recognition and sensor accuracy. Object recognition, also called the registration problem. Craig (2013) explains that a key idea of augmented reality is spatial registration. This is the concept that information has a physical space or location in the real world, just as a physical counterpart of the digital information would have. For example, if in the real world, information was displayed on a signboard, that signboard would have a physical location that was independent of the user. In AR, a digital signboard would also have to be assigned a physical location in the real world. The user’s interactions with this piece of information therefore can be the set of all the interactions that are possible with the digital piece of information, e.g. the signboard can be moved, overwritten, etc.; however, with AR the set of possible actions can also be enhanced, for example ‘magical’ powers can be assigned such that the user may be able to levitate the signboard by gesturing, which needless to say is not possible in the real world. In AR, the digital object need not actually have a digital counterpart. Registration in the real world has to be both spatial in nature and temporal. Close registration is desirable, i.e. the digital object should be placed in the real world with close tolerances. The tightness of the tolerances determines the usefulness of the practical application; for example, in surgery, the tolerances need to be very, very small, whereas in a game such a low tolerance is not required. Temporal registration is challenging on account of the amount of time required for processing the information. Any digital object must be re-rendered every time the user moves, because the view of the object depends on the user’s relative position to it. Lags in the overlay of the processed image on the real-time view of the world can negatively impact the experience significantly. However, this can be overcome by delaying the video feed of the real time physical world if this is used instead of direct sight of the real world.

Santos et al (2014) explain that the affordances that are designed into AR applications are derived from the very nature of AR, where there is a real-time integration of virtual elements to a real environment. Augmented reality affords real world annotation, in the form of the display of text and other symbols on real world objects. It also allows for contextual visualisation where the visual content is displayed in a specific context, such as adding virtual information to a library. Finally, AR also affords for vision-haptic visualisation, where interactions with virtual content is enabled.

AR requires three major components, the sensor to determine the state of the physical world where the application is deployed, a processor to evaluate the sensor data, which helps to implement the laws of the reality being built (this includes the laws of nature as well as the laws of the virtual world being built), and a display that is suitable for creating an impression of the virtual world and real world which coexist. The sensors can include keyboard and mouse, through which the user can provide inputs to the AR world. Other sensors are used for tracking, gathering environmental information, etc.

**2.3.1 Motion Tracking in AR**

The use of sensors for tracking motion in AR is one of the fundamental enablers of AR. AR must be spatially registered, which means that sensors are required to determine the position of the user, the real-world objects, the AR devices, etc. Position here includes location and orientation. In general, in order to fully determine the position, six degrees of freedom of the entity are tracked. This includes X,Y,Z location and yaw, pitch and roll. This is shown in Fig. 2.1 below. Yaw, pitch and roll are the rotations about the axis they are on.

Hainich (2009) explains that motion tracking is required in AR in order to stabilise the display. Acceleration sensors and motion prediction is used to stabilise images against head movements, and compensate for trivialities such as frame delays of the video systems.

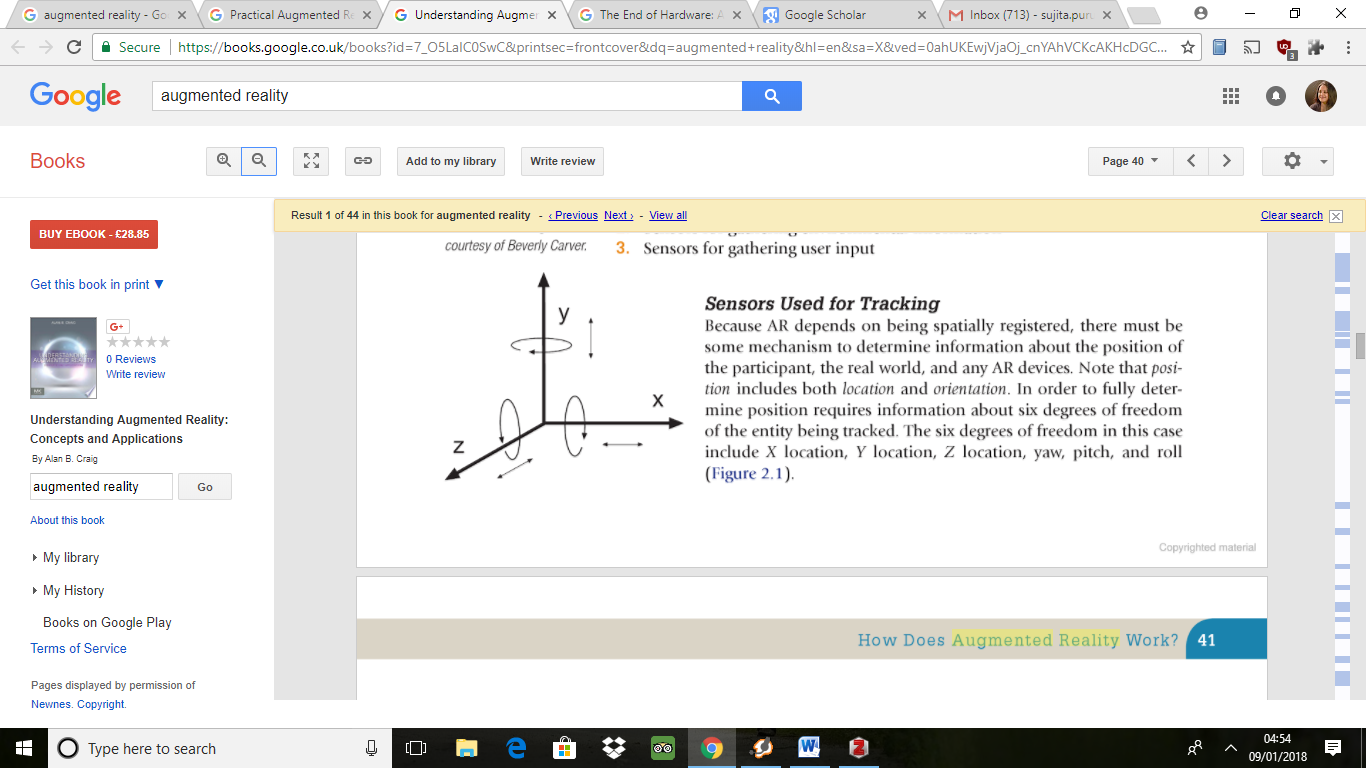


Fig. 2.1 – Six degrees of freedom of an entity (Source: Craig, 2013)

Dorfmuller (1990) explains that tracking user movements is an important issue in AR, because registration errors of viewer positions and orientations are directly perceived by the observer, when virtual and real objects go out of alignment. One of the problems is that the accurate tracking of the viewing pose is difficult. Different sensors are required to collect the variety of data required to facilitate robust and precise tracking. Sensors however are often beset with their own limitations, for example lacking in either accuracy, robustness, range, drift or noise sensitivity, hybrid systems, etc.

Tracking the movement of an individual can be significantly enhanced by the use of well-positioned sensors. However, in the case of fitness applications, the metrics to be tracked can be more than just the physical movement; the vital statistics of the user, such as heart rate, skin temperature, etc. can also be useful information to be fed into an AR fitness system. Barfield (2015) gives a good overview of the possibilities of incorporating wearable tech in AR. He explains that on-the-go use in a key aspect of wearable computers that makes them distinct from other devices. The wearable interface can be secondary to the user’s tasks, requiring minimum attention from the user. It can have an interface for the user to interact with, often in short bursts. Wearable computing interfaces are also often hands free. Mobile users tend to have reduced dexterity, eyesight, hearing and attention, which makes unencumbered interface design particularly challenging. Barfield (ibid) opines that speech interfaces are an obvious alternative – speech recognition is a field that is perhaps sufficiently developed to support this. Modern machine learning technologies have enabled better than ever speech recognition. In spite of the rich variety of accents and background noises, recognition rates are improving. Keyboards and other forms of input can continue to be maintained where speech is not appropriate, for example where privacy and confidentiality is an issue.

Barfield (2015) also explains that navigating interfaces when on the go is still a challenge. In spite of the range of interfaces that are available in AR today, such as trackpads in headsets, users still prefer a more subtle method of interaction. Some suggestions include mounting a remote controller on the user’s body, and a Bluetooth human interface device used for connection. He points to research which suggests that mini-trackpads and mini-trackballs can be highly effective for input while the user is on the go. Traditional WIMP (Windows, Icon, Menu, Pointer) interfaces are difficult to use on the go, as they require too much visual and manual attention. Smartphones can be said to have been useful in this area, bringing a new set of gestures such as swipes and taps. Gestural interfaces using motion sensors are found to be an effective input method for users that are on the go; however false triggering in this case is a challenge that has to be overcome.

The use of AR technology with motion tracking however allows for the opportunity for the user’s motion to be tracked in real time and feedback given based on the comparison of the ideal and actual body positions. For example, a trainee using an AR system designed for this purpose can have an ideal outline of their body projected onto a virtual mirror in front of them, and see how their actual pose stacks up against the ideal pose. They can then correct their poses themselves, over time leading to the memory of the correct pose being embedded in the muscle and the user enjoying greater benefits. In fact, prior work in this area has seen the use of technology to improve physical therapy (Judkins et al, 2005), where the user is retrained for simple movements and to improve the range of motion. Similar applications can be found in gaming. Anderson et al (2012) find that technology based therapy has some major benefits in that they are able to motivate the users and encourage them to adhere to their training schedules better than if they were to train on their own without the assistance of the technological system. They suggest that the technology based methods of training are found to be more enjoyable; however, the design of the activity is a strong moderator of the usefulness of the movements that are performed.

Nijhar et al (2011) explain that two classes of movement recognition can be identified in games that are currently commercially available. They are often termed as standard and motion plus controllers. They differ on the following aspects:

1. Accuracy and Responsiveness – In Motion plus controllers, the swing trajectory is more accurately detected and reproduced onscreen.
2. Swing Amplitude – in motion plus controllers, a greater swinging movement of the arm is required to produce a swing whereas in standard controllers, only a small movement is required to generate the same amount of swing. In this case it can be said that the motion plus controllers have a small disparity and the standard controllers have a large disparity; however, the large disparity is positive in that it reduces the amount of physical exertion needed to generate a virtual movement. This could be beneficial for people with impaired physical capabilities, allowing them to imagine themselves as good players, but it could be less than beneficial for fully able-bodied players who want to develop their fitness and are looking for the full benefits of physical exertion to the maximum physical capability that their body can exert.
3. Aiming System – In standard controllers, the aim is determined by how early a player swings, whereas with motion plus controllers, the swing follow through determines the direction of the ball.
4. Power – motion plus controllers are able to detect the swing velocity in tennis but standard controllers cannot do this.
5. Spin Shots – in motion plus controllers, spins can be added to shots by wrist rotation. From the technical perspective, this is the addition of yaw, pitch or roll along a tangential movement vector. Standard controllers do not support this.
6. Wrist Control – motion plus controllers are able to read wrist movements, and incorporate this into a tangent in a swing movement. Hence for example, a wrist twist with a swing will produce a directional swing of a ball according to the direction the wrist was twisted.

Nijhar et al (2011) also identify the following metrics that must be captured by AR sensing technology in order to facilitate effective motion tracking:

1. Swing Amplitude - This metric measures how wide or open a player’s forehand swings are, i.e. the maximum range of swings, calculated from the rotation of the player’s shoulder. In general, the swing is more realistic with increase in amplitude.
2. Max Speed (Power) – This metric measures how fast a player swings. Basically, this measure adds power to shots, making the shots faster. This is generally supported only by motion plus controllers.
3. Amount of Wrist Rotation – It refers at the amount of rotation in the wrist when a spin shot is performed. This is also generally only supported by motion plus controllers.
4. Swing Amplitude – This refers to how wide a player’s swings are. It refers to the maximum range of swings, that is calculated from the rotation of the player’s shoulder. In general, the swings are more realistic when the amplitude is increased.
5. Straightness of Swinging arm– This metric measures the angular displacement of the elbow of the swinging arm. It is in fact a measure of how straight the player’s swinging arm is. The swing is more realistic the more straight the arm is.
6. Amount of Wrist Rotation – This is a new feature that is supported by motion plus controllers. It is a measure of the angle of rotation of the wrist when a swing is executed.

**2.3.2 User Centred Design in AR**

Freidrich et al (2002) explain that AR applications should be developed with user centred design. Ergonomic methods are used for this purpose, to ensure that the AR systems that have been developed meets the requirements of the users and work processes. AR interfaces too have to be ergonomically designed, and AR functionality has objectives to achieve and value to contribute that requires careful design. Hence the design process should begin with an investigation of the customer or user requirements. Requirements should also take the form of specification of the assistance to work processes by AR systems. This is done in the analysis phase. Using a scenario based method, it is possible to assess typical activities in the fields of application along the value chain and prioritise them with regard to potential user- and task-oriented improvements. There is also the perspective of the hardware and software ergonomics to be considered, to be considered in the design and development of AR systems. Some example issues that could be considered in the user centred design for example includes the size of the information (text and graphics) that is displayed, usability tests, etc. User testing is a method that can be used in AR to ensure user friendly interfaces.

Anderson et al (2013) present the following design guidelines for AR systems:

1. Leverage Domain Knowledge - Experienced trainers have more knowledge than what can be expressed in a recorded movement. Feedback from instructors is found to be based on domain knowledge. The experts know how to segment movement, and which parameters of the movement are important. The authoring system should support the capture of this domain knowledge with minimal effort.
2. Motivate the User - Engagement and motivation is an important part of learning. The training system should provide feedback on the user’s progress, encourage the user to continue with their practice, and make it an enjoyable experience.
3. Simple Presentation, Low Cognitive Load - While practicing, the users should maintain a low cognitive load. The user’s attention should be on the movement, not on interpreting complex UI elements. A direct representation of the movement and simple scoring measures should focus the user on learning the movement.
4. Adaptive guidance Excessive guidance and video demonstrations can hurt learning, as users come to rely on the guides. Guidance should be reduced as the user learns
5. Summary Feedback - Feedback on individual movements can cause trainees to focus on small errors, rather than the larger systemic errors. Aggregating feedback from several performances allows trainees to see systemic errors in their movement. User driven learning Trainees have varying skill levels and preferences that will dictate their training needs. The system should allow users to progress at their own pace to maximize learning.

Nijhar et al (2012) make the important point that the users’ motivation is also an important factor in the design of the games. They explain that gamers can have different motivations, such as exertion, relaxation, competition, etc. Lazzaro’s study (2005) suggested that people’s motivations when playing computer games can be divided into four, namely:

1. Hard fun – here they obtain emotions from meaningful challenges, strategies and puzzles. The thrill is obtained from overcoming obstacles. The games therefore create emotion by structuring experiences in the pursuit of a goal. The challenge is for the user to focus their attention, and reap the rewards of progress and success. Players feel accomplishment when they use their skills to achieve success. These types of players enjoy games where there are multiple objectives, and where strategy is required, and not luck. Thus, in these types of games the level of skill required increases as the game progresses, and the complexity of the strategies also increases.
2. Easy fun – here the players’ attention is grabbed by ambiguity, incompleteness and detail. Immersion is required to maintain the user’s focus, and curiosity. The player enjoys the sensations of wonder and awe. Rich stimuli are therefore necessary in these types of games. Repetition and rhythm keep the players hooked for a longer time.
3. Altered States –Here the players are satisfied by the emotions generated by perception, thought, behaviour and interaction with rich stimuli, coming from the technological factors as well as interaction with other players. The players actually enjoy the experience of the game, during and even after the game. The social context is therefore very important here, in order to produce the emotions that keep the player interested. The focus is on the internal emotional state of the player, where they gain excitement, relief and satisfaction from the interaction with the technologically created stimuli.
4. The People factor - here the players achieve a sense of satisfaction mainly from their interaction with the other players. These types of games tend to be multiplayer games where there is strong interaction between the gamers. The player to player interactions create rivalries, competitive spirit, as well as teamwork and camaraderie. Teams can pursue shared goals, and emotions such as amusement, Schadenfreude, etc.

BODY COMBAT, which is the focus of the current research, can be considered to be an exertion gaming experience. Nijhar et al (ibid) suggest that the exertion gaming experience can be split into 3 components, the motivations that the players have when approaching the game, the strategies that the players adopt or use during the game, and the levels of immersion that the players reach during the game. Pasch et al (2017) narrow this down to only two types of motivations that occur in exertion games, achieving and relaxing. Achieving is when people play with the motivation to challenge their ability and to achieve the highest score. This is also termed as hard fun. Relaxing is when people play with the motivation to relax, to gain mental relaxation which comes from enjoyment of their movement skills. This is also called easy fun, and the players do not worry about the scores.

Mueller et al (2011) provide perhaps the most detailed linkage or relationship between movement and motivation in games, as well as linkage of movement and strategy. They explain that players engage with remote impact in seven different motivations or scenarios. Firstly, there is full body engagement, where the players exert themselves significantly, using their entire body to strike. Most of the players use their firsts, but many also use their fists. Some players also use the weight of their body by throwing themselves against their surface. The type of movement chosen appears to depend partly on how tired the players were. When their arms got tired for example, they were found to switch from punches to kicks in order to continue to play. Secondly, force intensity is found to be used as a challenge. The players tend to use a great deal of brute force during their play. The use of maximum force was found to be relatively common, and the players were found to enjoy the ability to apply extreme intensity in their physical actions. In fact, the use of maximum force itself was found to be a major challenge; it was difficult simply to hit with such intensity and hitting with such intensity resulted in exhaustion. Competitiveness arose in finding out who could hit harder, for example. The force was also found to be a source of stress relief; when the players were able to apply intense force, to the maximum of the physical capability, they found stress relief. This was found to be particularly notable because the use of brute force is discouraged in normal environments and in real life there are very little scenarios in which individuals can exert the maximum force possible without getting into trouble. This was also the case with the use of technology in general; technical products are fragile and have to be used with care and attention, and not brute force. The novelty of being able to unleash their greatest force, on a technology product is also thought to cause enjoyment. The ability to release stress in a social context was also found to be enjoyed.

Mueller et al (ibid) also find that players used their bodily movements for communication and self-expression. One common example of this is when a player uses their hands to communicate a victory sign, which is essentially to communicate the enjoyment of a win to their partner or other players. Bodily movements were also used to create strategic play; in their study Mueller et al (ibid) found that the players changed their strategy from the more traditional boxing behaviour Finding 5: Strategic play Some participants also noted that after playing for a while, they changed their strategy from more “traditional” boxing behaviour after some time. Instead of mixing up striking and ducking as players normally would in boxing, the players in their study switched to mostly rapid strikes applied in quick succession after some time. They suggest that the more offensive-oriented strategy did not necessarily secure a win more easily, but it resulted in a higher score overall. However, what is notable is that the players appeared to enjoy the opportunity to engage with this offensive strategy, as it allowed them to execute more hits. It was the exertion of force that gave them the high, rather than just the success of the strike. This in turn encouraged the players to hit as fast and as hard as they could. The joy gained from such exertion however had a negative impact on strategic play, which reduced as the offensive strategy was employed. Another reason why such physical exertion provided the players with joy is that the new bodily experiences could be enjoyed with reduced physical risk to the participants. Traditional combat-style games, including BODY COMBAT, are more likely to result in injury as compared to the AR games. The ability to exert maximum force with no consequences presented an attractive course of action to the players. The hit to the strategy was also due to the nature of the game; Mueller et al (ibid) suggest that because the players would not get hurt if their opponents hit them, there was no incentive to engage in defensive actions. If they got hit by the opposing player for example, they did not experience pain and it did not affect their own strength and reaction. Therefore, it was indeed a better strategy to simply engage in offensive action; this maximised the points gained, for the time and strength available. This leads to the conclusion that the players did indeed take into consideration the limitations of the technology when deciding on their strategy in the game. In fact, Mueller et al (ibid) found that the players also took into account the tracking limitations of the camera based tracking system, when developing their game play strategies. Many players realised that the camera captured movement in a limited area and not the entire room, and therefor used this border as part of their strategy. One way this was done is by moving their bodies outside the area captured by the camera; this meant that the attacks from their opponents would not register, as the available area of the body to hit was reduced significantly and their opponents would not win the points from those attacks. Moving in and out of the area captured by the camera was also used as part of the strategy to launch surprise attacks on opponents who had not yet worked out these limitations of the motion tracking technology employed.

**2.4 Summary**

Thus far this literature review has attempted to review the state of the art in AR technology and its application in BODYCOMBAT. We saw that BODYCOMBAT is a particular fitness programme that has many benefits and therefore is a worthy candidate for the development of a technology based system to encourage users to take up the fitness programme. We also showed that technology assisted systems for current technology in the field of AR is sufficiently advanced to make the development of an AR based system useful.

The literature review also examined the state of the art in AR technology. The benefits and limitations of AR technology were discussed, as with the design of new AR systems. It was seen that AR technology is sufficiently mature to support the development of a new system that can act as an aid to BODYCOMBAT training. The technology can support motion tracking to a degree that would be useful for users who wish to train in BODYCOMBAT in the privacy of their homes, pacing themselves. Therefore, the case for the development of the system is made. In the next chapter, we visit the research methods and methodologies adopted in the current research.

**Chapter 3 - Research Methodology**

**3.1 Research Philosophy and Methodology**

The research methodology is the specification of the steps that are to be adopted by the research in his or her study of the research problem. The articulation of the choice of research methods adopted is also the specification of the logic behind the design of the research (Kothari, 2004). Different methods are of course suitable for different research projects; the researcher bears the responsibility to design a research effort or project that is valid. In order to do this the researcher has to identify the research philosophy and research methods that agree with the research as well as help in the achievement of the research aims and objectives.

Kothari (ibid) also recommends that the research design that is appropriate for a particular research problem, will usually involve the consideration of the following:

1. the means of obtaining the information;
2. the availability and skills of the researcher and his staff (if any);
3. explanation of the way in which selected means of obtaining information will be organised and the reasoning leading to the selection;
4. the time available for research; and
5. the cost factor relating to research, i.e., the finance available for the purpose

The current research adopts the philosophy of post-positivism. Here the methods are considered to be value neutral, in that the methods on their own do not contribute anything to the process unless they are applied properly. However, if the methods are applied improperly they can also detract from the research and hence appropriate use of methods is necessary. It is accepted that the researcher’s worldview will have an impact on the results that are obtained, as well as the choice of the research methods and methodologies that are adopted in the research.

**Learning Theories**

One of the implicit subject matters considered in the current research is learning. BODY COMBAT is a field of sports where the individuals still have something to learn. Therefore, it is also relevant for the research to consider learning theories that may be relevant, in order to understand the paradigm in which an AR system that supports the sporting activity would sit. Three theories of learning can be considered, namely behaviourist, cognitive and constructivist.

The behaviourist school of thought focus on the outcomes of stimulus; the social meaning is largely ignored. People are thought to learn from trial and error (also called connectionism) and conditioning. Stimulus is connected to response, and this connection is strengthened or broken depending on the consequences of the action. Trial and error produces more consequences and impact on such connections. Conditioning is where the learner learns what to do go get the desired reward. In this approach, learning is considered to be a step by step approach. Cognitive approaches consider the internal mental structures of the learner. Learning is considered to be an information processing activity, where information about the structure of behaviour and environmental events is transformed into symbolic representations. Constructivism on the other hand is concerned with how learners build their own mental structures through interaction with their environment (Cushion et al, 2010).

**3.2 Research Methods**

The main research method that is adopted in this work is the literature review. The literature review seeks to inform the research effort as well as establish the boundaries of the body of knowledge in the subject area. The sources for the literature review include peer reviewed journal articles, textbooks and reputable websites on the subject matter.

Current literature on the subject area is however limited; the subject area is highly multidisciplinary in nature and also newly evolved. Therefore, the research will aim to formulate a theory or set of hypotheses about the relationship between AR technology and self-learning in BODY COMBAT. This will be done by studying prior applications of AR technology in sports and fitness. This was found to be predominantly in the gaming arena.

A Grounded Theory approach was adopted in order to enable the research to develop theory from a systematic collection of empirical data. The data is secondary data gathered from the literature review. However, a sufficiently wide body of literature was consulted in order to facilitate the triangulation of the findings and provisionally verify the emerging theory. Grounded Theory is a generally employed in research as a methodology for qualitative analysis. The research findings are grouped into similar concepts in order to make them easier to analyse and form more abstract categories. These categories form the basis for the creation of a theory, or a reverse engineered hypothesis. This analysis process starts as soon as the first publication is read for the literature review. Preliminary findings from the initial literature reviews are then used to further guide the literature review process such that ultimately the researcher is able to verify and further explore the emergent concepts and categories. This will allow the researcher to strengthen the validity of the proposed theory, identify and categorise the relationships and further analyse these findings to validate them.

The design principles for the design of AR systems will be applied to the proposed design in the next chapter.

**3.3 Summary**

Thus far this chapter has attempted to present a brief review of the research methods and methodologies adopted in the current research. The next chapter presents the design of the proposed AR system as well as analysis of its benefits and limitations.

**Chapter 4 – Results and Discussion**

**3.1 Designing Mediated Combat Play**

There are many technology-assisted physical exertion games available off the shelf today from commercial companies such as Nintendo’s Wii, Microsoft’s Xbox Kinect, etc. Most of these types of games support multiple players, who may nor may not be in physical proximity to each other. However, this research is yet to find a game that uses mediated body-to-body interactions; Mueller et al (2014) also find the same. Mediated body to body interaction here is defined as the situation where bodies act on and react to each other, more than just touch. Combat play is an example where body to body interaction moves beyond just touch; there is push and pull, and other types of interactions between two or more people. The defining characteristic of the current crop of games that are technology assisted, whether by AR or not is that their players mostly play independently, either by taking turns or playing in parallel. This type of activity however is not characteristic of traditional sports where there is a significant amount of body to body interactions. For example, in martial arts and boxing there is a huge amount of body to body interactions; even in football and rugby there is a lot of body to body interactions. Some technology assisted games have attempted to simulate body to body interactions to a certain extent through the use of avatars; the players play with an online avatar, or against an avatar. However, there is still a lack of support for games that facilitate real life physical body to body interactions between two real players. It could be said that one of the main limitations that has led to this situation is the limitations of the sensing and actuating technologies that are unable to support this type of body to body interactions with sufficient accuracy.

It was seen in the literature review that tracking user movements in an important issue in AR, where one of the problems is that the accurate tracking of the viewing pose is difficult. Different sensors are required to collect the variety of data required to facilitate robust and precise tracking, but the sensors were unfortunately often beset with their own limitations, for example lacking in either accuracy, robustness, range, drift or noise sensitivity, hybrid systems, etc. (Dorfmuller, 1990). The main limitations are in the sensing and actuating technologies, where the technology is perhaps not accurate enough to support the close body to body interactions that would take place. Mueller et al (2014) explain that the current crop of commercial games in the area such as the Nintendo Wiis, Microsoft Xbox Kinect, etc. require the bodies of the players to be separated to tell them apart. This serves to limit the opportunities for body to body interaction, and therefore rules out body to body combat as one of the games or activities that can be supported by the technology.

A key point to note is the different motivations of the players when they play the games, and the impact of these different motivations on the requirements of the technology to support the game. In the literature review we examined some of the motivations of gamers that have been studied in current literature, e.g. Nijhar et al (2011), Pasch et al (2017), etc. Although the motivations have been associated with differing strategy, there is still no clear-cut link between the required levels of movement recognition precision and the players’ motivations in the game. Pasch et al (2017) for example explain that there is a relationship between motivation and whole-body playing strategies; Different motivations can lead to different strategies in whole-body sports games. They suggest that when the player’s motivation is to achieve, they will optimise their strategy to obtain the greatest amount of points using the least amount of movement. On the other hand, players whose motivations are to relax will try to recreate movements from the actual sport. However, Pasch et al suggest that it is not clear as to whether this holds across different genres of exertion games and with players of different experience levels. Furthermore, it is also not known whether the strategies devised by the players are limited by the accuracy and speed of the movement recognition afforded by the current technology. For example, if the players were to have controllers with significantly higher movement recognition precision, would they change their strategies? Are they developing their strategies based on their knowledge of what the technology is capable of, and maximising their chances of winning taking this into account?

Initial studies by Bianchi-Berthouze et al (2007) find that the relationship between engagement and body movement has not been studied thus far in mainstream current literature. They point to the studies in cognitive and affective sciences have shown the important role played by the body over the mind; this leads to the suggestion that thought grows from action and that action is the driver for change. In other words, this suggests that the way our body interacts with the environment affects the way we perceive the environment. Following this line of thinking it can be said that the precision of movement recognition is important in a game, because it constrains the way in which the players’ bodies can move, and consequently the way their body interacts with the environment, and therefore the way they perceive the environment; ultimately this impacts on the strategies that they develop to play the game. Bianchi-Berthouze et al (2007) in their initial studies come to the conclusion that an increase in body movement that is allowed by the game results in an increase in the player’s engagement level; increased body movement affords the player a stronger affective experience. This preliminary result is also supported by Lendley et al (2008) who suggest that an increase in movement afforded by the input device made for a more engaging experience, and that this was not compromised by the increase in social interaction. Overall therefore it can be said that the more a player can move in the game the better it is; because then the more immersed they will be in the game. However, the actual mechanism or dynamics by which the increased movement brings about greater immersion is yet to be clearly articulated in current research. This means that it is still not possible to specify in significant detail, the characteristics of controllers that would be able to afford greater precision of movement recognition, and the type of movement that should be facilitated if any.

Mueller et al (2014) identify four mappings that represent the challenges that need to be overcome if AR is to be used in sports which have notable body to body interactions, such as BODY COMBAT. These are:

1. Motion Mapping – Mapping the real world physical movement of the players to the virtual world is a challenging task on account of the fact that the sensors have to firstly accurately detect the movement, identify which player’s movement it is, and then translate it to the virtual world, and subsequently execute the processing necessary; for example in a BODY COMBAT game, this would involve computing the ideal movement and comparing it with the actual movement, and then giving the necessary feedback to the user in real time. Thus, not only are accurate sensors necessary, but high power computing is also necessary to perform the processing of the data sufficiently fast enough for the feedback to be useful. Mueller et al (ibid) recommend that the players’ entire bodily movements are mapped to a virtual avatar. This would be a literally one to one mapping, where a physical strike would be mapped identically to the virtual one, in terms of not only trajectory of movement but also speed and force. The virtual strike would therefore have to simulate the impact of the trajectory, movement, speed, etc. on the virtual recipient of the strike. This full body identical mapping is useful because it allows the players to engage in a rich set of tactics. This is called literal one to one mapping.

Another option is to do only partial one to one mapping. Here only the movements of subset of the body are mapped, e.g. the hands only, in a boxing game. This limits the ability of the players to use their torso for game tactics.

A third option is the complexity reducing mapping, where the game designers can choose to reduce the complexity of the movements that are mapped. Here the full movement of the body is tracked, but is converted into more simplified representations in the virtual world. This type of mapping could be more useful for players whose motivations are to relax or have ‘easy fun’ as discussed in the literature review (Nijhar et al, 2011 and Pasch et al, 2017). From the technical point of view, this is very easily implemented; for example, the six degrees of freedom outlined by Craig (2013) could be reduced to just three degrees of freedom along the x, y and z axes. This means that the yaw, pitch and roll along each axis could be removed, to reduce the complexity of the motion. This would also have the impact of simplifying the strategies that the player could adopt, for example tangential force is all but eliminated, and hence a pull movement to topple the enemy cannot be a part of the strategy.

Complexity-increasing mapping is also conversely possible; designers can also choose to utilize the mapping in order to add complexity to movements. This could be button press movements, special moves, etc. This is perhaps one area in which augmented reality can definitely add benefit, or enhance gameplay. For example, it is not inconceivable that a player can strike and generate force as well as light, in AR. The implementation of the motion can materialise the light in the AR, and thereby enhance game play significantly.

1. Mapping 2: Location Mapping – this is when movement is mapped into a virtual representation. There is the possibility of physical disparity between the bodily action and its virtual representation. From the game design point of view, designers can choose to support physical disparity to a greater or lesser extent, which affects opportunities for bodily interaction. Designers can also mix different physical disparities for different actions, varying them throughout an experience. When there is a small disparity, there is only a small distance between the player’s limb and the virtual representation, close to zero at the point of impact. Small physical disparity supports the proprioceptive sense. The user can act on the virtual representation through direct manipulation. No complex mental mapping between physical movement and virtual representation is required. Proprioceptive sense is thought to be linked to stress relief; the small disparity means there is limited demand on the mental functions, which allows the players to focus solely on physical actions. One way to achieve small disparity is to attach sensors to the player’s body.

Large disparity is when the physical distance between the players’ bodies and the virtual representation is around 1-1.5 metres, and relatively much larger compared to when striking the surface. In contrast to small disparity, when there is large disparity the players need to engage a mental mapping process where they had to consider how much they needed to move in order for their virtual shadow representation to avoid the strike. Large physical disparity is often deployed to make the mapping more efficient, e.g., movements of a computer mouse are normally smaller than movements of the associated cursor, reducing the physical effort required. This runs contrary to the premise of many exertion games that aim to encourage and facilitate physical effort. In Remote Impact, increasing the physical disparity meant stepping further away from the interactive surface, and hence closer to the camera. Due to the conical shape of the capture area of the camera, participants’ shadows got bigger, so players created larger representations of themselves. This allowed, for example, a small arm movement to turn into a very large virtual swing; participants used this to stimulate their play.

1. Force Mapping - Players of Remote Impact appreciated the opportunity to apply brute force [17] to the interaction surface (F2), which affected the visceral feeling of the experience. Prior work by Berthouze has suggested that this is important, as it can facilitate players’ feelings of presence and fantasy [2]. We propose that designers should consider the extent to which the force of movements is sensed and mapped. Unit force: Designers can choose to ignore the amount of force applied during participants’ movements and simply detect if an action was successful or not. This can simplify

the sensing implementation and also support balancing [19], allowing players of different strengths to play together. In Propinquity the force of movements is not sensed, and in Wii Boxing, the force of movements is mapped discretely to the avatar, so that only once a hit reaches a certain threshold, it results in a harder avatar punch. Functional force: Probably the most-liked feature of Remote Impact was that harder hits resulted in larger scores. The force of movements was sensed and mapped in Remote Impact, which rewarded participants’ physical effort. However, the force was not mediated across the distance, for example, players did not experience a hit through force-feedback devices. This affected participants’ body-to-body interactions: their focus sometimes shifted from force investment as a way to drive bodily interactions to force investment as a way to engage in parallel competitions about determining who can hit the hardest (F2)

1. Control Mapping – Designers need to consider the extent to which bodies have control over other bodies. In mediated environments this translates to the extent bodies have control over avatars and vice versa, but also includes to what extent avatars have control over other avatars. As such, we argue that designers need to consider both the mapping between bodies and avatars and the mapping between avatars. For both kinds, designers have two broad choices: Unidirectional mapping between body and avatar: Remote Impact, just like Wii Boxing, features a unidirectional mapping between the player’s body and the virtual shadow, the player’s avatar. If a player moves, the avatar moves. This mapping is unidirectional, as any movement of the avatar does not result in the player moving. If the opponent hits the avatar, the player does not experience this hit in a bodily sense: the only feedback the player receives is the cartoon-style visuals and audio effects (F6). The lack of bodily feedback meant that there were few incentives to engage a mix of different tactics. As a result, some players focused on simple hitting actions, meaning that the unidirectional mapping between body and avatar affected the bodily interactions between participants (F5). Bidirectional mapping between body and avatar: Alternatively, designers can choose to support a bidirectional mapping between the player’s body and his or her avatar. In Remote Impact, if an avatar was struck, the player did not experience this with his or her body. However, we can envision that with advances in force-feedback technology this could be supported. Regardless of whether this bidirectional mapping is technically feasible, designers should consider any ethical and safety concerns when computers offer bodily feedback, in particular when it can be forceful as in combat-style interactions. Loose mapping between avatars: Remote Impact featured a loose bodily mapping between avatars: if an avatar was struck, a point was scored, however, the avatar did not experience this bodily, i.e. the avatar did not move backwards as a result of the impact. Tight mapping between avatars: Wii Boxing features a relatively tight mapping between avatars: a struck avatar experiences the hit bodily, most often in the form of moving backwards. This does not lead to a broken motion mapping (M1), as the avatar’s body is not tracked. It should be noted that the design of Remote Impact did not aim to offer a completely loose mapping between avatars. Although avatars did not react to bodily actions, the experience for players hitting their partner’s avatar was one where they felt resistance through the mattress surface. Furthermore, the avatar seemingly moved as a result of the input: the surface was squashed, providing the sensation something “gave” and reacted to the physical action in a tangible way. Since the projection also follows the squashed surface, this created the illusion that the avatar being hit was reacting to the physical action. Remote Impact therefore tightened the mapping between avatars by facilitating perceived reactions such as the projection on the malleable surface and offering tactile feedback in addition to the visual and audio effects. Interestingly, by using proximity and wearable sensors Propinquity portrays a tight mapping between avatars even though it does not feature virtual representations in the form of visual avatars.

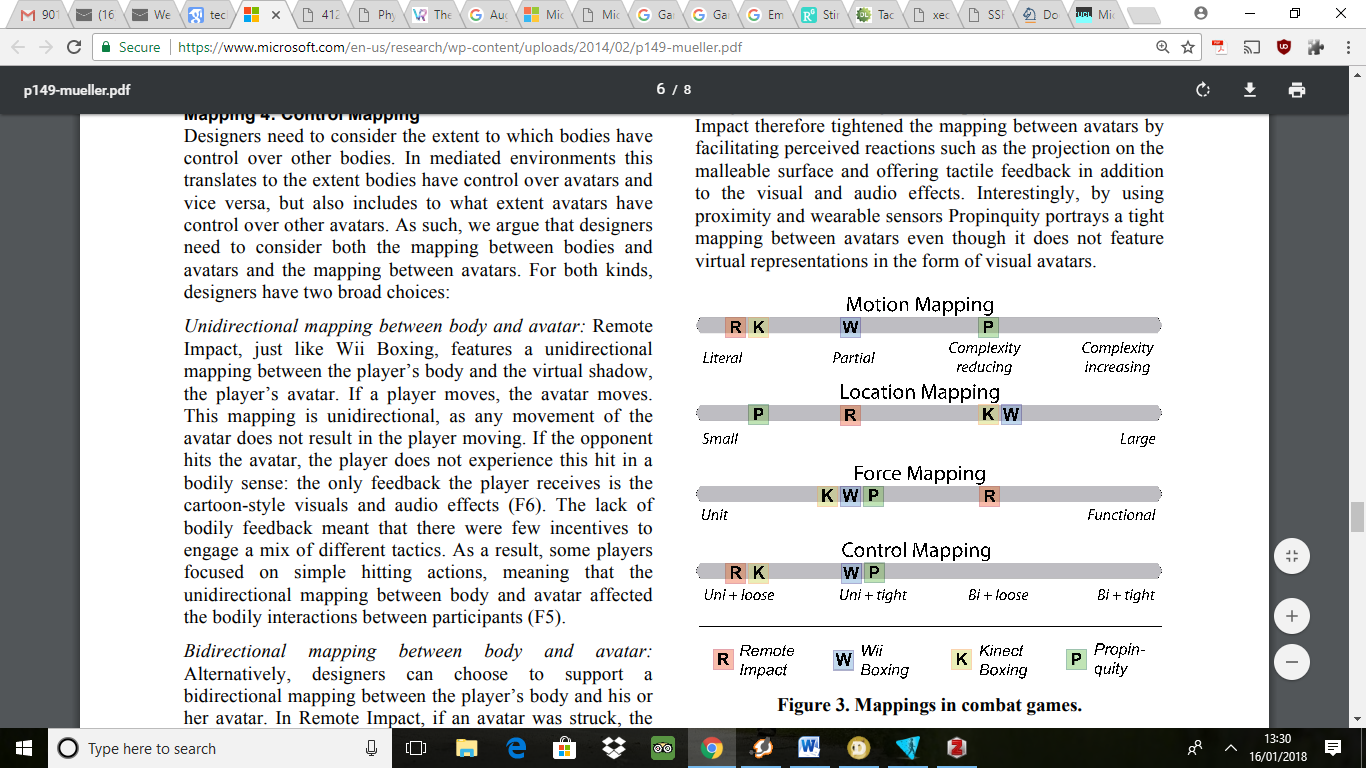


Fig. 4.1 – Mappings in combat games

**4.2 Discussion**

Mueller’s (2011) Exertion Game Schemas can be applied to BODY COMBAT classes very effectively. This Schema helps to explore the formal structures of the activity, the experiences of the people involved; and the larger context in which the activity takes place. The schema is shown in Fig. 4.2 below.

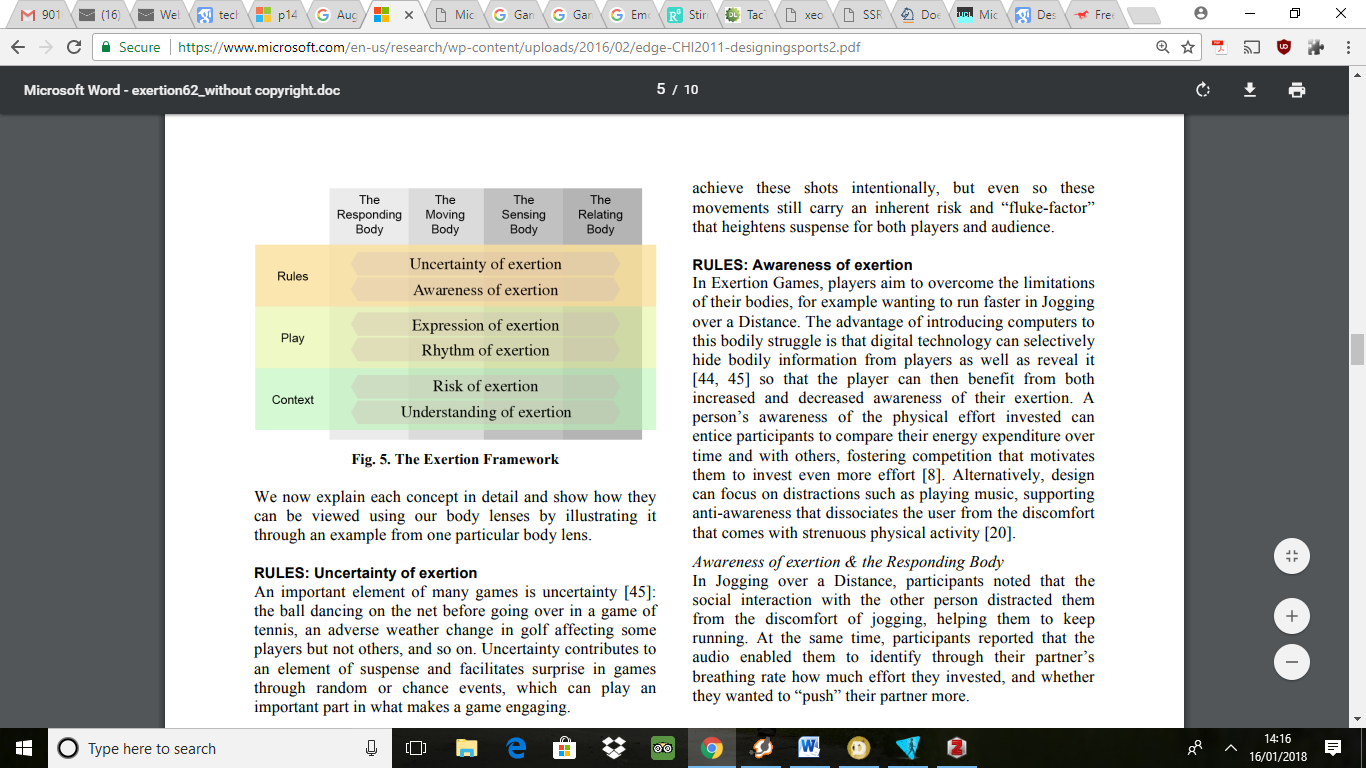


Fig. 4.2 – Mueller et al (2011) Exertion Game Schema

We apply Mueller’s (2011) rules in the games of exertion to BODY COMBAT classes to arrive at the following findings:

**RULES: Uncertainty of exertion**

In most games there is an element of uncertainty which is required in order to engage the player. This uncertainty is also present in BODY COMBAT. In games it could very well be the uncertainty involved in a ball dancing on the net before going over, an adverse weather change in golf affecting some players but not others, etc. in BODY COMBAT this would take the form of uncertainty in the response of the others in the body to body interaction, as well as uncertainty of the strength and accuracy of movement of the individual itself. Uncertainty contributes to an element of suspense and facilitates surprise in games through random or chance events. This in turn plays an important part in making a game more engaging. This also holds true for BODY COMBAT classes. In conventional computer games controlled by pressing buttons, any chance encounters have to be artificially introduced through computer code that is explicitly programmed– simply pressing a key does not often offer a rich set of possibilities for uncertainty in terms of action and effect. However, in BODY COMBAT the uncertainty is introduced through the response of the other individuals in body to body interaction, as well as the unknown physical limits of the individual itself.

This is typical of exertion games, where generally the uncertainty tends to arise through the abilities and movements of the body. The body’s response to exertion is difficult to predict, both for the opposing player and for the technology or system designers; the players themselves may not know exactly how long they can keep up. Furthermore, the variety of bodily movements can cause even simple actions to go wrong (e.g. missing a free-throw in basketball or a short putt in golf, or, in the case of BODY COMBAT, was the kick sufficiently strong and sufficiently well aimed to fell the opponent?).

**Exertion as Uncertainty** –designers need to be aware of the fact that they have to mediate the relationship between the uncertainty involved in the activity giving rise to exertion in the body as well as the uncertainty in the virtual world.

**Uncertainty of exertion & the Sensing Body** - The physical characteristics of real world objects such as balls affords for rich interaction between the body and the object. There is a nonlinear relationship between the actions of the body and the effects on the real world, moderated by the laws of nature. It is this uncertainty that gives rise to the sports or games situations, where the outcome is not known in advance. An example of the unpredictability of the interactions between the body and the physical objects used in sports is seen in the use of the term ‘lucky shot’ across different sports. Unpredictable reactions or impacts of the interactions between the body and the physical object that are favourable are often termed lucky shots because they were unanticipated. However, these ‘lucky’ shots can be replicated intentionally if the players practise them sufficiently. In general, it is the ‘fluke-factor’ that generates suspense for the players and the audience in a sport. In BODY COMBAT, it is clear that the response of the other player cannot be predicted. Whether they will evade the physical attack, or respond with their own attack, and what type of attack, is the cusp of uncertainty.

**RULES: Awareness of exertion**

In Exertion Games, the objective of the players is overcome the limitations of their bodies, or stretch their bodies to the limits of its capability. Technology can be of assistance to the individuals who have this objective, as it can selectively hide or display information in a manner that is beneficial to the individual. For example, some information can be displayed, and others hidden so that the player is less aware of their physical exertion, thus allowing them to continue beyond what they would have otherwise. This also holds true for BODY COMBAT. Distractions in the form of interactions with other people can keep the individual’s attention away from their own physical exertion.

A person’s awareness of the physical effort invested can encourage the individuals to compare their physical achievements, for example strength of punch or kick, with that of the other players or co-learners, thus creating and fostering competition that would motivate these individuals to invest even more effort in that activity. In the case of BODY COMBAT, AR technology can be used for more accurate comparisons, as well as for recording of achievements to engender competitiveness between participants across different locations. The competitors or co-learners need not be located at the same physical location. The design of AR technology supported BODY COMBAT classes can focus on distractions such as playing music and body to body interactions with other individuals, thus supporting the disassociation of the individual from the discomfort that arises from their strenuous physical activity.

**Awareness of exertion & the Responding Body**

In general, social interactions with other people tend to distract an individual from the general discomfort of physical exertion and help them to continue with the activity longer than without the distraction. Similarly, in BODY COMBAT, mapping the movements of the opponents with small disparity can create a real lifelike experience of body to body interaction with a player that is geographically in a different location. At the same time, the participants experience can be enhanced by other features such as the audio that would enable them to identify their partner’s breathing rate, and evaluate how much effort they invested, and consequently also decide how far they wanted to push their partner physically into further exerting themselves.

**PLAY: Expression of exertion**

Physical exertion can be considered to be a form of self-expression. The way in which people move, and the extent and pattern of exertion and their interaction with the physical world around them including other people holds rich and expressive interactions that tell us more about the people. In sports for example throwing fists to oneself or to one’s opponent is a commonly used gesture to indicate a variety of emotions. Similarly, celebratory dances can also be commonly seen. These types of expression have come to be termed as ‘metagaming’ in exertion games. Metagaming simply means what happens during a game, other than the game itself. Technology can choose to be neutral, or support or obstruct metagaming. For example, the audio feed can be conveyed, or restricted based on programming choices. Expletives can be detected and deleted or conveyed. However, in the case of AR such metagaming strategies that are expression by the body itself, such as crude gestures, may be more difficult to censor, and add more processing overhead. Nevertheless, metagaming should not be eliminated totally as it does contribute towards a better experience. AR technology however has the option of augmenting the reality, for example by adding special effects when a high degree of sportsmanship is displayed by any individual. In the implementation of BODY COMBAT classes using AR, it is possible for such special effects to be implemented in suitable circumstances to encourage the individuals, for example when some achievements are surpassed, or significant effort is made.

**PLAY: Rhythm of exertion**

The Rhythm of exertion is the recurrence of a beat in the body’s actions, according to a pattern. The system should be able to identify and support this rhythm, such that when it is absent but should be present the missing rhythm can be recognised, and alerts generated. Rhythmic movement can be with or without music; it is often a reflection of the user’s pulse. Rhythm is beneficial for physical exertion as it is known to improve athletic performance, human motivation, and have a positive impact on the acquisition of motor skills. It also helps the individuals to dissociate from the discomfort of the physical exertion, and thus enable them to exert for longer. AR technology has been used in rhythmic exercise such as dance programmes, where players are taught to synchronise their movements to music as well as with their dance partner(s). In BODY COMBAT, music could be used to train the individuals in their movements, and posture. It could also be used during the periods when there is body to body interaction, to pace the movements. For example, as the play peaks, faster music could be played to help the players to exert themselves more. Technology could also be used to support safe play, such that when the body to body interactions are becoming too strong so as to injure one player, music could be slowed down or instructions issued to players to protect them from injuring themselves or their partners/opponents. Thus it is clear that AR technology can be used to promote safe learning.

**Rhythm of exertion and the Moving Body**

From the perspective of the moving body, rhythm arises from continuous movement. Technology can be used to identify the innate rhythm of each person and thereby control their activity and exertion levels to make it optimal.

**CONTEXT: Risk of exertion**

Exertion is not without risk, as the body is vulnerable to over exertion and injury from activities. Injury and related issues are a common running issue in any sport, and this is no different in BODY COMBAT. Learning sports supported by technology is no different, as the individual is still exposed to risk of injury. However, users may have a different perception of risk online; for example, if the opponent is a virtual avatar, then the opponent cannot be hurt. However, users who alternate play between the virtual avatar and a real-world opponent may end up getting confused about the level of force they are inflicting on their real world opponent and therefore increase risk; disparities in the translation of activities from the real world bodily movements to the online avatar can also increase the risk of injury to the individual through over exertion. In virtual worlds where there is no risk, choice becomes meaningless. Exertion however requires a commitment to physical actions, as well as the potential consequences that arise from these actions.

In the case of BODY COMBAT, the relevant question is whether the individual is playing with a real-world opponent or a virtual avatar. If playing with a virtual avatar, clearly there is less risk involved. The player could harm himself through injury arising from over exertion. However, when playing with a real-life opponent, there is the risk of injuring the opponent through the use of excessive force. The individual may experience an affective response when the avatar they are playing against gets hurt. However, getting physically injured can have a negative impact on the quality of life of the individual and his opponent long after the gameplay. Mueller (2011) explains that it is the very vulnerability of the human body that makes is constantly prepared for danger and surprise, and it is this preparedness that shapes the life experiences of the individual. Without risk, there is no thrill, and without thrill, there is little motivation for the individual to act. The important thing is to get the balance between risk and thrill right,

**Risk of exertion and the Moving Body**

In the context of designing for technology supported physical exertion it is important that the risks arising from exertion are managed. Reduction of risk is essential but as was seen it is not possible to remove risk without eliminating thrill as well.

**CONTEXT: Understanding of exertion**

Managing the risks arising from exertion whilst at the same time attempting to maximise the benefits that can be gained from physical exertion and managing the thrill gained essentially requires the system designers to understand the support the development of knowledge about the body itself. Two aspects are identified as important, knowledge and skill. Knowledge of the body includes knowledge of the limits the body is capable of, safe boundaries, etc. It is separate from the scenario in which the body is being exerted. One example of this knowledge is the knowledge of normal heart rates; sensors can be used to continuously monitor the players’ heart rates, and when the heart rates increase beyond the safe levels, the system can be programmed to generate alerts.

Skill is the ability to do a specific thing, for example throw a ball in a particular manner, hit in a particular manner, etc. From the point of view of AR games designed to support physical activity, this is called kinaesthetic literacy. Design approaches include the mapping of exertion actions and game actions according to the abilities of the players and the challenges that is set. An example of this in the development of a game to support BODY COMBAT is matching players with similar skill levels. This can make the learning experience more enjoyable. In the system, this can specifically be done by:

* 1. manual selection of difficulty level;
  2. transformation of athletic abilities by “handicapping”;
  3. pairing with similarly-skilled opponents in networked play; and
  4. dynamic manipulation of game challenges in response to momentary and long-term changes in players’ physical capabilities (e.g. detect when the player gets tired and adjust the difficulty accordingly).

In terms of the precision of movement recognition, it is clear that there is a need for greater precision in movement recognition as Nijhar et al (2011) find that with an increase in the level of movement recognition precision there is also a consequent increase in the level of immersion of the player or learner. This holds across the different types of players or learners, i.e. those who are into hard exertion or soft fun and relaxation. The reason for this is that the controller fits into the players’ expectations better when there is greater precision in movement recognition. There is no need for the player to mentally compensate for the shortcomings of the controller, and therefore the player can immerse in the activity to a greater depth. For players that are motivated to achieve, and this can hold true for learners in BODY COMBAT as well, the result of greater movement precision recognition is that the game becomes more complex. In BODY COMBAT learning scenarios, the learner would be able to learn more accurately. The controller is more intuitive and consequently less of a distraction. This makes the players feel more challenged, cognitive and emotionally involved and more dissociated with the real world.

**4.3 Summary**

Thus far this chapter has presented a discussion of the findings from the current research. It is seen that there are different dimensions to the design of a self-learning course in BODY COMBAT that have to be considered. These various dimensions and influencing forces and factors have been discussed and their benefits, constraints etc. identified. The next chapter wraps up the research by presenting the overall conclusions from the current research and identifying further areas of research.

**Chapter 5 – Conclusions**

**5.1 Conclusions**

The current research set out to identify how augmented reality can improve technology that supports self-learning in body combat classes. It is seen that the technology to support AR is developing rapidly; there are many games that are commercially available today at a standard that is sufficient to ensure that the players are able to enjoy the games. AR technology can support various types of mappings of motion to suit the requirements of the current scenario. The research also found that self-learning in physical sports such as BODY COMBAT requires the mastering of new postures and motions. In BODY COMBAT specifically, it is seen that the kicks and punches have to be executed properly in order to obtain the most benefit and also not to injure oneself. Overall it can be said that AR technology can help in the learning of BODY COMBAT by making repetitive tasks pleasurable as well as correct. The use of this technology allows the players to exert maximum force with reduced risks, and the possibility of this acts as a motivation as well as a source of pleasure. Therefore, in BODY COMBAT the use of AR technology can help the learner to put greater effort in and relieve the monotony of repetitive tasks. Hence it can help the players to learn the required motor skills in a shorter time, as it helps to keep their attention and engagement. The structuring of the BODY COMBAT teaching exercise into classes can be supported by the AR technology. The other side benefits of using AR technology is self-paced learning and increased privacy as the learning can now take place in a location of the learner’s choice.

The facility for feedback that the AR technology enables can be said to indeed enhance the provision of teaching. Current research shows that players are motivated to achieve goals in games, and therefore the learning process if structured appropriately can encourage the learners to learn faster by making the learning process enjoyable.

The objectives of the research were identified as:

1. To investigate the state of the art in augmented reality – the main limitation of the current AR technology that supports games is found to be the precision of the movement recognition. The current research found a variety of limitations in this area. For example, the cameras that sensed or detected the movement had a limited spatial scope. This meant that the players quickly worked out that the cameras had this limitation and worked out a strategy to use this limitation to their advantage against opponents. In the case of self-learning in BODY COMBAT classes, the vice versa could be true. The learners may not realise that the cameras that detect motion have a limited spatial scope, and they could be learning a wrong movement simply because the camera failed to detect their movement and give accurate feedback. It was also found that current movement recognition technologies may fail to separate two or more bodies in close body to body interaction. This limitation is perhaps more relevant for self-learning in BODY COMBAT. The current research found that body to body interaction is rich and varied in combat play, and this rich and varied body to body interaction is poorly supported at best by the current AR technology. Most of the commercial games are designed such that the players mostly play independently, either by taking turns or playing in parallel. This type of activity was rightly identified as not being characteristic of traditional sports where there is a significant amount of body to body interactions. The limitations were identified to be in the sensing and actuating technologies in particular.
2. To investigate how self-learning in body combat can be improved - it is clear that self-learning can be improved using AR technologies by increasing the convenience of the users – allowing them to learn it at a place and time of their choosing. Beyond this, it is seen that the joy derived from maximum physical exertion can also be experienced by learners of BODY COMBAT. However, the downsides to using AR technology in terms of changes in strategy and consequently learning as a result of the limitations of the technology is yet to be clearly and specifically identified.
3. To identify the manner in which augmented reality can be used to improve self-learning in body combat – AR technology supports movement recognition to a sufficient degree of precision to facilitate individualised feedback especially in the early learning stages. This can allow for posture correction and learning of how to exert the right amount of force. AR technology can also increase enjoyment from learning, by facilitating the maximum exertion of force with reduced risks.

The current research set out to examine state of the art technology in the subject areas of augmented reality and motion tracking in order to establish the boundaries of what is practically possible and propose potential solutions that could be implemented to support self-learning more effectively. It was seen that the technology is in relatively nascent stage, although there are a new crop of commercial applications that use this technology. Significant areas of research remain unexplored, in terms of the human processes that facilitate learning and enjoyment, as well as the role of the AR technology in enhancing the learning activity. The findings from the current research however suggest that there is scope for positive contribution from AR technology in enhancing the learning activity in self-learning in BODY COMBAT. The research also identified the design constraints that would arise in the development of any

**5.2 Further areas for research**

It is clear that there are many further areas for research that arise from the findings of this research. The research areas are also disparate; for example, research in human cognitive processes, to understand how human beings form their gameplay strategies, identifying the impact of environmental factors, game affordances, etc. on the strategy development of the player is one area. By understanding how players formulate their game strategies it is possible for the AR games to cater to the needs of the players better, and also to explore the boundaries of what is possible. For example, the current research found complexity increased motion mapping to be possible, where the ability of the players can be supercharged with additional effects; AR makes this possible, but understanding human cognitive processes in game play can make such additional features truly augmenting reality; players can be made to feel that they really have intuitive superpowers.

Another prime area for research is of course the technological capabilities in the technology that supports and facilitates AR. The current research has identified that the limitations in sensing and actuating technologies is one of the main limitations that would have negative impact on any attempt to develop games that promote self-learning of BODY COMBAT. A number of different AR technology assisted games have been found to have attempted to simulate body to body interactions in a variety of different ways. One approach is to use avatars, either by mapping the movements of the player onto an online avatar or by making the player play against an online avatar. However, this still highlights the lack of support for games that facilitate real life body to body interactions between two real players. Therefore, there is definitely scope for research to develop the sensing and actuating technologies that would be able to support this type of body to body interactions with sufficient accuracy.

Bringing the two areas together, it is possible to see that there would be an impact on the human cognitive process and enjoyment, when there are different levels of body to body interaction. It is clear that a player would experience different sensory stimuli and emotions when the body to body interactions are between the player and an online avatar and when it is between two real life players. Further research is clearly necessary to understand the impact of increased body to body interaction on the enjoyment and motivations of the game player or learner.

Another gap in current research is also in the area of people with limited physical abilities. One of the main areas in which BODY COMBAT could be used is in helping people who have suffered accidents or illness and sustained physical disability to regain physical fitness. The guided learning aspect would be especially useful in this case. Whilst the sports benefits of BODY COMBAT is well known, the manner in which AR technology can enhance the learning in this scenario is not yet explored in current literature. It is however an area in which major benefits could be reaped due to huge practical significance of the application.

**References**

Anderson, F., Annett, M. & Bischof, WF. (2012). Tabletops in motion: the kinetics and kinematics of interactive surface physical therapy. CHI EA, 2351-2356.

Anderson, F., & Bischof, WF. (2013). Learning and Performance with Gesture Guides. CHI 1109-1118.

Barfield, W. (n.d.). *Fundamentals of Wearable Computers and Augmented Reality, Second Edition*. Retrieved from <https://books.google.com/books/about/Fundamentals_of_Wearable_Computers_and_A.html?id=QxUqCgAAQBAJ>

Cushion, C, et. Al, (2011) Retrieved from <https://www.ukcoaching.org/sites/default/files/Coach-Learning-and-Dev-Review.pdf>

Henderson, SJ. & Feiner, SK. (2011). Augmented reality in the psychomotor phase of a procedural task. ISMAR, 191-200.

Leatham, J. (2017, September 22). The Future of Augmented Reality in Fitness. Retrieved December 23, 2017, from https://www.vrfitnessinsider.com/the-future-of-augmented-reality-in-fitness/

Anderson, F., Grossman, T., Matejka, J., & Fitzmaurice, G. (2013a). YouMove: enhancing movement training with an augmented reality mirror. In *Proceedings of the 26th annual ACM symposium on User interface software and technology* (pp. 311–320). ACM.

Anderson, F., Grossman, T., Matejka, J., & Fitzmaurice, G. (2013b). YouMove: enhancing movement training with an augmented reality mirror. In *Proceedings of the 26th annual ACM symposium on User interface software and technology* (pp. 311–320). ACM.

Aukstakalnis, S. (2016). *Practical Augmented Reality: A Guide to the Technologies, Applications, and Human Factors for AR and VR*. Addison-Wesley Professional.

Barfield, W. (2015). *Fundamentals of Wearable Computers and Augmented Reality, Second Edition*. CRC Press.

Craig, A. B. (2013). *Understanding Augmented Reality: Concepts and Applications*. Newnes.

Dorfmüller, K. (1999). Robust tracking for augmented reality using retroreflective markers. *Computers & Graphics*, *23*(6), 795–800.

Friedrich, W., Jahn, D., & Schmidt, L. (2002). ARVIKA-Augmented Reality for Development, Production and Service. In *ISMAR* (Vol. 2002, pp. 3–4).

Guglielmo, L. G. A. (2008). Intensity domainand metabolic load to a Body Pump and Body Combat workout.

Hainich, R. R. (2009). *The End of Hardware: Augmented Reality and Beyond*. Booksurge.

Kipper, G., & Rampolla, J. (2012). *Augmented Reality: An Emerging Technologies Guide to AR*. Elsevier.

LeisureDb. (n.d.). 2017 STATE OF THE UK FITNESS INDUSTRY REPORT - OUT TODAY. Retrieved January 9, 2018, from http://www.leisuredb.com/blog/2017/5/5/2017-state-of-the-uk-fitness-industry-report-out-now

Yamabe, T., & Nakajima, T. (2013). Playful training with augmented reality games: case studies towards reality-oriented system design. *Multimedia Tools and Applications*, *62*(1), 259–286.

Zealand (www.bka.co.nz), B. D. O., Auckland, New. (n.d.). BODYCOMBATTM and core training. Retrieved January 9, 2018, from https://www.lesmills.com/uk/knowledge/fitness-research/bodycombat-and-core-training/

Bianchi-Berthouze, N., Kim, W. W., & Patel, D. (2007). Does Body Movement Engage You More in Digital Game Play? and Why? In *Affective Computing and Intelligent Interaction* (pp. 102–113). Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-74889-2\_10

Lindley, S. E., Le Couteur, J., & Berthouze, N. L. (2008). Stirring Up Experience Through Movement in Game Play: Effects on Engagement and Social Behaviour. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 511–514). New York, NY, USA: ACM. https://doi.org/10.1145/1357054.1357136

Mueller, F. “Floyd,” Edge, D., Vetere, F., Gibbs, M. R., Agamanolis, S., Bongers, B., & Sheridan, J. G. (2011). Designing Sports: A Framework for Exertion Games. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 2651–2660). New York, NY, USA: ACM. https://doi.org/10.1145/1978942.1979330

Nijhar, J., Bianchi-Berthouze, N., & Boguslawski, G. (2011). Does Movement Recognition Precision Affect the Player Experience in Exertion Games? In *Intelligent Technologies for Interactive Entertainment* (pp. 73–82). Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-30214-5\_9

Pasch, M., Berthouze, N., van Dijk, B., & Nijholt, A. (2017). *Movement-Based Sports Video Games: Investigating Motivation and Gaming Experience* (SSRN Scholarly Paper No. ID 2954844). Rochester, NY: Social Science Research Network. Retrieved from https://papers.ssrn.com/abstract=2954844