BRAINPLAY: AN INVESTIGATION OF SERIOUS GAMES THAT TAP INTO COGNITIVE PROCESSES

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‘This thesis is the result of the author’s original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.’

Signed: Date:

Video games are a growing industry, one that is exploring markets such as education, healthcare and society. The problem is that video games, or serious games, for health have yet to make an impact in a commercial market. The question that arises is why healthcare has not adopted video games in health care?

Previous work in health and psychology has explored the benefits video games can have on the following: cognitive processes; behaviour; and quality of life. However, the gap in previous research does not consider the development of a serious game for health by commercial game developers or investigate what healthcare professionals perceive a serious game to offer.

To approach this gap, this research reviewed the literature on game design frameworks and utilised one specific framework, the mechanics dynamics aesthetics (MDA) framework, to design a set of serious games for health referred to as Brainplay.

The study involved three user studies to explore the potential usability and perceived usefulness of the games in the intended context: (i) to understand whether Brainplay was still perceived by the general public as a game and elicited ‘play’ using a quantitative user experience survey; (ii) to understand whether the MDA framework could be understood by commercial game developers through thematic analysis of one-to-one interviews; (iii) to understand whether healthcare professionals would perceive a potential use for Brainplay in healthcare, again through thematic analysis of one-to-one interviews.

The conclusions this thesis can make is that Brainplay still elicited play with the public. Yet, when commercial game developers were interviewed, knowledge and usage of the MDA, or other game design frameworks, did not seem necessary to developing games for health. This thesis also concluded that the three healthcare professionals interviewed, from different background of healthcare, perceived different purposes for Brainplay within healthcare.

Key Words

Serious Games, Game Design, User Experience, Cognitive psychology, Play.

Glossary:

Association for Computing Machinery Digital Library (ACM); artificial intelligence (AI); Cognitive behavioural game design (CBGD); conventions components actions emotions (CCAE); Human computer interaction (HCI); Hedonic motivation system acceptance model (HMSAM); Mild cognitive impairment (MCI); Mechanics dynamics aesthetics (MDA); National Center for Biotechnology Information (NCBI); National Health Service (NHS); software development kit (sdk); Technology acceptance model (TAM); United Kingdom Interactive Entertainment (UKIE).

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1.1. CHAPTER ONE: INTRODUCTION

Video games are a growing industry. The industry started as a niche entertainment market to grow to one of the largest and popular markets around the globe. The global games audience is estimated to be nearly a quarter of the population of the world, between 2.2 and 2.6 billion people (UKIE, 2017). Video games are not limited to the few who own consoles; mobile games, tablet device games and social network websites have opened the video game market to a larger audience. Video games have also moved into new markets, with games like; Minecraft Edu (Mojang, 2017) which take the highly popular three-dimensional voxel game to classrooms; Virtual Battlespace 3 (Bohemia Studios, 2017) a simulation video game to help train soldiers; and Sea Hero Quest (Glitchers, 2017) where players can play on their mobile devices but help collect global data for dementia research. Video games are no longer limited to the entertainment industry.

Video games have moved into healthcare with research conducted into cognition, emotion, wellbeing and awareness. With a specific focus on cognition, there have been studies to view where video games have shown to improve reflexes and problem-solving ability (Chandra et al. 2016; Oei & Patterson, 2014). However, within the UK there has not been an influx of video games used or promoted by the national health service (NHS) with only one known game, Nintendo Wii Fit, endorsed by the NHS (Wallop, 2009).

Within the present game development climate there are multiple education paths into video games, with specialist roles such as artists, level designers, narrative designers, blogger, reviewer, animation programmers, quality assurance testers, sound design etc. Today a development team can range from their hundreds to a solo developer and there are game design methods as well as production methods to help deliver a product to market (Salen & Zimmerman, 2003; Flanagan, 2009; Macklin & Sharp, 2016).

With the growing development of game design and the potential market move into healthcare there is potential for video games to explore methods of designing games for a specific purpose within a serious context such as healthcare and education. In section 3.1.3 of this thesis, the researcher reviewed the current game design frameworks and selected a framework which was used to develop the video game prototype. Section 1.2 will detail the motivation for pursuing games for healthcare.

1.2. MOTIVATIONS

As stated in the section 1.1, within the UK there has been a lack of video games endorsed, promoted or utilised by the NHS (Wallop, 2009). The lack of games endorsed by the NHS provided the first motivation for this research. Combined with the growing amount of research into cognition, health and video games (Green & Bavelier, 2003; Nezerwa et al. 2014; Mishra, Anguera & Gazzaley 2016), this research explored the potential of video games in healthcare and interviewed health care professionals on whether they would like to see video games in healthcare or not.

The second motivation was to determine whether video games designed for healthcare would still elicit 'play' and would be perceived as enjoyable and 'fun'. This research developed a video game that could potentially be used to assess or diagnose individual's cognitive processes and explored whether members of the public perceived playing the developed video game as 'fun'.

Finally, the third motivation explored whether game development professionals understand the design decisions made by this research and could use a game design framework to develop serious games for healthcare.

These three motivations presented the overall aim of the thesis which was to develop a 'serious game' that elicits 'play' from an existing game design framework, which could be developed by commercial video game developers and explore what potential areas of healthcare a serious game could, or could not, be applied to.

The overall aim presents three research questions:

1. Are serious video games that are designed to assess or diagnose cognitive processes, still perceived as 'fun' video games?
2. Are game design frameworks necessary to the development of serious games for healthcare by commercial game developers?
3. What are the potential uses of a serious video game in healthcare?

1.3. THESIS OVERVIEW

This thesis is organised into ten chapters

1. **Chapter One Introduction**: Highlighted the area of research, the motivations for this research and outlined the research aims.
2. **Chapter Two Background**: The background chapter presents the game design terminology that will be frequently referenced throughout this research. It outlines which theory of cognitive processes will be used.
3. **Chapter Three Previous Work**: The previous work chapter presents a review of game design frameworks focused on game development and healthcare/cognitive video game development. The review selected which framework was used as a method for creating video games based on cognitive processes. The previous work chapter also included a summary of existing video games designed for cognition. This was conducted to observe what design choices or methods were used to create video games based on cognitive processes.
4. **Chapter Four Methods**: The methods chapter outlines three studies to answer the research questions stated in section 1.2; a user study to observe whether a prototype designed for this research is still perceived as a video game; a set of interviews to discuss the usefulness of a game design framework and whether external game developers support the design process of the prototype; and a set of interviews with healthcare professionals to determine the potential of video games with healthcare, specifically using the prototype developed from this research as an example.
5. **Chapter Five Prototype Development:** The prototype development chapter discusses the design process of the prototype, Brainplay. The chapter details the chosen technology, the game design process involving the mechanics dynamics aesthetics (MDA) framework, early prototypes designed and the final digital prototypes developed.
6. **Chapter Six Implementation:** The Implementation chapter describes how Brainplay was developed into a digital prototype. It details the processes of creating each of the games within Brainplay and how the prototype was ported to tablet technology.
7. **Chapter Seven Game-Play Evaluation:** This chapter describes the process of the user study which was conducted to test if Brainplay was still perceived as a game. User experience was measured using a variation of the technology acceptance model (TAM), the hedonic motivation-system acceptance model (HMSAM) to gather participants immersion, control, enjoyment and curiosity. The chapter includes the results of this study with statistical analysis as well as a discussion of the results.

8. **Chapter Eight MDA Evaluation:** This chapter details the interviews gathered for the professional game developer’s opinion on how Brainplay was used and whether the use of the MDA framework was needed or required.
9. **Chapter Nine Potential Application in Healthcare:** The final study explores the potential of Brainplay within a healthcare setting. To do this, the researcher interviewed three healthcare professionals from diverse backgrounds and gathered information regarding the demand for video games in healthcare, where would a game like Brainplay be used and what they thought Brainplay could measure.
10. **Chapter Ten Future Study and Conclusion:** The last chapter provides a concise delivery of what was discovered in this research. If the initial hypotheses from the studies were confirmed or not, as well as the other observations found by this exploratory research. This chapter of the thesis also suggests the areas of future interest and research.

2.1. CHAPTER TWO: BACKGROUND

The background chapter includes two main points that are necessary to outline and define for this research.

Firstly, in section 2.2 an explanation and definition are given for cognition. The section details the multiple areas of study within cognition and defines the cognitive processes that are a focus of interest in this thesis.

Secondly, in section 2.3 the background will detail the terms of ‘games’ and ‘serious games’. The section will also detail the importance of play within games as well as the psychology state of Flow that is often referenced within the study of games.

2.2. DEFINING COGNITION

There are multiple areas of study within cognition, including cognitive psychology, study of mind and intelligence, philosophy, artificial intelligence, neuropsychology and cognitive processes (Thagard, 1996). With such a broad area of study available, it is important to specify the specific area of cognition relevant to this research, which is cognitive psychology.

Within the literature of cognitive psychology there are processes and structures that are interdependent to make up the cognitive system (Eysenck & Keane, 2010). Eysenck and Keane (2010) define topics such as perception, attention and working memory as cognitive processes within cognitive psychology (2010). Further, they detail that higher-level processes (e.g. working memory) are comprised of basic processes (e.g. problem solving). For clarity, when this research uses the term ‘cognitive process (or processing)’, it is referencing perception, attention, memory etc. as defined by Eysenck and Keane (2010).

The study will use the cognitive process definitions and theories laid out by Groome et al. (2013) and Eysenck & Keane (2010). Each cognitive process has been described below in Table one.

TABLE ONE DEFINITIONS OF COGNITIVE PROCESSES

Cognitive Process	Definition
Perception	“Perception involves building up a model of the world around us and the objects and people in it” (Groome et al. 2013)
Attention	“Attention generally refers to selectivity of processing” (Eysenck & Keane, 2010)
Thinking & Reasoning	“The study of problem-solving has shown that we use a limited number of strategies and heuristics to solve a range of problems and these allow us to work within the limitations of our memory system” (Groome et al. 2013)
Language	“Language involves a complex system operating at a number of levels from basic sounds of speech, through word, sentence and discourse levels.” (Groome et al. 2013)
Working Memory	“Working memory as a workspace where analysis and processing of information would take place” (Groome et al. 2013)
Long Term Memory	“…long-term memory store and that information enters into the long-term store through rehearsal and other processing activities in the short-term store.” (Eysenck & Keane, 2010).

2.3. GAMES AND PLAY

2.3.1. SERIOUS GAMES

The definition of a serious game is an ongoing discussion where there is no unanimous definition. Early theories of serious games (or serious play) are proposed by Huizinga (1949) and Callois (1962). Serious games culminate principles of play, social behaviour and interaction to influence a player. Abt (1970) was credited as the first scholar to use the term “serious games” in his theory on games. Breuer and Bente (2010) discuss that the definition of serious games changes depending on the person using it and their background. In addition to defining the term of serious games, there have been numerous theories on how to define a game, not necessarily a video game either. Early theories presented by Suits (1978) defined the act of playing a game as “the voluntary attempt to overcome unnecessary obstacles”. Suits (1978) description of a game has been fondly used in more modern research of video games by researchers such as McGonigal (2011), Juul (2003) & Sedig, Parsons & Haworth, (2017). Abt’s (1970) research into serious games has contributed to the further discussion of serious games, sparking conversations and theories from leaders in serious games theory (Bogost, 2010; Flanagan, 2000; McGonigal, 2011; Breuer & Bente, 2010; Aarseth, 2018). At the time of writing, research by Aarseth (2018) has been funded to investigate and provide a concise definition on serious games.

Within the discussion of defining serious games there are arguments to whether ‘fun’ or play is an important part of serious games. Breuer & Bente (2010) highlight the discussion in their paper where they suggest the definition faces a contradiction “Are games not fun by definition and hence not serious? On the other hand, one could argue that all games are serious.” Abt (1970) suggested serious games were ‘purposefully thought out and are not intended to be played primarily for amusement’. Abt (1970) suggested that serious games were to provide a serious purpose and not intended to entertain, a definition that was echoed by Michael & Chen (2006). A broader definition of serious games was given by Zyda (2005) who stated “Serious Games have more than just story, art and software (…) they involve pedagogy: activities that educate or instruct, thereby imparting knowledge or skill. This makes games serious”. The definition presented by Zyda (2005) suggests that serious games do not need to place entertainment as a latter focus but instead involve a pedagogy or activities to impart knowledge. Zyda’s (2005) definition relates to the work of Breuer & Bente (2010) where games could be considered serious through their purpose of delivering entertainment. Juul (2003) presented a short paper on how to define a game where he discussed the works of Caillois (1961), Huizinga (1951), Salen and Zimmerman (2003), Suits (1978), Avedon & Sutton (1981) and Kelley (1988). From the sample of researchers, Juul

(2003) reviewed their definition for a game to define key principles that were unanimous with the selected researchers. Although Juul's (2003) paper discusses the definition of a game, there is merit in discussing the principles and how they would relate to serious games.

Juul's (2003) defining principles of a game suggested six features. Firstly, there are rules which have t be sufficiently well defined so that the player understands constraints of what the can do and provide clarity to the player. Next, games have variable and quantifiable outcomes which can be loosely described as there are different methods for a player to complete or play a game. That some outcomes of the game are better than others, there is valorisation of an outcome. Player effort is required to play a game, therefore suggesting that games offer a challenge to the player. Next, that there is a psychological attachment to the outcome by the player. The psychological attachment to an outcome comes from the discussion of psychology in games, where players can become invested with a character or story and potentially experience strong emotions such as empathy or anger towards a game. Finally, games have negotiable consequences where games can optionally be assigned real-life consequences. What this means is that games have the potential to affect a player's life where the experience of a game could affect a person's opinion on a subject matter. A popular example is *That Dragon, Cancer* (Numinous Games, 2018) which has been labelled as an empathy game. *That Dragon, Cancer* (Numinous Games, 2018) is a story about parents dealing with the loss of one of their children to cancer. A player could come away from *That Dragon, Cancer* and harbour a different opinion on the importance of cancer treatment, a consequence of the game. The negotiable consequences as suggested by Juul (2003) aligns with some perspectives on how to define a serious game. Where the valorisation of an outcome and consequences from playing a game could be interpreted as traits of a serious game.

Serious games have seen popular use in education and learning literature. As mentioned earlier Michael & Chen (2006) define serious games as an education and learning tool, where the primary purpose of a serious game is to educate and inform and not to be entertaining. The perspective of serious games as an educational tool has seen a breadth of interpretation, however to only encompass serious games within education is limiting. Prensky (2001) suggests a digital game-based learning as the next step in education as generations of people are becoming more technologically aware. Within Prensky's work, they discuss how modern technology such as games have improved cognitive skills and how games could a new method to educate. Education and serious games have also given rise to different terms often connected to serious games such as edutainment and e-learning. Michael and Chen (2006) discussed the term of edutainment as a popular term utilised by the media in the 1990's but suggested serious games were more than edutainment as they go beyond the traditional methods of teaching, suggesting how interaction with games produces outcomes such as reward and challenge incites motivation. E-learning has been discussed in psychology, pedagogy and computer science and often related to serious games (Haythornthwaite and Andrews 2007). Simply defined, e-learning has been used to describe any from of learning from a digital device but does not require any form of fun or entertainment. Although these terms discuss education and learning specifically, serious games have been used in other disciplines such as health, awareness and social wellbeing therefore further discussion needs to include how serious games encompass other disciplines outside education.

In the discussion of serious games, play is a concept that often arises within the discussion of games. Play shares some similarity to serious games as it is another term that has multiple interpretations. Play has had numerous definitions in games and activities. Sutton-Smith (1997) defines play as an activity that is fun, voluntary, intrinsically motivated, of free choice an offer and exciting escape. Huizinga (1951) defines play as “a free activity standing quite consciously outside “ordinary” life.” Eberle (2014) published an article on the philosophy and definition of play as “play describes action, the lack of action and attitudes depending on its tense.” Eberle (2014) further suggested that play is “purposeless, voluntary, outside the ordinary, fun and defined by rules” not a dissimilar description to what defines a game by Suits (1978) and Salen & Zimmerman (2003). Defining play in games is rooted in psychology where the interconnectivity of serious games involves design, psychology, social interaction and learning. Gray (2015) suggested that each player experience is different from another and that ‘play’ can be considered as self-chosen and self-directed, suggesting each player could interpret and different understanding from gameplay. Related theories on play also include self-determination (Deci & Ryan, 2000) and flow (Csikszentmihalyi, 2002). These theories explore the playful relationship between a player and a game. The theories suggest learning and experiencing through self-efficacy and motivation opposed to traditional learning methods. Play has often been discussed with games as a crucial defining trait of a game. Whether games are regarded as enjoyable or fun they are often eliciting play from the player. Providing an enjoyable or fun experience is a key trait of a game, otherwise the game would potentially be seen as an assessment and less of a voluntary experience.

Serious games for health have gained a growing interest in recent years. Commercial development of games that encourage exercise, such as Pokemon Go (Niantic 2018) and in earlier years the Xbox Fitness (Sumo Digital 2016). A review by Wattanasoontorn et al. (2013) reviewed serious games for health using the classification guide presented by Sawyer and Smith (2008). The review by Wattanasoontorn et al. suggested two classifications of serious games, games that were for patients and games for non-patients.

The categories for patients included games that involved, health monitoring, detection (of symptoms), treatment or therapy, rehabilitation and education. Whereas the categories for non-patients involved games that promoted health and wellness, training and simulation for professionals and training and simulation games for non-professionals (awareness). However, Wattanasoontorn et al. (2013) did not discuss the definition of serious games for health as they acknowledged the ongoing debate on how to define a serious game. They did acknowledge that research had shown games to improve education and how serious games were commonly associated with learning but held promise in other disciplines, as evident by their review. It could be suggested that there is a gap in how serious games for health are defined.

The aim of this thesis is not to debate the differences and definitions of these terms however a running interpretation should be justified for clarity. Breuer and Bente (2010) suggested that serious games could be a victim of contradiction where they are both a purposeful tool and an entertainment to the player. It is therefore suggested that the definition of serious games is a combination including: Suits' (1978), the open potential of serious games to impart knowledge or skill presented by Zyda (2005) and Juul (2003) and Salen & Zimmerman (2003) suggestion of key features of a game. Therefore, the suggestion of this thesis is that serious games can be defined as "the voluntary attempt to overcome a set of rules, systems and challenges that are presented to the player that result in negotiable quantifiable outcomes which can impart knowledge or skill."

2.3.2 GAME DESIGN THEORY VERSUS GAME DESIGN PRACTICE

Within game design are theories of play (Gray, 2015; McGonigal, 2011), fun (Koster 2004), value (Flanagan & Nissenbaum 2014) and emotion (Isbister, 2016). Play has been discussed in section in 2.3.1 of serious games but there are further perspectives on theory side of game design. Play receives a lot of attention due to the interconnectivity of games and play. Game design scholars are interested to understand what makes us play and what motives play. De Koven (2013) discusses the theory of play in his book where they describe playing games well. De Koven (2013) suggests that playing well at a game is not just succeeding but developing a sense of completeness, that all the purposes you may have are fulfilled in playing. De Koven's (2013) perspective on serious games makes an argument for games as a tool of mental wellbeing, being able to give the player a sense of purpose and then a sense of completion. On the other hand, Rieber (1996) defines play as an action opposed to a sense, where play is shares similarities to the definition of a game.

Rieber (1996) discusses the fallacy that play is the opposite of work as that would be considered leisure. In fact, Rieber (1996) asserts that work has the ability to be considered play if an individual is engaged, intrinsically motivated and provides an extrinsic outcome to the individual. In their research article, Rieber (1996) discussed related theories of play such as flow theory and Piagetian learning theory. Flow theory (Csikszentmihalyi, 2002) describes a peculiar state where a person is both absorbed and engaged by an activity that they seem to excel at that activity almost automatically. Csikszentmihalyi (2002) defined flow as "the state in which people are so involved in an activity that nothing else seems to matter; the experience is so enjoyable that people will do it at great cost, for the sheer sake of doing so". Piagetian learning theory comes from the works of Papert (1980) pedagogy and research in learning which revolves around the idea of self-determination and self- reflection in undergoing an activity. The idea of self-determination or autonomy shares similarities with Deci & Ryan's (2000) self-determination theory (SDT) as mentioned in the serious games section. Deci & Ryan (2000) research has been applied to games, business, sport and health in discussing why individuals are motivated to undergo certain actions or tasks. Play holds a number of theories to how they affect the design of game, the next section will discuss other theories outside of play.

Play and fun are often associated in games as the nature of play is to engage and motivate us, in doing so fun and entertainment are elicited. However, there are discussions to how fun could be discussed as a theory itself. Koster (2004) discusses fun within game design in the context of how games differ from reading (or stories). Koster (2004) suggested that the differences between games and stories are at two ends of a string, where games are good at objectification and experiential teaching and stories teach vicariously but are also good at empathy. However, Koster (2004) also discussed the different types of fun that can come from games as the term fun is hollow without justification. Koster (2004) described that there are multiple forms of fun proposed by other researchers where some identify fun as sense-pleasure, social frameworks or make believe (Hunicke, Zubec & LeBlanc, 2004) and fun broken down into dozens of complex emotions (Ekman, 1970). Another suggested theory of game design comes from values at play in games (Flanagan & Nissenbaum 2014). Flanagan & Nissenbaum (2014) published a book on the values at play in games. Within their book they discussed how games enrich understanding of sociocultural patterns and the effect of media on designing new games. The value of play discussion comes from how a player's values and belief can shape the experience that they take part in. Flanagan & Nissenbaum (2014) suggested the Values at play Heuristic for game design, made up of three components of discovery, implementation and verification. Discovery involves identifying the values that are relevant to a given project and defining those values within the context of the game where implementation includes translating those values into game elements. The verification component is about the designer's validity in identifying values at play. Finally, there are theories on how emotion play a part in game design. Theories have on how empathy (Schrier, 2010) have been discussed, however the theory of emotion in games has been discussed by Isbister's (2016) work. Isbister's (2016) discussed how choices, social play, connection and intimacy help design games. One of the first concepts discussed by Isbister (2016) is the theory of meaningful choices, suggesting that games differ from other media as they offer players the change to influence outcomes through their own efforts. Isbister (2016) relates meaningful choice to the theory of flow (Csikszentmihalyi, 2002). In addition, Isbister (2016) discusses why playing together matters and discusses the emotional responses that differ when we play games socially. Isbister (2016) reported that competitiveness against a real-life person meant a player was less likely to become bored or uninterested in a game. Thus, suggesting play takes different forms depending on the social context a game is applied to.

The brief introduction to theories in game design highlights different perspectives on self-motivated activities and play but also highlights theories towards game design. Where Flanagan & Nissenbaum (2014) discuss how designers can implement and verify key values of play and Isbister (2016) suggests how play can change through social context (whether single player or cooperatively). These theories are presented to explain why individuals play but to also further the development of video games. However, there is a lack of evidence to suggest these theories are implemented into game design. Scholars mentioned in this section had identified games that illustrated a theory, an example would be the Sid Meier's

Civilisation (Isbister, 2016 citing Sid Meier 1991) strategy game that contains numerous (meaningful) interesting choices that change how the game will play. In practice, game design often takes on a mechanical or production side development. The game design features of rules, systems and culture are one example by Salen & Zimmerman (2003). However, the production side of game development in practice is often compromised of waterfall and scrum methods.

In section 2.3.1 the mechanical side of game design and development was briefly explained. Juul (2003) presented the features that define a game and in doing so, briefly touched on the mechanical side of game development. The term mechanical is used to describe the actual features that are implemented the game such as the genre of game (shooter or adventure) or the number of lives a player has. Rules are what are described as the formal structures that define a game (Salen & Zimmerman, 2003). For example, the game of tag could be played in a video game setting or physically, the rules of the game would be the same. Systems are what are referred to as the complex components of a game (Salen & Zimmerman, 2003). They encompass objects in the game, variables, mathematical systems such as physics engines and the environment that the game is placed within. Rules and systems make up the complex structure to designing a game and they do overlap with the concept of play. In addition, there have been discussions to how rules are defined and what they mean to the design of games. However, the theory side of why we play, and serious games have yet to make an impact into the commercial market.

Commercial development of video games is not the same between each studio or development team. There are large companies with multiple studios that work on various parts of the same game, referred to as triple A development. There is then independent or 'indie' development which are often small start-up teams working on smaller titles. Different team structures and sizes require different approaches to development. Scrum and waterfall management are two examples of the type of game development management that operate in game development practice. Scrum is a lean method of management that involves regularly meetings that are often short in time (Sliger, 2011). Scrum is used to ensure team members are where they should be at the stage in development. Waterfall, or Production of large computer programs, on the other hand is a linear set of tasks that require stages of development (Benington, 1983). For example, an environment artist would not be able to paint a 3D environment if a level designer had not mapped out and designed the level, this means there would be an order to how development could work. With the industry still developing its production methods there is room to improve how game development, particularly for serious game development, can be improved. Research into serious game frameworks and development could aide in the development of commercial development by identifying problems in areas such as health. Once identified, research can explore the areas where serious games have the potential to help, whether through health, wellbeing, education, awareness etc. The work of this thesis is to suggest a conceptual bridging between game design theory and game design practice, within the area of serious games for health.

2.3.3. SUMMARY

This section provides some insight into the ongoing discussion of what defines a 'game' and what defines a 'serious game'. The research in this thesis does not aim to provide a new definition of serious games but it is important to clarify the definition for further research where serious games are suggested to be "the voluntary attempt to overcome a set of rules, systems and challenges that are presented to the player that result in negotiable quantifiable outcomes which can impart knowledge or skill." In addition, there is the suggestion that there is a gap between game design practice and game design theory. Where theory has developed conceptual frameworks and models for bridging games to different disciplines such as health, game design practice predominantly remains in production-based development. The research discussed in this chapter highlighted three points that should be considered in the development of a video game prototype, seen in section 5.1, and the user studies, sections 7, 8 and 9:

(i) The design of a video game should be adhered to the game design features of Juul (2003) & Salen and Zimmerman (2003), establishing rules, systems, challenges, quantifiable outcomes and value for the player

(ii) A game should elicit the experience of play to create a game that could be defined as a "voluntary participation" or fun and entertaining.

(iii) The 'serious purpose' of a game could be interpreted differently due to the experience of play and its uniqueness to an individual (Gray, 2015).

3.1. CHAPTER THREE: PREVIOUS WORK

Both researchers and developers have created various methods to design 'games' and 'serious games', suggesting different approaches are required to deliver the 'serious' nature of a video game (Oceja & Fernandez, 2016; Rankin et al. 2008; Salen and Zimmerman, 2003; Flanagan, 2009; Macklin & Sharp, 2016; Kiili, 2005). To understand the availability and benefits of game design frameworks and decide on which framework to use in this research, a review was conducted of previous work to determine which game design framework could be used to develop games that model cognitive processes.

The reason for reviewing previous work on game design frameworks was to justify the choice of a suitable game design framework to design video games that model cognitive processes. The second research question in section 1.2 asked;

"Are game design frameworks necessary to the development of serious games for healthcare by commercial game developers?"

This research sought to present a method for creating games that could model cognitive processes and could be further developed by commercial game developers. It also sought to present the design decisions of creating games that model cognitive processes so that future study could replicate the development of games in this research.

The researcher searched the PubMed central database through the National Centre for Biotechnology Information (NCBI), the Association for Computing Machinery Digital Library (ACM) and ResearchGate for journals on game design frameworks and existing games were designed to assess or diagnose cognitive processes. The review of research was conducted to explore which game design framework was best suited to create a video game(s) that would still be perceived as a game and provided a structure that future study, or commercial developers could replicate to create video game(s) to model cognitive processes.

3.1.1. INCLUSION CRITERIA

Journals and articles were included in the review if they adhered to the following criteria:

(1) Cited as game design framework
(2) Open Access (For those in commercial development to access the literature used in this review)
(3) Proposed a method for creating games
(4) Provided a clear justification for the use and effectiveness of a game design framework or model
(5) Published in the English language

In addition, journals and articles were included if they provided:

(1) A possible serious game design framework
(2) An example of video games that modelled cognitive processes

If any journals or articles presented the following, they were excluded from the review:

(1) Presented a framework with little justification for application
(2) Poster presentation and conferences papers
(3) The design of physical games as opposed to digital games
(4) Systematic reviews that were not reviewing game design frameworks

To clarify, game design framework refers to a research journal or publication providing a design process. Whether that process is a theory or a practice-based model, it would need to demonstrate the theory of design and its relationship to game development. The clarification is required as there are instances of research publications and journals which review existing frameworks or do not present a theory or practice-based model. The second criteria required publications to be open access, which severely constrains the scoping review of previous work. However, the justification for this constraint is two-fold. Firstly, open access journals would be available to commercial game developers whom would not likely have access to journal databases. Secondly, the open access constraint helps build the bridge between theory and practice based, demonstrating what models and frameworks are available to developers. The limitation of constraining to open access publications could mean that game design frameworks were missed in the inclusion criteria, which may have led to a different outcome in the scoping review.

The proposed method for creating games was included in the inclusion criteria as there are articles which are concerned with designing experience or what motivates playing games but do not expand further to how to design a game. Examples such as Chesham et al. (2017)

and Hilgard et al. (2013) provide research on what older people prefer to play and how to measure experience. Although interesting and potentially of interest for further research, these research articles do not provide a design approach to creating a game with a specific goal or experience in mind. Consequently, the exclusion criteria presented limitations. The first exclusion criteria are whether the publication on a game design framework is presented without enough justification for the design approach or theory. An example would be a game design framework that has not evidenced the key design components such as mechanics and play. The second exclusion criteria presented a limitation in that poster presentations and conference papers were omitted by the scoping review. The justification for omitting the poster presentation and conference papers was due to the reliability of the publications. Poster presentations and conferences papers on a preliminary search presented game design frameworks without any evidence of testing. Testing was defined as developing a game through a proposed framework or model and evidencing that the theoretical or practice-based framework has proved the framework as a usable approach for game development. Excluded journals have been reviewed separately as proceedings in section 3.1.6.

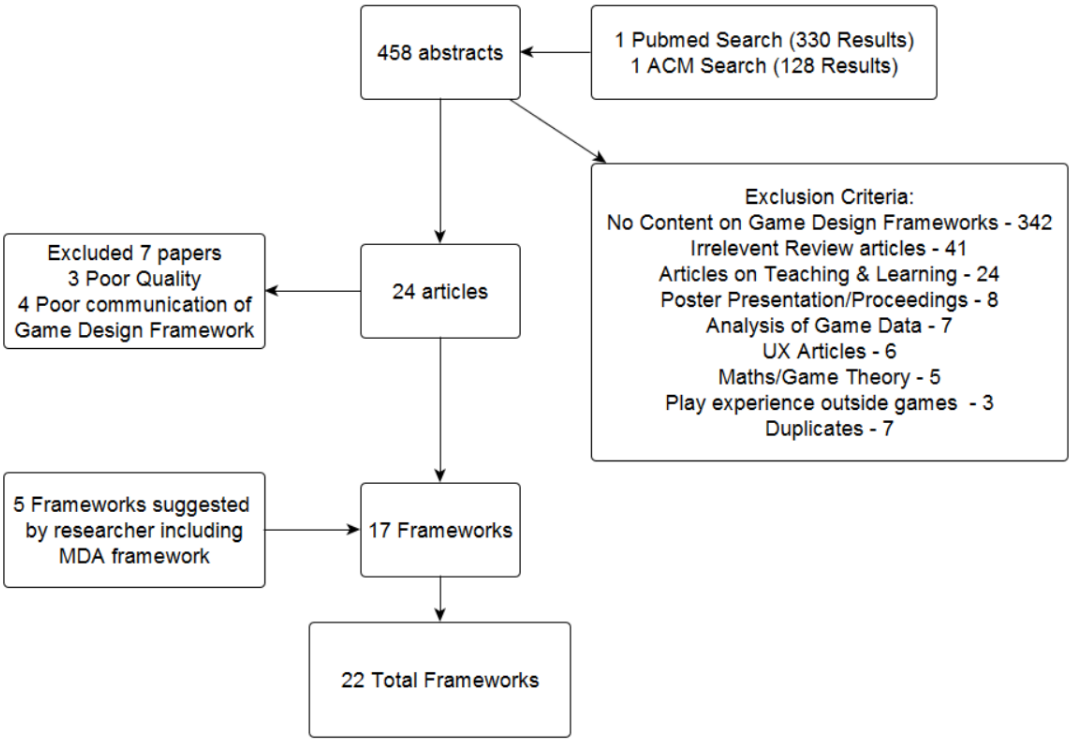


FIGURE ONE REVIEW STRATEGY OF PREVIOUS GAME DESIGN FRAMEWORKS AND METHODS

3.1.2. BRAIN TRAINING GAMES

Although there has been the suggestion of a gap between game design theory and game design practice regarding serious games for health, there is one area that has received attention, brain training games. Brain training games saw a rise in popularity with the release of the Nintendo DS (2018) handheld console that had the Dr Kawashima Brain training series released (2006). Brain training games promoted the idea of training your brain and potentially improving mental health (Nintendo. 2006). Brain training games could provide design approaches and methods to bridge the gap between theory and practice but the consensus towards brain training games is divided.

Brain training games became popular with mobile games such as Lumosity (2018) and Cognito (TidePool, Inc. 2014) that received media attention. A review of brain training games concluded that there was some potential in relation to cognitive stability, however there was a small amount of evidence to the success of brain training games in preventing cognitive decline (Stanford, 2014). However, it was evident from the Stanford review and others (Kable et al. 2017; Baniqued et al, 2013a) that there were too many consumers manipulated into the fear of cognitive decline, thus spending money on brain training games as well as lack of evidence to the use of brain training games. Publishers were capitalising on the anxiety of consumers. In response the Stanford (2014) consensus offered five recommendations which advised: further research to understand the types of challenges and engagements benefitting cognitive function; that physical exercise is a moderate approach to improve general health; single studies conducted by researchers with financial interests in the product is not enough to assume that a game has been rigorously examined; no studies have demonstrated that playing brain games cures or prevents Alzheimer’s disease or other forms of dementia; and no studies have demonstrated the expectation of one shot brain games will help with prevention of cognitive decline.

McGonigal (2011) stated that commercially available games that aren’t brain training games are already educating and testing player’s cognitive skills. This assertion is supported by Shute et al. (2014) who investigated the effects of *Portal 2* and *Lumosity* on cognitive and non-cognitive skills (Shute et al. 2014). In the study, participants were randomly assigned to play either *Portal 2* a popular video game or *Lumosity,* a popular brain training game (Shute et al. 2014). In the test, the participants completed a set of online tests that measured cognitive and non-cognitive tests before and after playing the games. The result of which saw *Portal 2* players performing better on the measured tests compared to the group who played *Lumosity.* In addition, Kable et al. (2017) utilised Lumosity in a randomized controlled trial to measure cognitive training where they found some neural regions of the brain were stimulated but not the cognitive processes promised by developers. A study by Baniqued et al. (2013a) investigated how brain training programs, not limited to games, could broadly improve cognitive abilities. The results of fifteen hours of training showcased an improvement in completing the brain training program over time but there was little evidence of this training transferring to other tasks (Baniqued et al. 2013a). Transfer is the term used to describe cognitive ability from one task, improving a different task. McLaughlin et al. (2018) investigated the feasibility of brain training games in middle aged adults where games where used alongside a cognitive battery (measurement of cognitive ability). The results of their 12-week investigation suggested improvements in executive functions and the feasibility of brain training games for that specific demographic. The developed games, named Brain powered games (BPG) where then used in a follow up investigation with the target audience.

An area that has not been explored widely is the development or design of brain training games. Studies often use games such as Lumosity as the tool to measure cognitive ability but there are few examples of design processes to how a brain training game was made. However, there are examples such as Giordani et al. (2015) who developed a computer-based training platform directly for at risk African children. Giordani et al. (2015) identified the technology available and the simple mechanics required for young children who may have limited knowledge or understanding of technology tools. Similarly, a study by Lu et al. (2017) conducted a design-based approach to evaluating cognitive traing games for older people. Their study involved older people and administrators of cognitive care to help design a cognitive computer game that created an iPad prototype. User experience by Lu et al. (2017) identified satisfaction with the game and its usability but suggested further work was needed to investigate the cognitive training in mobile games. These examples highlight that co-design is a dependent factor in designing brain training games for assessment.

A key point that should be discussed is although there is a debate on the feasibility of brain training games. The ‘term’ training is used which suggests a different interaction to playing a game. Where an individual in these studies trains for four, six or twelve weeks, they are training at the game (Baniqued et al. 2013a; McLaughlin et al. 2018). It could be argued that they are working at the game and potentially not enjoying or playing with the games. This could be evident by McGonigal (2011) suggestion that games are already educating players and the study conducted by Shute et al. (2014) where a game recorded an increase in cognitive activity over the brain training game. The difference in interaction may cause positive results as they are training on the same games or programmes whereas observing improvement in cognitive ability through play is something that has not been explored further. A covert approach to monitoring play may present further exploration to how brain training games and video games differ in their method of delivery, one aims to train where the other creates a playful experience.

3.1.3. SEARCH STRATEGY

The researcher conducted three stages in the search of game design frameworks. The first stage identified publications known to the researcher that demonstrated game design methods or models, often used within higher education. This provided five frameworks suggested by the researcher.

The second stage involved identifying game design methods/framework that was published in literature or a journal. The researcher conducted a search through the National Centre for Biotechnology Information (NCBI), focused on the PubMed Central database, for game design frameworks that have been used in healthcare setting (https://www.ncbi.nlm.nih.gov/ , 330 results in total, see appendix 1). This ensured that the literature considered the inclusion of a serious game design avenue from a healthcare perspective.

The third stage conducted a search through the Association for Computing Machinery Digital Library (ACM) (http://dl.acm.org , 128 results in total, see appendix 1). Identifying literature through ACM was to ensure the discovery of game design frameworks proposed by individuals from a computing background.

Finally, the researcher searched the citations of the mechanics dynamics aesthetics (MDA) framework (Hunicke, LeBlanc & Zubek, 2004) through ResearchGate, as this was the source of the highest number of citations for the MDA framework. The MDA was identified by the researcher as a key publication in game design and further studies had commonly cited the MDA as a key game design framework. Using the MDA framework as a search term was due to the number of frameworks that have adopted the MDA into new models and this research explored how other researchers had developed a different game design method or framework.

The resulting abstracts from these searches were analysed to identify any potential relevant material that would contribute to the discussion of game design frameworks.

3.1.3.1. QUERY METHODS

The inclusion criteria created the constraints for the review of research, limiting the review to published articles cited a game design framework or model. Query methods were used to discover the articles that were screened in the scoping review. For example, ‘video games’ was a key term used to search for game design frameworks as design framework for applications, board games and physical games are different in their nature of interaction, therefore potentially not suitable for the design of digital games that utilise different interactions that rely on the play being driven to progress. The query methods used to search for papers was constructed around specific search terms seen in figure two below and appendix one:

Advanced search on NCBI (("video games"[MeSH Terms] OR ("video"[All Fields] AND "games"[All Fields]) OR "video games"[All Fields] OR ("video"[All Fields] AND "game"[All Fields]) OR "video game"[All Fields]) AND design[All Fields] AND frameworks[All Fields]) AND "open access"[filter] Advanced search on ACM (+video +game +design +framework) Search strategy for ResearchGate – MDA Citations, Video game design Frameworks

FIGURE TWO QUERY METHODS

As seen in figure two, the search in each of the three databases used similar key words in their search. In the case of framework, terms such as model, design approach and principles were used to widen the search for articles. The key use of ‘design’ was to constrain the search to creative and philosophical approaches to how games can be designed, rather than development. Development would suggest a more mechanical approach to developing systems within a game, rather than the experience or interaction elicited from a player. The NCBI search presented the greatest number of results as the terms used where searched in all fields which led to a number of articles on game theory, statistics and user experience outside video games.

3.1.3.2. ARTICLES SCREENED

This research presents five frameworks that were discovered from publications known to the researcher regarding game design frameworks. The MDA framework was included in this list.

Of the total 458 articles that were screened from PubMed and ACM, 443 were excluded from the review. The 342 journals and articles were excluded due to the fact they failed to meet the inclusion criteria of the search strategy. A further 101 articles were omitted due to the exclusion criteria. The 101 were compromised of 41 review articles not relevant to game design; 24 articles that were focused on learning/teaching; 8 poster presentation or proceedings; 7 were an analysis of game data; 6 were concerned with user experience; 5 were mathematical paper concerning game theory; 3 addressed the experience of play outside video games and 7 were highlighted as duplicates (found in both searches).

A total of 6 articles were selected for final review from PubMed and 9 articles form the ACM search. These articles showcased either a framework or model for designing a video game and met all the inclusion criteria. Of the 541 citations associated with the MDA, a total of 10 articles were discovered from searches or related searches to the MDA framework. In addition, there were the 5 frameworks declared by the researcher to be added selected game design frameworks.

These articles were closely analysed for their content and their contribution to the research. Of the total 24 articles, 7 were omitted for their poor content or communication of their study.

The results, a total of 17 frameworks were discovered using the search strategy, out a total of 458 sources explored (3.71%) were deemed relevant to the review of game design frameworks. With the addition of the 5 publications added by the researcher, there are 22 frameworks to analyse and discuss. Figure one referenced earlier in section 3.1.1 illustrates the selection process for game design frameworks.

3.1.4. REVIEW

A total of seven subject areas were identified when the review of the 22 total articles was carried out. The seven subject areas are:

- Game design Principles
    - The publications demonstrated that the framework uses core game design principles in the justification for its design as stated as a key point from section 2.3.3.
- Serious Game Development
    - The inclusion or focus on development of a serious purpose in a game.
- Cognition Inclusion
    - The framework is developed specifically for the development of video games that assess or diagnose cognitive impairment
- Education/Learning
    - The framework has been developed to teach a specific skill set, or a communication tool for learning.
- Flow & Play
    - This subject area identified that the framework considers theory of Flow (Csikszentmihalyi, 2002) and/or theory of ‘play’.
- Digital Health
    - Identifies that the framework is inclusive or designed for, use in digital health.
- Game development and research
    - This subject area highlights research that has been conducted to further the development of games. Frameworks or models that are created to further game development.

The twenty-two frameworks or game design methods taken forward for review offered different approaches and purposes for their design. Within the literature, sixteen articles included a core concept of game design within the study/research (72.72%). Four articles provided a game development framework for the further application or research of game design frameworks (18.18%). Five articles contained a core focus on serious games as part of their research (22.73%). Six articles discussed the theory of flow within video game development (27.27%). Three articles discussed the development of a framework regarding digital health (13.63%), with a further three (13.63%) articles that included a focus on cognition in the development of a framework. Finally, eight articles presented frameworks for the use/development of education/learning (36.36%).

Table two below highlights which articles met certain subject areas after review. A description of each of the subject area and the relevant articles can be found below the table. An overview and summary of each of the frameworks can be found in appendix 2.

TABLE TWO SUBJECT AREAS FOR GAME DESIGN FRAMEWORKS

		Subject Area						
Paper	Author(s)	Game Design Principles	Serious Game development	Cognition Inclusion	Education & Learning	Flow & Play	Digital Health	Game Development & Research
Cognitive behavioral game design (CBGD): a unified model for designing serious games	Starks (2014)		✓	✓	✓	✓		
Gamification: What It Is and Why It Matters to Digital Health Behavior Change Developers	Cugelman (2013)	✓					✓	
Engaging Elderly People in Telemedicine Through Gamification.	Vette et al (2015)						✓	
Development, Usability, and Efficacy of a Serious Game to Help Patients Learn About Pain Management After Surgery: An	Ingadottir et al (2017)						✓	
ENED-GEM: A Conceptual Framework Model for Psychological Enjoyment Factors and Learning Mechanisms in Educational	Fjaellingsdal & Klockner (2017)				✓	✓		
A Framework for Evidence Based Visual Style Development for Serious Games	McLaughlin et al(2010)		✓	✓	✓			
User Centered Game Design: Evaluating Massive Multiplayer Online Role Playing Games for Second Language Acquisition	Rankin et al (2008)	✓	✓					
Game Design for Social Networks: Interaction Design for Playful Dispositions	Järvinen (2009)	✓						
A Framework for Analysis of 2D Platformer Levels	Smith et al (2008)	✓						
Instructional Objectives to Core-Gameplay: A Serious Game Design Technique	Hall, Wyeth & Johnson (2014)	✓	✓					
Toward an Understanding of Flow in Video Games	Cowley et al (2008)	✓				✓		
Actors, elements, and innovative interfaces in game experiences: CCAE as a model for analysing game elements	Oceja & Fernandez (2016)	✓	✓					
From Game Design to Service Design: A Framework to Gamify Services	Klapztein & Cipolla (2016)	✓						
Player–Game Interaction and Cognitive Gameplay: A Taxonomic Framework for the	Sedig et al (2016)			✓				
Educational Game Models: Conceptualization and Evaluation	Amory & Seagram (2003)	✓			✓			✓
Digital game-based learning: Towards an experiential gaming model	Kiili (2005)	✓			✓	✓		
Games, motivation, and learning: A research and practice model	Garris, Ahlers & Driskell (2002)	✓			✓			
Critical Play: Radical Game Design	Flanagan (2009)	✓				✓		✓
Designing educational games through a conceptual model based on rules and scenarios	Zarraonandia et al. (2015)	✓			✓			
How Game thinking can revolutionize your business	Werbach & Hunter (2012)	✓						
Design and Play: A Detailed Approach to Iterative Game Design	Macklin & Sharp (2016)	✓				✓		✓
MDA: A Formal Approach to Game Design and Game Research	Hunicke et al (2004)	✓			✓			✓

Table two showed that none of the frameworks discovered in the body of literature fulfilled all of the subject areas. Out of the twenty-two frameworks, six did not address or reference game design principles outlined in section 2.3.3. As game design principles are a crucial requirement to justify the design of video games, this research did not discuss the six frameworks that omitted detail on game design principles. From the remaining sixteen frameworks, this research observed how many of the frameworks fulfilled at least two other subject areas as well as the game design principles.

TABLE THREE FRAMEWORKS THAT FULFILL THREE SUBJECTS

		Subject Area						
Paper	Author(s)	Game Design Principles	Serious Game development	Cognition Inclusion	Education & Learning	Flow & Play	Digital Health	Game Development & Research
Educational Game Models: Conceptualization and Evaluation	Amory & Seagram (2003)	✓			✓			✓
Digital game-based learning: Towards an experiential gaming model	Kiili (2005)	✓			✓	✓		
Critical Play: Radical Game Design	Flanagan (2009)	✓				✓		✓
Design and Play: A Detailed Approach to Iterative Game Design	Macklin & Sharp (2016)	✓				✓		✓
MDA: A Formal Approach to Game Design and Game Research	Hunicke et al (2004)	✓			✓			✓

The purpose of omitting frameworks that did not include more than two more subjects was to explore a framework that addresses game development as well as other subjects.

The five frameworks in table three do not address serious game development or attempt to include cognition. Frameworks such as *user centred game design* (Rankin et al. 2008) and the conventions components actions emotions (CCAE) model (Oceja & Fernandez, 2016) focused primarily on a framework for serious game design and no other subject.

The five frameworks in table three shows that more complex frameworks that are inclusive of other subject areas do not focus on serious game development, instead they are principally concerned with game design principles. Looking at the third subject, the cognition inclusion, there were a couple examples (Stark, 2014 and McLaughlin, Smith and Brown, 2010) that incorporated cognition into the design of a framework. Where Starks (2014) adopted the cognitive behavioural model into a game design framework, a similar problem arises to the serious game subject in that there are multiple theories on cognition and it was not the aim of this research to define one interpretation of cognition. With the background establishing the definitions of cognitive processes, the inclusion of cognition into any framework could have caused disconnect between the researchers given interpretation of cognition and frameworks given interpretation of cognition.

The sixth subject area, digital health, was not also fulfilled by any of the five frameworks in table three. As this thesis is an exploratory venture into the potential use of video games modelling cognitive domains, the subject area did not seem necessary to be a requirement of a game design framework.

All but one of the five game design frameworks fulfilled the *game development and research criteria.* Kiili (2005) proposed the digital game-based learning experiential model which did not provide enough evidence in this research to suggest it was not providing research to further the development of future games, rather providing a model to elicit learning through games, which was not the objective of this research. This research is left with four remaining frameworks/models to choose from.

The differences between the four remaining frameworks are that Hunicke et al. (2004) and Amory & Seagram (2003) fulfil the *education and learning* subject area while Flanagan (2009) and Macklin & Sharp (2016) fulfil the *Flow and play* subject area. Amory and Seagram (2003) educational models were concerned with marrying educational theory to game design and proposed a model to identify personas in the target audience. Although interesting, the focus on education in this aspect is too distant from this researches questions, therefore Amory and Seagram's models were omitted. Hunicke et al. (2014) fulfilled the *education and learning* subject due to the contribution that the proposed mechanics dynamics aesthetics (MDA) framework was designed to help educate students, professionals and academics understand the develop of video games. In this instance, the MDA framework is suggested to fulfil both the *education and learning* subject and the *game development and research* subject.

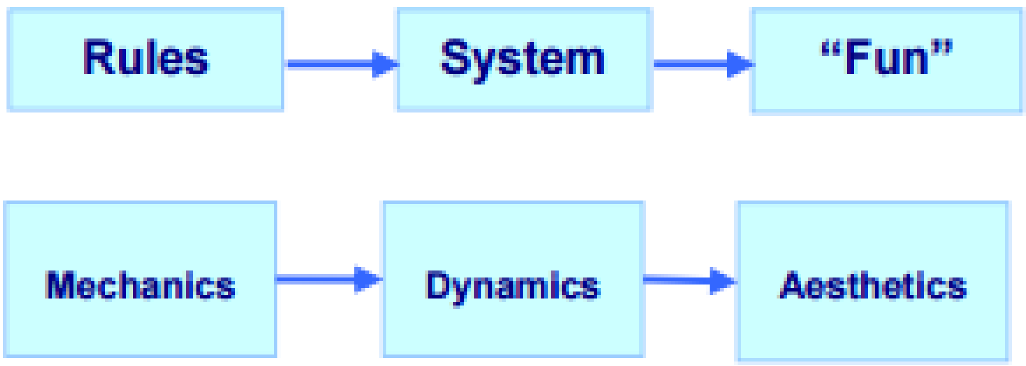
The other two potential frameworks fulfil the subject of *Flow and Play*. As discussed in the background chapter (section 2.3), understanding flow and encouraging play through design are important to defining a 'game'. Flanagan (2009) and Macklin & Sharp (2016) proposed two methods for creating play before game development. Flanagan (2009), Macklin & Sharp (2016) and Hunicke et al. (2014) all featured an iterative design process where a developed game would be reviewed and refined with each stage of testing. If this research were to be carried forward to a doctoral study, then the iterative development process would be adopted.

However, selecting a framework from the three frameworks of Flanagan (2009), Macklin & Sharp (2016) and Hunicke et al. (2014) needed to be justified. Where Flanagan (2009) and Macklin & Sharp (2016) suggest methods to design play, Hunicke et al. (2014) approached game development from the view of what the designer wished to convey, which was more in line with the goal of this research, to model cognitive processes through game design. Where the MDA framework detailed how a player views a game and how a designer (or developer) views the game (see Figure three). The MDA framework presented a process that this research would follow. Where the view of the player was observed through user experience and the development process from the view of the designer was discussed with game development professionals. This thesis has established that the appropriate framework to use in the development of a serious game for health is the MDA framework.

3.1.5. MDA

The mechanics dynamics aesthetics (MDA) framework was proposed by Hunicke, LeBlanc and Zubek (2004) as a method for designing games, but also to review and analyse games for how they were designed. The model showcased the view of how a designer develops a video game differs to the view of the player. Figure three is taken from Hunicke, LeBlanc and Zubec (2004) research article and illustrates the MDA. As described in section 2.3.3, rules and systems are the key components of game design but in the MDA framework they are described as mechanics and dynamics retrospectively.

> *Mechanics* describe the components of the games. Such as the difficulty and how the games are constructed. For example, which genre has been chosen to be designed?
>
> *Dynamics* describes the experience of the game. How the participant of the game interacts with the mechanics. For example, in a racing game there will most likely be a steering wheel to give the player control over steering or a game developed for touch devices will most likely utilise touch and tap interaction.
>
> *Aesthetics* refers to the participants emotional responses when they interact with the game.



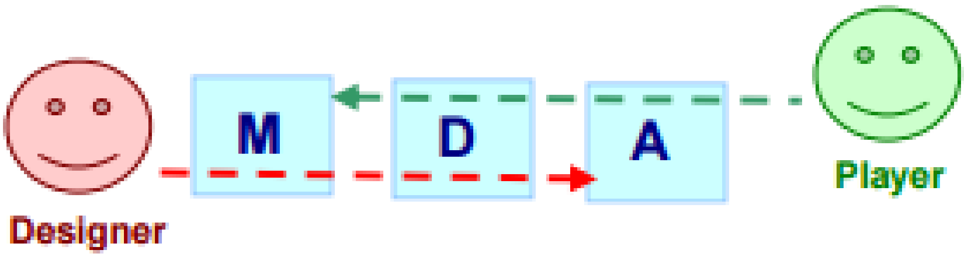


FIGURE THREE MDA DEVELOPMENT BY HUNICKE LEBLANC AND ZUBEK (SOURCE: HUNICKE, LEBLANC AND ZUBEK, 2004)

Hunicke et al. (2004) describe games as artefacts, where the content of a game is its behaviour. In this context they suggest that rules and systems create the behaviour of the game which then build into the emotional relationship (the aesthetics) between the player and the game. Hunicke et al. (2004) propose the MDA as a lens, a method for viewing a game, where a designer can analyse how the mechanics give rise to the systems used and then how the systems give rise to the aesthetics of a game. Hunicke et al. (2004) describe aesthetics as the emotional interaction between the player and the game, or what makes games fun. They detail eight examples of aesthetics which are:

1. Sensation: games as sense pleasure
2. Fantasy: Games as make-believe
3. Narrative: Game as drama
4. Challenge: Games as an obstacle course
5. Fellowship: Game as social framework
6. Discovery: Games that are exploring uncharted territory
7. Expression: games as an act of self-discovery
8. Submission: games as a pastime (retro games) (Hunicke et al. 2004)

These aesthetics' are some examples which can be used to describe the aesthetics present in a game. The examples given by Hunicke et al. (2004) suggest charades as experiences of fellowship, expression and challenge and Quake (REF) as an experience of challenge, sensation, competition, and fantasy. The similarity identified is that both Quake and charades pit the players against each other. Therefore, the MDA could be used as a lens to identify what players enjoy and what the y could enjoy, it could be suggested that if a player enjoys the challenge of charades they would potentially enjoy Quake. Dynamics help create aesthetics such as challenge by creating systems such as time constraints, scores, and levels of difficulty (Hunicke et al. 2004). Dynamics help to create feedback systems where the player can achieve the goal of the game and in doing so elicit an experience. The mechanics operate at a higher level of the dynamics and they involve the constraints of a game. Mechanics in the example of quake would be the type of weapons, bullet speed and locations where the player will respawn, these will have a direct effect on how the player interacts with the dynamics. Finally, figure three showcases how the MDA is viewed from a design view and from a player view. The designer sees the mechanics first, how they will create the game space and what constraints or concept the player will face. Whereas the player will first experience the aesthetics of a game before interacting with all the dynamics in place. The MDA framework for serious game development allows the design of games to focus on developing rules and mechanics that would model cognitive processes. Consequently, the player will view the games from an experience before understanding the underlying reason for gameplay. Using the MDA framework in this capacity could mean that the prototypes are still viewed as games and perceived as fun, yet model cognitive processes through mechanics.

3.1.5. PROCEEDINGS

In section 3.1.1. the inclusion criteria constrained the review to omit conference papers, poster presentation and other journals that did not meet the inclusion criteria. Although some of these journals presented interesting content, they were not specific to what was required for the review. However, the following paragraphs discuss journals that were omitted from the review and their potential in future research.

The results of the NCBI PubMed database search produced 330 results as stated in section 3.1.3. Of those results, a considerable number were excluded for not providing content on game design frameworks, but they did have some relation to video games. Journals by Swiechowski et al. (2015), Groves et al. (2015) and Przybylski & Weinstein (2016) present examples towards the perceptions of games. Swiechowski et al. (2015) presented a review of recent advances in general game playing, particularly the advancement in artificial intelligence. Swiechowski et al (2015) presented the technical advancement of games and suggested how these technical advancements could be transferred to the design across genres. For example, how a complex AI opponent could be used in a different platform. Whereas Groves et al. (2015) looked at the perception of games towards addiction. Groves et al. (2015) carried out three studies to assess the pathological video game use and its effects on user’s thoughts, behaviours and attitudes. Like the discussion of how games can be used as an awareness tool, Groves et al. (2015) suggested that pathological game use affects behaviour. However, Przybylski & Weinstein (2016) conducted a study into how electronic games are viewed where participants with little exposure to games were predispostioned to have a negative view of video games. Przybylski & Weinstein (2016) studies suggested that the incoherence on the opinion of games could be attributed to those who have directly experienced games and those without any experience. Those with experience playing games viewed the notion of games causing aggression with sceptically, but those with little experience suggested a strong correlation. Media often revisits the discussion of games as an addiction and results in research journals investigating addition where often, the results are incoherent. As the aim of the thesis was not to discuss addiction in games, these papers were omitted from the review. However, the idea of behaviour change in games could be an area of further research to video games and cognition.

In addition to the perception of games, the NCBI database search presented journals associated with fitness and exercise. These journals did not provide game design models or frameworks but presented methods to how games could be used to tackle obesity (Shiyko et al. 2016; Spook et al. 2016) and exercise (Azevedo et al. 2014; Bamparopoulos et al. 2016). Shiyko et al. (2016) conducted a study where 47 women played SpaPlay, a computer game designed to help adopt healthier diets. The game was developed from the self determination theory (SDT) and incentivised players with real life rewards. The self-determination approach to design presents the most interesting design approach in the journal, where gamification strategies were applied to autonomy, relatedness and competence that make up SDT. Deconstructing the design of SpaPlay and the justification for the gamification strategies would present an interesting case study to observe how the strategies could be applied to an individual with mild cognitive impairment. However, Shiyko et al. (2016) did not discuss the process to select SpaPlay and its suitability for their investigation. Furthermore, the description of SpaPlay states SDT is used to sustain players but with little evidence as to whether the players were sustained due to the nature of the study, or whether it was due SpaPlay eliciting play and enjoyment. Similarly, Spook et al. (2016) utilised a game called 'Balance it' to observe dietary intake. Spook et al. (2016) Balance it application created a self-reported goal attainment that was used to monitor and record dietary changes. Again, the design rationale would have provided an interesting case study although a common limitation associated with self-reported goal attainment is that users can falsely report data.

The search through ACM did produce results of video game design frameworks that were not included in the review. These frameworks were omitted due to their difference in subject matter, such as culture (Jamieson et al. 2016), problem solving (Cooper, 2014), security (Pierre-Louis, 2010) matchmaking (Chen et al. 2017) and artificial intelligence (Conroy & Wyeth, 2011). Jamieson et al. 2016 presented a multiplayer framework for how multiple users can integrate and understand the game rules, no matter the cultural background. As the design of a video game prototype is concerned with modelling individual cognitive ability, a multiplayer approach to design would not be required. Although, there is potential future research into how cognitive ability changes in a multiplayer setting compared to single-player. Jamieson et al. (2016) presented the mechanic that simulated the disadvantage of someone entering a culture they do not understand; a similar approach could be conducted if the research was to raise awareness of mild cognitive impairment by simulating mild cognitive impairment for those with no impairment. Cooper et al. (2014) published a book on using games to solve scientific problems due to the technical capabilities of games. The book suggested the use of long term engagement and reward structure as a different approach to answering scientific questions, like that of what was suggested by Swiechowski et al. (2015). Conroy & Wyeth (2011) presented a technical approach to creating realistic artificial intelligence for the games industry. Their study suggests an attempt at bridging the game between theory and practice by modelling human behaviour of aiming where they are looking into a digital game space. The theory was that an improvement in realistic artificial intelligence would result in better immersion from the player. Given the scope of the research, developing a complex AI to challenge the player would have potentially immersed the player in a video game prototype. However, artificial intelligence is not a requirement to developing an enjoyable experience.

Further proceedings included improvements for technical development in video games such as behaviour in animation (Lau & Kuffner, 2005), architecture in 3D space (Stricker et al. 2011) and interfaces (Karpouzis, 2017). In addition, there were conference proceedings that included the design of gesture controls (Lu et al. 2013) and body language displayed in game (Beck et al. 2012). Although the accessibility of games is important and is further discussed in section 4.2.2, the objective of the research was not to develop innovative controls. These conference proceedings present advancements to the technical capabilities of games but do not expand on the design, experience or play of games. Therefore, conference proceedings such as these were omitted from the search. However, there were conference proceedings that were excluded that could have potentially be included in the scoping review. For example, Marsh et al. 2006 presented the hierarchal activity-based scenario (HABS) as a theoretical framework for engaging people in in-game activities. The HABS framework was suggested to be used as a method of identifying problematic aspects of game design, like how the MDA can be used as an reflective framework for analysing a game. Marsh et al. 2006 utilised the HABS in the development of an education serious game in order to observe behaviour. With the focus of education and behaviour there may have been a potential to assess the use of the HABS as a framework of game development, but most likely changes to how a behaviour change framework could be adopted to analyse or model cognitive processes. Comparable to Jamieson et al. (2016) approach to multiplayer experience of culture, Andreoli et al. (2017) presented the FRACH framework that was used to conceive, design and evaluate collaborative serious games in cultural heritage. Andreoli et al. (2017) assessed the efficacy through a section of HippocraticaCivitasGame to solve a puzzle given to players. The FRACH was developed to elicit fun and educate while in the field of educational heritage. The collaboration element of the FRACH presents a possible future interest in observing how older generations could use collaboration in games to aide each other in cognitive challenges.

The limitation in this review constraining to open-access and omitting conference papers limits the discussion and possibilities that could be explored through serious games and cognitive psychology. The examples presented in these proceedings highlight different approaches that could be taken further. Yet, the proceedings do highlight the growing breadth of research in games and the vast range of design frameworks or model presented. The excessive number of frameworks or models potentially presents a large problem of saturating both research and industry game development with too many theoretical approaches to design while lacking a finite number of rules or key principles to guide and bridge the gap between game design theory and practice.

3.2. EXISTING VIDEO GAMES & COGNITIVE PROCESSES

This thesis has established and justified the chosen game design framework of the MDA framework in section 3.1.3. This section will explore the relationship between video games and cognition to understand what research has taken place, and where some areas of research have been neglected. The researcher is concerned with what mechanics and dynamics were used in existing video games to assess and diagnose cognitive impairment/processes.

3.2.1. SCOPE

This section adopted the same search strategy as the framework review in 3.1.2. The literature identified the mechanics and dynamics used in existing games that were used to assess and diagnose cognitive impairment.

In addition, this research used the search terms of "video games and cognition", "video games and cognitive processes" to gather examples of games that had been used in studies to assess or diagnose cognitive impairment/processes.

3.2.2. VIDEO GAMES AND COGNITION

The results of the previous work review in section 3.1.3 discovered twenty-five articles that used games to measure specific cognitive processes or games that assessed cognitive impairment.

To organise the existing games from publications, seven categories were identified to sort the body of knowledge surrounding video games and cognition. The seven categories were determined by the researcher as a method of grouping and identifying key aspects of the existing games.

These seven categories are described as the following:

- Cognitive Training and Assessment
  - Articles and games that targeted to ‘enhance’ or ‘train’ cognition.
- Commercial Video Game Development
  - Where video games designed for cognitive assessment, diagnosis or treatment etc. had been used within commercial games. Or where commercial games had been used within cognitive psychology
- Mild Cognitive Impairment (MCI) and Healthcare
  - Games that targeted to help or monitor individuals with mild cognitive impairment (MCI) as well as games associated with dementia
- Video Game Based research
  - Articles and games used to understand the relationship between an individual’s cognitive ability and video games.
- Exercise and physical interaction
  - Games that used physical movement as a key mechanics in their gameplay in relation to helping, training or investigating cognitive processes.
- Quality of Life and Wellness
  - This category was inclusive of video games that promoted the quality of life or wellness within individuals with mild cognitive impairment.
- Potential of Video Games
  - The exploratory element of video games and cognitive processes. Where had games explored outside cognitive assessment or diagnosis?

TABLE FOUR VIDEO GAMES AND COGNITION

		Subject Area						
		Cognitive Training and Assessment	Commercial Video Game Development	MCI and Healthcare	Video Game Based Research	Exercise and Physical Interaction	Quality of Life and Wellness	Potential of Video Games
Title	Authors							
Video games, cognitive exercises and the enhancement of cognitive abilities	Anguera & Gazzaley, 2015	✓						
Effects of cognitive training interventions with older adults	Ball et al, 2002	✓						
Selling Points: What cognitive abilities	Baniqued et al, 2013	✓	✓					
Can training in a real-time strategy	Basak, Boot, Voss & Kramer, 2008	✓	✓					
Cognitive training for persons with MCI	Belleville, 2008	✓		✓				
Developing serious games specifically	Bouchard et al, 2012			✓	✓			
Playing Action Video Games, a Key to Cognitive Enhancement	Chandra et al, 2016	✓						
Applying Mobile application	Coppola et al, 2013	✓					✓	
Cognitive Enhancement in	Dobrowolski et al, 2015	✓			✓			
Computerized Touch Panel	Fukui et al, 2015	✓		✓				
Playing for a real bonus	Gamberini et al, 2006	✓						✓
Computer-based cognitive	Garcia-Casal et el, 2016	✓		✓				
The Cognitive Neuroscience of Video Games	Green & Bavelier, 2006	✓		✓	✓			✓
Mindtraining: Playful interaction	Hackner & Lankes, 2016				✓	✓		
Studies involving people with	Joddrell & Astell, 2016	✓		✓				
Capitalizing on cortical plasticity	Kramer & Erickson, 2007			✓		✓		
Gamification of Cognitive	Lumsden et al, 2016	✓						

		Subject Area						
		Cognitive Training and Assessment	Commercial Video Game Development	MCI and Healthcare	Video Game Based Research	Exercise and Physical Interaction	Quality of Life and Wellness	Potential of Video Games
Title	Authors							
A Taxonomy of Serious Games for dementia	McCallum & Boletsis, 2013a,			✓	✓			✓
Dementia Games: A literature review of	McCallum & Boletsis, 2013b			✓	✓			
Video Games for Neuro-cognitive Optimization	Mishra, Anguera & Gazzaley, 2016	✓		✓				
Alive Inside: Developing Mobile apps for the	Nezerwa et al, 2014			✓	✓		✓	
Playing a puzzle video game with changing	Oei & Patterson, 2014	✓	✓		✓			
The effect of active video games on cognitive	Stanmore et al, 2017			✓	✓	✓		
A randomised pilot study to assess the efficacy of an	Tarraga et al, 2006	✓		✓	✓			
The Parkin'Play Study	Van de Weijer, 2016			✓	✓			
Designing Tablet-Based Games for Seniors	Vasconcelos et al, 2012	✓		✓			✓	

Table four above, as well as the description of categories in appendix 4, showed that there were multiple applications for the design of video games to potentially assess cognitive processes. Table four suggests the potential focus of future study which could be to focus on the development of video games for cognitive training/assessment, or an observation of quality of life generated through video games as few of the identified games have explored those areas.

This thesis is concerned with how to design serious games for health that will still be perceived as video games and explore where they are best suited within a healthcare environment. To better develop video games that could be used to assess or diagnose cognitive processes, the researcher took the games referenced in the twenty-five articles detailed in Table four and reviewed how they have been used or designed to assess cognition or cognitive processes.

3.2.2.1. CHARACTERISTICS OF EXISTING GAMES ASSOCIATED WITH COGNITIVE PROCESSES

The researcher has suggested within the twenty-five publications in Table four there are various purposes and applications for games within healthcare. The publications demonstrate examples of games to train and assess cognition, help with MCI, provide an improvement to quality of life and suggest commercial games that can be used to assess cognition

The next step was to understand how existing video games were designed or used to assess cognitive process. The researcher sought to identify the existing mechanics and video game genres that were used to assess or diagnose cognitive processes to justify the development of new prototype video games. A description of the game development mechanics from the twenty-five articles used can be found in appendix five. Below presents a summary of game genres / mechanics associated with specific cognitive processes in existing games.

Working Memory

Appendix five details games such as SmartBrain (Educamigos, 2017 cited by McCallum & Boletsis, 2013b), Aquasnap (Van de Weijer et al. 2016) and The Ryokansan (Ohtsu Computer cited by Fukui et al. 2015) each display characteristics of games that could be associated with memory. Each of the games involved short term recall of a position or detail of an object and rewarding the player for their success. Other games such as Memocubes (Platina Games cited by Baniqued et al. 2013b) and Simon Says (Neave.com cited by Baniqued et al. 2013b) display a matching action, where the player must ‘match’ two identical images, patterns, or sounds to succeed.

Long Term Memory

Only two articles identified games to showcase a test of long term memory. AquaSnap (Van de Weijer et al. 2016) and The Ryokansan (Ohtsu Computer cited by Fukui et al. 2015) involved remembering or reciting objects from a long duration of play. In the case of The Ryokansan, the players were asked to recite a childhood story that should have been known to their demographic. This suggested testing common knowledge in games is a method of testing long term memory.

Perception

The existing games suggested they tested perception presented a mixed genre of games. Digital Switch (Miniclip cited by Baniqued et al. 2013b) and Jungle App (Coppola et al. 2013) involved players having to find and select the desired object. Whereas other examples such as Crashdown and Alpha-attack (Miniclip cited by Baniqued et al. 2013b), displayed fast paced games where the player must perceive a danger to their character and react in time. Crashdown and Alpha-attack were also associated with processing speed (Baniqued et al. 2013b).

Attention

The recurring mechanic in attention games gave suggested the action of avoidance and multitasking as seen in examples like AquaSnap (Van de Weijer et al. 2016), Filler (Knogregate.com cited by Baniqued et al. 2013b) and Cathode (Armor Games cited by Baniqued et al. 2013b). In these existing games, the player had an objective to destroy opponents or collect points but must avoid multiple incoming dangers that would end gameplay.

Processing Speed

The only example found from the articles in appendix 5 was AquaSnap (Van de Weijer et al. 2016) where the player was challenged to capture an image of multiple objects as quick as they could. It appeared that the majority of articles encompassed processing speed within a test of perception. It is suggested that processing speed was often a test of reaction and within most of the existing games in appendix 5; quick reaction speed would determine an individual's success in a video game.

Thinking & Reasoning

The existing games presented as a test of thinking & reasoning suggested the mechanic of problem solving. Sushi-Go-Round and Bloxorz (Miniclip cited by Baniqued et al. 2013b) described games where the player must learn a pattern or solve a puzzle in order to complete the game. Whereas one of AquaSnap (Van de Weijer et al. 2016) mini-games and TwoThree (Armor Games cited by Baniqued et al. 2013b) involved problem solving but with a constraint on the time the player has to solve the problem.

Language

Existing games that aimed to test or model language often involved 'word-play'. SmartBrain (Educamigos, 2017) featured a word guessing game with a selection of given letters, whereas Mindtraining (Hackner and Lankes, 2016) involved a quiz on word association. The examples in appendix 5 suggested language games involved the act of writing or guessing a word in order to succeed.

Summary

These attributes are important to consider in the development of a video game prototype as the design decisions, or video game genre choice, provided the justification for mechanics and genre. The researcher identified the attributes across the twenty-five publications so that the video game prototype would be able to adopt similar genre/mechanics to potentially assess cognitive processes.

3.3. SUMMARY

This chapter has discussed the selection of a game design framework and through reviewing the previous work literature on game design frameworks; the MDA framework has been justified as a suitable framework to utilise in the development of a serious game for health. The MDA was used in the prototype development chapter (section 5.1) to develop the video game prototype.

Through the previous work, the researcher identified attributes in existing games that have been used to assess cognitive impairment. Section 3.2.2.1 highlighted characteristics of existing games which the researcher used to justify the development of the video game prototype.

The next chapter of this thesis details the methods for approaching the research questions proposed in section 1.2.

4.1. CHAPTER FOUR: METHODS

The motivations in section 1.2 highlighted that there was a lack of serious games for health utilised within the NHS so there was a gap for the future development of serious games for health. Section 2.3 discussed the importance of play and suggested what a video game should communicate to its players. Section 3.1 established that the MDA framework was a potential game design framework that could be utilised to develop a serious game for health. Section 3.2 detailed a list of existing video games that have been used in studies to assess cognitive processes.

The following chapter describes the approach this research took to answer the research questions outlined in section 1.2 which were;

1. Are serious video games that are designed to assess or diagnose cognitive processes, still perceived as 'fun' video games?
2. Are game design frameworks necessary to the development of serious games for healthcare by commercial game developers?
3. What are the potential uses of a serious video game in healthcare?

4.2. TARGET AUDIENCE, USER REQUIREMENTS AND ACCESSIBILITY

In developing games to model cognitive processes, a target audience aids in focusing development for the chosen user's requirements. As an objective is to model cognitive processes in video games, which may provide use to healthcare professionals, a target audience could be quite complex. Mild cognitive impairment (MCI) affects 15 to 20 percent of individuals aged 65 and over (Alzheimer's Association 2018). However, there have been individuals to develop early on-set mild cognitive impairment due to factors such diabetes, smoking, lack of exercise, depression and high blood pressure. Furthermore, there are learning challenges such as attention deficit hyperactivity disorder (ADHD) (NHS, 2018) that affect children and adults which is often managed using cognitive behavioural therapy (CBT) (NHS 2016). NHS (2018) suggested that most cases of ADHD are diagnosed between the ages of 6-12. The range of ages that are affected by mild cognitive impairment or learning difficulties presents a challenge to how to design for a specific target audience. However, it can be suggested that children and those over 65 are a potential target audience as children are the most likely to be diagnosed with a learning challenge compared to adults and those over 65 are most likely to develop MCI.

There has been evidence of both age groups utilising video games and related technology as a form of entertainment or interaction (McCallum & Boletsis 2013a; Lu et al. 2017; Ayres, 2013). For those aged 65 and over, tablet technology has proved popular for its touch interface opposed to a controller with multiple inputs (Ayres, 2013). In addition, a quarter of the UK population video game players are aged 56 years and above (Bakhshi, 2017). Gametrack (2016) evidenced that games are most popular with children aged 11-14 with 81 percent of that populations playing games, closely followed by children aged 6-10 of which 69 percent of that population play games. Gametrack (2016) also evidenced that those aged 6-64 used computers 21 percent of the time, smartphones 19 percent of the time and tablet technology 15 percent of the time. Tablet technology has proven popular with older generations by offering people with MCI a different source of communication and entertainment (French 2017). French (2017) discusses the use of games and puzzles used by half the population in their study. There was the suggestion that the games and puzzles improved the confidence and sense of accomplishment. French (2017) further states that other members of their sample used to technology such as mobiles and tablets to remain independent, using the internet on these devices to answer questions they had. Although these are positive steps towards using games and technology to help people with MCI, there are user requirements that need to be considered.

4.2.1. USER REQUIREMENTS

With the suggestion that the target audience would be people over 65 years of age with MCI and potentially young children (aged 6-12) with learning challenges, user requirements need to be adhered to. First and foremost, the game(s) developed would need to be universally suitable for their audience. Therefore, mature themes such as violence seen in some shooter and action games would not be suitable for the target audience. The social care institute for excellence (SCIE, 2017) suggests a person-centred approach to the user requirements of an individual with MCI where: focus on the patient's abilities, remember engagement can be from any level or sensory simulation, pay attention to individuals preferences and capabilities, indicate what needs to be done clearly and make sure carers and family are onboard. Furthermore, SCIE detail that digital technologies minimise clutter on screen, ensure sufficient lighting is good, text is large enough and controls are clear. These requirements could be applicable to younger children adhering to this approach would minimise frustrations for a younger demographic. Similarly, a person-centred approach has been adopted to develop technology tools for children with ADHD (McKnight, 2010), where the developer has developed a relationship with children with ADHD to understand what challenges they face when using mobile and tablet technology. McKnight (2010) identified key guidelines to developing software for children with ADHD. Firstly, that the design of software is neat and uncluttered, much the same for those with MCI. Second, that software provides a calm environment with soothing colours and free from distraction. That the software provides reinforcement and reward for completing tasks. That large and clear text is used, similar again for those with MCI. Utilising brief and clear instructions, again similar requirement for those with MCI.

4.2.2. ACCESSIBILITY GUIDELINES

The user requirements have suggested accessibility guidelines for those with MCI or learning difficulties towards developing games or other associated software. The most predominant accessibility guidelines are to make sure the screen is clear and uncluttered and features large clear text and instructions (McKnight, 2011; SCIE ,2017). The game accessibility guidelines (Gameaccessabilityguidelines, 2018) discusses basic, intermediate and advanced accessibility guidelines that should be considered in game design. On the basic level are motor, cognitive, vision, hearing and speech. The motor category associates with control and mobility where there should be consistency in the use of controls. For example, a mouse left click is the consistent method to select and interact and it does not randomly change the controls. Additionally, with touch devices, make sure interactive elements have enough space between them. Google (2018) and android development highlight very similar accessibility guidelines when developing google and android apps for their store. Google (2018) underpin three key principles to accessibility, where an application should be: clear, where the layouts are clear instructions to navigate are clear; robust, where the applications is designed to accommodate a variety of users; and finally, specific, where the application published should support assistive technologies available on the chosen platform e.g. PC or tablet.

Furthermore, in recent years the accessibility of games has gained further media attention and importance. Moss (2014) reported the importance of why accessibility matters to individuals and families. In their article they discuss how the development of accessible controls, whether they are specifically designed controllers or subtle changes such as increases text size, can improve the quality of life for those struggling to access video games. When considering the target audience, the user requirements were discussed in the previous section so that the design could constrain what would be needed. If the research were to investigate stroke rehabilitation, the touch control would most likely not be used as movement would be restricted. Instead, motion controls would present an easier access to that specific demographic. Includification (Barlet & Spohn, 2012) presented a document that highlighted the key principles to design for inclusivity and accessibility. A section on cognition discussed the importance of tutorials, especially for those with autism or similar learning difficulties. Without clear explanation of goals or controls, a person with MCI may become frustrated with a game before they even properly engage with the video game. In addition, Includification suggests the addition of levels of difficulty so that the player can learn the controls and select what best fits their ability.

The development of a video game prototype will attempt to adhere to the guidelines suggested. Each of the games will strive to include a clear set of instruction or tutorial and the potential to include levels of difficulty in the video game prototype. With feasible time, the video game prototype attempted to include an options menu where text and audio setting can be changes.

4.3. APPROACH

The objective of this research was to explore: whether video games could be designed to assess cognitive processes from a game design framework; whether the developed video game prototype was still perceived as fun; and whether those games would have a potential use within healthcare. This research carried out three user studies to explore the research questions stated above.

The researcher conducted a mix of quantitative and qualitative approaches to explore the research questions. A quantitative approach was used to observe the user experience and interaction with the video game prototype (see section 4.5.1 for further details). A qualitative approach was used to evaluate the design process of the video game prototype and whether the MDA framework would be necessary to commercial developers creating serious games for health (see section 4.5.2. for further details). Finally, a qualitative approach was used to explore the potential use of the developed video game prototype within healthcare (see section 4.5.3 for further details).

The MDA framework acted as a development method that created mechanics, dynamics and aesthetics for the video game prototype as described in section 3.1.4 (Hunicke, LeBlanc & Zubek, 2004). The method of using the MDA framework related to the exploratory element of video games designed to assess or diagnose cognitive processes could be developed using the MDA framework.

The game development required an iterative design process, using the MDA framework and the review of existing games associated with cognition in the previous work chapter (section 3.2). The researcher developed a video game prototype using the MDA as a method of design and analysing the mechanics of existing games identified in section 3.2.2.1. This was done to replicate existing games and explore whether serious games designed for health could be used within healthcare. The development of the video game prototype is described in the next chapter, Prototype Development (section 5.1).

This research then conducted user studies. This research utilised the developed video game prototype to conduct three user studies detailed in sections 4.5.1, 4.5.2 and 4.5.3.

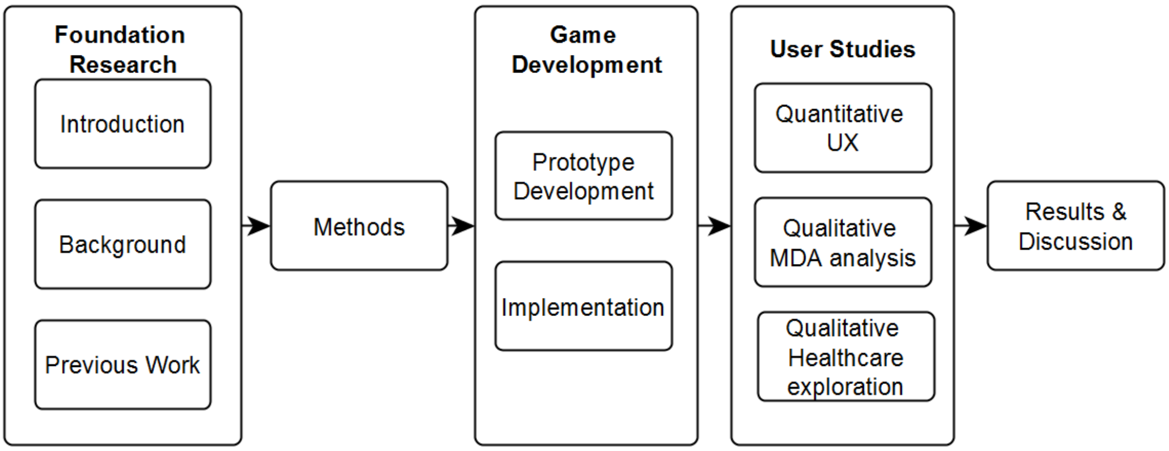


FIGURE FOUR APPROACH TO METHODS

4.4. GAME DEVELOPMENT

The game development required an iterative design process to develop video game prototypes that could potentially be used to assess or diagnose cognitive impairment. Using the previous work research in chapter three, a video game prototype was developed using the MDA framework where the developer considered the mechanics and dynamics in relation to the design of existing video games that had been used in publications of video games measuring cognitive processes. The development of the video game prototype is detailed in chapter five, prototype development (5.1).

From prototype development, the video game needed to be implemented into a playable interactive format (see chapter six Implementation, section 6.1). The implemented video game prototype was then used in the user studies to determine whether; the video game prototype was perceived as a 'game'; the design of the video game prototype using the MDA framework was necessary to the development of video games that could potentially assess cognitive processes; and whether the developed video game prototype had the potential to be used within healthcare.

4.5. USER STUDIES

4.5.1. QUANTITATIVE UX – GAME-PLAY EVALUATION

The first study aimed to evaluate whether the video game prototype created from the MDA were still perceived as a game and that the video game prototype elicited play as referenced in section 2.3.3. A user experience survey was used to gather feedback on the perception of the video game prototype.

The design, procedure, results and discussion for the game-play evaluation is detailed in chapter seven (7.1).

4.5.2. QUALITATIVE MDA ANALYSIS – MDA EVALUATION

The second study in this research aimed to explore the design decisions of the video game prototype using the MDA framework. It explored whether the MDA was necessary to create serious games for health by commercial game developers. Potentially exploring how further games for health care associated with cognitive psychology could be developed in a commercial setting using the MDA framework. The approach involved one-to-one interviews with professional game developers and analysing the results using thematic analysis (Cote and Raz, 2015; Lapan, Quartaroli & Riemer, 2012).

The design, procedure, results and discussion for the MDA evaluation is detailed in chapter eight (8.1).

4.5.3. QUALITATIVE HEALTHCARE EXPLORATION – POTENTIAL APPLICATION IN HEALTHCARE

The final study explored whether the developed video game prototype could be used within a healthcare setting. This research involved interviewing healthcare professionals to understand whether video games could potentially assess or diagnose cognitive processes. It also attempted to review if video games were desired, demanded or even have a place within healthcare.

In addition, the study was also concerned with exploring whether healthcare professionals perceived the benefit of having a video game that could assess cognitive processes; an example of this was a working memory process in the video game prototype identified as a working memory process by healthcare professionals.

The design, procedure, results and discussion for the potential in healthcare study is detailed in chapter nine (9.1).

5.1. CHAPTER FIVE: PROTOTYPE DEVELOPMENT

This chapter discusses the design decisions and the development of a video game prototype called Brainplay which was designed as a suite of eight games, but the scope of this research meant only three of the designed games were implemented into the final prototype. Each of the games was designed to assess a cognitive process outlined in section 2.2.

Chapter three on previous work established that the MDA framework was selected as the game design framework and section 3.1.3 detailed the principles of the MDA framework. Chapter three on previous work also detailed existing video games that assessed cognition in 3.2.2. These existing games were used to influence and justify the design of the video game prototype, Brainplay.

5.2. TECHNOLOGY PLATFORM

The prototype games could be developed for console, personal computer (PC) or mobile technology. However, the literature suggested that tablet technology was an accessible platform to older generations (Ayres, 2012; Joddrell and Astell, 2016). The United Kingdom Interactive Entertainment (UKIE) stated that 32.4 million video game players in the United Kingdom and although 23% (10.9million) play on console and 14% (6.8 million) played games on tablets (UKIE, 2017). The statistics of UKIE suggested that tablet technology was accessible to the public therefore the researcher developed the video game prototype Brainplay for tablet technology to target a broad age range demographic.

5.3. GAME DESIGN PROCESS

The video game prototype Brainplay was developed using the MDA framework which adhered to the game design principles presented by Salen and Zimmerman (2003) as detailed in 2.3.3.

The MDA framework is a process of three steps (Hunicke, LeBlanc & Zubek, 2004):

1. *Mechanics* describe the components of the games. Such as the difficulty and how the games are constructed. For example, which genre has been chosen to be designed?
2. *Dynamics* describes the experience of the game. How the participant of the game interacts with the mechanics. For example, in a racing game there will most likely be a steering wheel to give the player control over steering or a game developed for touch devices will most likely utilise touch and tap interaction.

3. *Aesthetics* refers to the participants' emotional responses when they interact with the game.

The previous work chapter suggests most game design frameworks focus on a specific purpose, for example, a game could be developed as an education tool, a game for training, a healthcare awareness game or even just a game for entertainment. In the case of the MDA framework, which provides a model to develop games from, there was the potential to design video games with a focus on assessing, measuring or diagnosing cognitive processes.

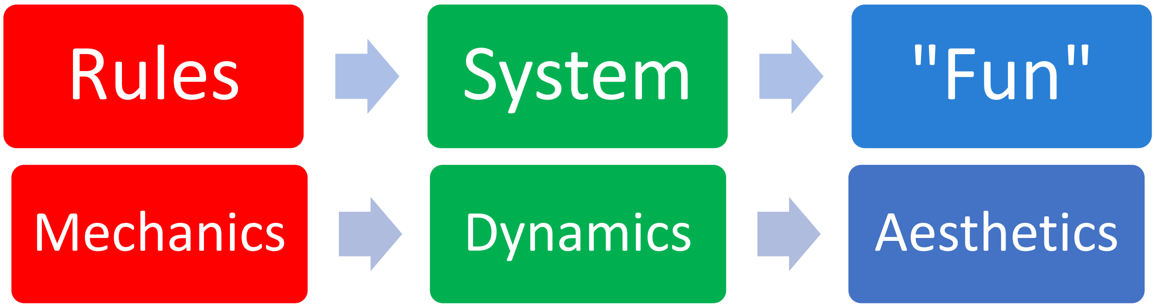


FIGURE FIVE MDA, FORMAL APPROACH TO GAME DESIGN (HUNICKE, LEBLANC & ZUBEK, 2004)

This research used the MDA framework to create a suite of video games that could be used to assess cognitive processes. From Figure five, the researcher was able to constrain and focus the design process by first designing the rules of the game. The rules, or mechanics, (left column, highlighted in red in Figure five) acknowledged the basic processes of a high-level cognitive process, such as perception and the mechanics/rules, such as number of attempts before game over, that were present in existing video games identified in section 3.2.

After the rules were created, the systems, or dynamics (middle column, highlighted in green in Figure five) were put in place which would make up the forms of interaction between Brainplay and the player. These dynamics are the interaction between the player and the controls given to them. In theory, the correct balance of creating rules and systems would elicit 'fun', or more accurately 'play'. Creating a game that has a clear set of goals and understandable mechanics alongside dynamic inputs from the player should reward the player with feedback which would evoke a desirable emotional response, the aesthetics part of Figure five (right column, highlighted in blue).

5.3.1. ALTERNATIVE DEVELOPMENT PATHS

The design framework has been justified, however the development process could be approached in multiple ways. The development method was to prototype of concept where the games developed were designed to test the research objectives. Developing the games of Brainplay required justification that the games were not just ideas. Therefore, existing games that have suggested evidence of modelling cognitive processes were used as a template for the development of Brainplay. The games were therefore sharing similar mechanics and dynamics with games that had already been involved in the study of games and cognitive psychology. Prototyping a proof of concept meant there was no requirement to involve other parties in the development, although involving health care practitioners or those with mild cognitive impairment could have produced altogether different games.

Approaching the design from a patient-person involvement would have created a number of challenges to the study. First, a large enough sample would be required to develop a game that would appeal to multiple people. The challenge lies in what every individual ‘likes’ and ‘dislikes’, or what an individual with MCI could accomplish in a game. A group of people with MCI could have different impairments and therefore all require different games to suit individual needs. Investigating the individual needs through game development could be a potential for future research but the scope of the research was to broadly examine serious game development techniques and methods to create engaging games for those with MCI. Patient-person involvement would require a longer development time than the given three months that the developer used to create Brainplay, as each iteration would need to be shared with the patient or person involved. There would then need to be an analysis and discussion around what the game was doing well and what it was lacking. There is merit in patient-person involvement but there is a potential need to investigate how game development processes can accommodate a client into the development while utilising the breadth of research that already exists. A development method for the future could be to use the existing games as guide to development and setting goals with a patient or person involved in the development.

Alternatively, a game jam approach could have been taken. A game jam approach would have seen multiple games from different groups of people. The groups of people could be solely game developers or involve health care practitioners. A game jam is often referred to as a short-term event where teams of developers create a game within a constrained time period (e.g. 12- 48 hours) around a specific theme (e.g. cognitive psychology). A game jam approach could have produced multiple games with different approaches to developing games that model cognitive processes while potentially including health care practitioners or individuals with MCI in the development. The developed games from a game jam could then be analysed and discussed. The development teams would then be questioned to how and why they approached the theme and the discussion would provide the justification as to how the games were informed. The challenge in developing games through a game jam process is that development teams may not develop games around the theme or lack a game design framework approach to justify how their developed game(s) model's cognitive processes. Other challenges are that no games could be produced and not reaching saturation for a required number of developers. Game jam development teams can be any size but are often three to five members. Brainplay developed three games in its development time with X others that were designed but uncomplete for the user studies. If three games were a minimum requirement for discussion in a game jam then 9-15 game developers would be required to meet at the same time to develop a game. Therefore, the challenge in game jams lies in accommodating a number of developers and/or health professionals to travel to a game jam site and develop a game over a certain time period. However, it is further interest in future study to see how teams of game developers, patients and healthcare professionals could develop a game and how it would be received by members of the public.

5.4. EARLY PROTOTYPES

Brainplay is a suite of eight games that were prototyped early with the potential to assess cognitive processes laid out by Eysenck & Keane (2010) and Groome (2013). The eight games were prototyped using the information established in the chapter two Background about cognitive processes (section 2.2) and the review of existing games in the previous work chapter (section 3.2).

The results of the existing games review suggested a game genre or mechanics for each of the cognitive processes and the MDA framework provided a process that helped develop the early prototypes. In summary, the existing games from section 3.2.2.1 suggested;

- **Working memory** games:
  - involved short term recall of a position or detail of an object and rewarding the player for their success
  - Or, displayed a matching action, where the player must 'match' two identical images, patterns, or sounds to succeed
- **Long term memory** games suggested:
  - remembering or reciting objects from a long duration of play
  - testing common knowledge
- **Perception** games:
  - involved players having to find and select the desired object
  - Or, displayed fast paced games where the player must perceive a danger to their character and react in time
- **Attention** games suggested the action of avoidance and multitasking
- **Processing speed** games were often a test of reaction and commonly assessed in perception games.
- **Thinking & Reasoning** games suggested:
  - the mechanic of problem solving
  - Or, learn a pattern / solve a puzzle
- **Language** games suggested the act of writing or guessing a word to succeed

Each of the following sections describes the early paper prototypes and design concepts that could potentially assess a specific cognitive process. This chapter also documents which three, of the eight games, were developed and implemented onto a tablet device.

5.4.1. WORKING MEMORY GAME DEVELOPMENT

Initial research considered how video games could help with dementia. How a video game could assess, monitor or address working memory was the first conceptual idea to be developed.

An early concept for a working memory game was a game called “Musical Mah-jong” “Musical Mah-Jong” used a concept of the matching tile game format, but with a musical element in the game. This allowed for two methods of play, matching image or sound to one another. The design for Musical Mah-jong was influenced by the research of music therapy to help with Alzheimer’s patients (Sauer, 2014).

However, the researcher concluded that the inclusion of audio sound cues within the mechanics could have potential isolated those players who are hard of hearing or isolated players utilising a tablet device with poor audio quality.

The iteration on “Musical Mah-Jong” kept the mechanics of matching tiles and suggested a Pictionary style game. Figure six below showcases how the game would have worked in a physical version if the design had been carried forward.

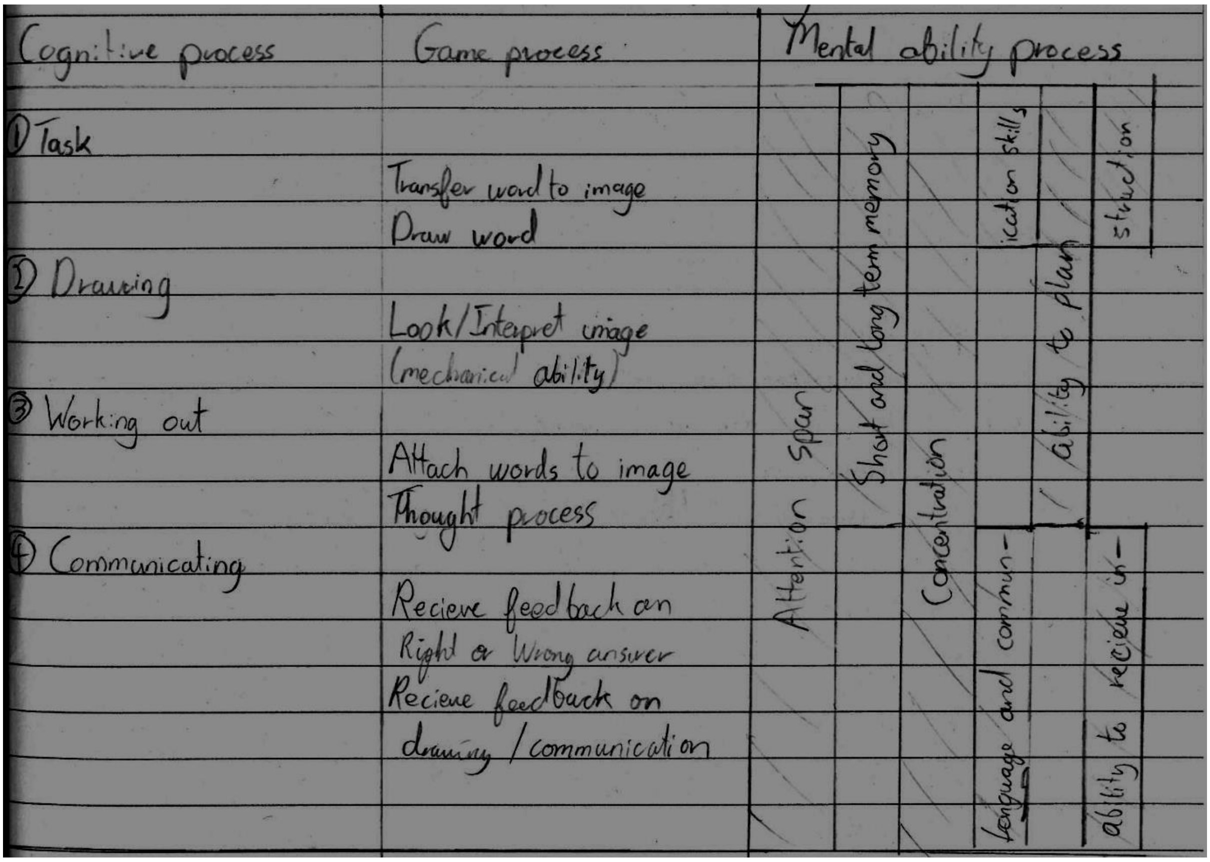


FIGURE SIX PICTIONARY STYLE GAME DESIGN NOTES

Cognitive processes for playing game were;

1. *Task – Transfer word to image*
2. *Drawing – Look/ Interpret image (mechanical image)*
3. *Working Out – Attach words to image (Thought process)*
4. *Communicating – Receive feedback on right or wrong answer. Receive feedback on drawing/communication*

The Pictionary style game was suggested to be a physical multiplayer game and build social skills between patients with dementia; however the direction of this thesis was in the use of digital technology and not on social skills between dementia patients. The direction of the research was focused on exploring the development of video games that could potentially assess cognitive processes.

After early conceptualisation as described above. This research utilised the research conducted in the previous work chapter to hypothesise that the mechanic of 'matching' two identical images, patterns, or sounds to succeed was associated with working memory. It was at this point a physical prototype with playing cards was tested. A matching tile game using two decks of cards to match identical cards was constructed. This was done to test the mechanics of the game and explore if the game could be given rules and systems as defined by Salen & Zimmerman (2003) and presented in the MDA framework (Hunicke, LeBlanc and Zubek, 2004).

The previous work chapter highlighted existing games that the researcher used for reference when designing the working memory video game, specifically the design of The Ryokansan (Ohtsu Computer cited by Fukui et al. 2015) which utilised a similar mechanic where it hid images faced down and challenged the player to find as many pairs under a certain time limit.

This research had identified a pattern in the design of video games for working memory. This information was used to create a game that reflected similar mechanics of:

- Matching objects/tiles/entities
- A method of scoring; number of matches or time
- Hidden elements that require a short-term memory challenge

5.4.2. THINKING AND REASONING GAME DEVELOPMENT

This research was originally focused on developing games for dementia where there was an initial concept for a video game to assess the cognitive process of thinking and reasoning. As thinking & reasoning is associated with problem solving (Eysenck & Keane, 2010), there was a preliminary concept for creating a true or false game where participants had to work out whether statements presented to the player were true or false. An early concept attempted a story-based game approach but that would involve the player making decisions to progress a linear story. However, this created concern whether the model of thinking & reasoning would be lost through a narrative driven game. To simplify the representation of thinking & reasoning, an early digital prototype of how a true or false game could function seen in Figure seven was created.

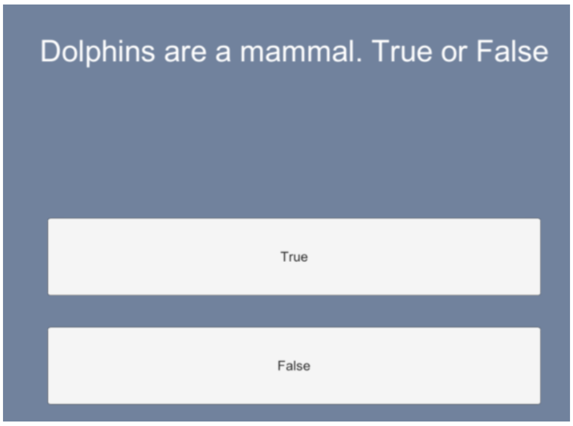


FIGURE SEVEN TRUE OR FALSE CONCEPT

As established in section 3.2.2.1, the existing games that were used to assess thinking & reasoning differed between presenting a problem to the player or presenting a set of tools or interactions to the player and having the player figure out how to progress. Another feature seen in existing games that assessed thinking & reasoning was a process of finding a solution to a time constrained problem.

This research proposed that a game for thinking or reasoning must possess one or both of the following design qualities shared by other games exploring this area such as:

- Problem solving element
- Testing decision making

This research reviewed the accuracy of a true or false game and how it could be used to measure or observe thinking & reasoning. After speaking with Dr William McGeown, a cognitive psychologist at Strathclyde University, the suggestion was that a true or false game was predominantly testing language skills over thinking & reasoning. There was a hypothesis by the researcher that the true or false game would be affected by an individual's level of education rather than their ability to think on a problem and provide an answer. This was hypothesised due the design of true or false questions presenting a fact and a fabricated fact. Differences in education would most likely present different results amongst a public population.

This research then returned to centralising an idea that would adhere to the design qualities stated above and utilise the existing games described in section 3.2.2.1. The researcher developed the concept of an 'odd one out' video game that was conceptualised from the children's activity of problem solving (Bowkett, 2014). The concept of an 'odd one out' video game was developed onto the tablet technology that was referred to as 'Odd Ones' which is detailed in section 5.5.2.

5.4.3. LANGUAGE GAME: WHICH WORD

As stated at the beginning of this section in 5.4, existing games for language involved the act of writing or guessing a word to succeed. The Mindtraining (Hackner and Lankes, 2016) application featured a word style quiz and similarly the Cogniplay (Vasconelos et al. 2012) featured spelling and word association games.

From the examples given in the previous work chapter, this research proposed that a video game for language should feature:

- A form of word play
- Quiz or trivia genre game

The researcher looked at cognitive assessment for testing language for an idea on how to conceptualise a language video game. However, this research discovered that most of language tests were conducted vocally. An example is it the controlled oral word association test (COWAT) which is an existing cognitive test used to test language by giving a participant three letters and asking them to state as many words starting with those letters in the given time (Ruff et al. 1996). A digital representation of this test would have required microphone integration and a complex artificial intelligence (AI) to understand the words spoken. A concept based on the COWAT would require a video game that could understand different accents and record a score. The replication of the COWAT into a digital representation was feasible, but the development of a video game that could replicate the COWAT would be longer than the timeframe for this research.

Figure eight below was a rough concept of language as a trivia game where the questions would have utilised player inputted data to create questions. For example, a player would add photos of friends and label them with names; the quiz would then present pictures of friends and ask the player to identify ‘X’ where ‘X’ would be the name of a friend. This concept was suggested when the researcher was developing video game concepts for dementia patients. The trivia game would have worked as a method for reminiscence therapy, asking them to recall names of people they knew.

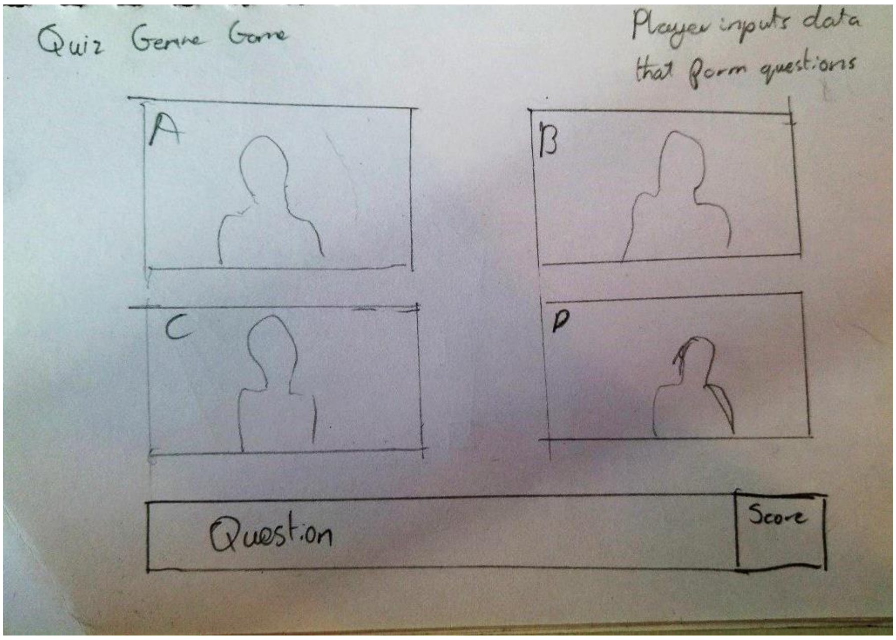


FIGURE EIGHT EARLY TRIVIA GENRE GAME

The researcher hypothesised a key issue with the data input trivia game idea and that was the dynamic of asking players to input details. The player would need to spend time inputting data to create the game which the researcher hypothesised would not make for an engaging or fun experience to elicit play.

Instead, this research decided to develop a trivia game with established data so that player could play straight away without inputting data. When looking at the COWAT, there was the suggestion that word association was a key theme from spoken answers. The researcher carried this idea of word association to create a word association style trivia game that was timed like that of Cogniplay’s design (Vasconcelos et al. 2012). The trivia game was carried forward to development onto tablet device and was referred to as ‘Which Word’. The design of ‘Which Word’ is described in section 5.5.3.

5.4.4. PERCEPTION GAME: PESKY-PENGUINS

The initial design of a perception game involved observing shape and sound in animal characters. The Parkin' Play study (Van de Weijer et al. 2016) modelled the basic processes of perception through the mechanic of tracking multiple shapes of fish in the game Aquasnap. Jungle App (Coppola et al. 2013) used animal photograph shapes to challenge their target market of Parkinson's patients by giving the participants a specific animal to look for and having animals appear and disappear on the screen. These games inspired the design of a video game prototype to assess perception.

The first design proposed by the researcher for the perception game was 'Birds Eye View' that took a garden environment and challenged the player to catch specific birds and insects that were established by the game. For example, the player would have two minutes to catch five red birds or three bees. Figure nine shows an early sketch and mock-up of 'Birds Eye View'.

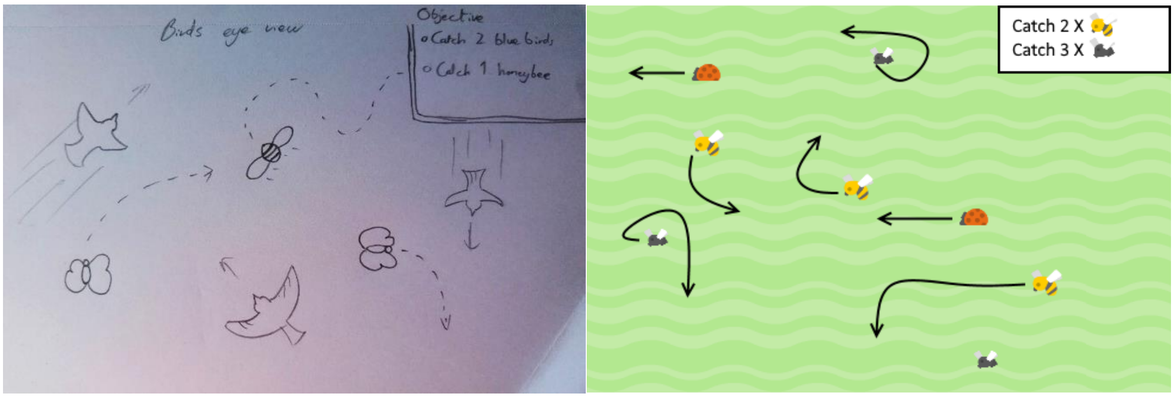


FIGURE NINE 'BIRDS EYE VIEW' CONCEPT

Each creature would display a different behaviour, some flying in straight lines across the screen and large in size, in comparison to the other creatures to present a potentially easier objective compared to insects like butterflies, flies and bees that would present a different behaviour with random movements across the play screen, potentially making it harder for them to be 'caught'.

The existing games in section 3.2.2.1 identified that games categorised under perception had an association with processing speed and attention. The existing games suggested games for perception involved players having to find and select the desired object or displayed fast paced games where the player must perceive a danger to their character and react in time.

The mechanics and dynamics from existing games suggested that a video game that could potentially assess perception should;

- Present a visual (and potential audio) challenge through shape, colour or image
- Involve the process of identifying the objective of the game
- include searching the display space for how to progress

However, the use of behaviours could suggest that the player would not rely on perception to complete 'Birds eye view' but could instead learn the patterns to succeed. Removing the behaviours meant the design of the perception game would use shape and colour to challenge the player. The iterative process led to the development of a static appearing shapes and colours, like that of the Jungle App (Coppola et al. 2013) pictured in Figure ten.

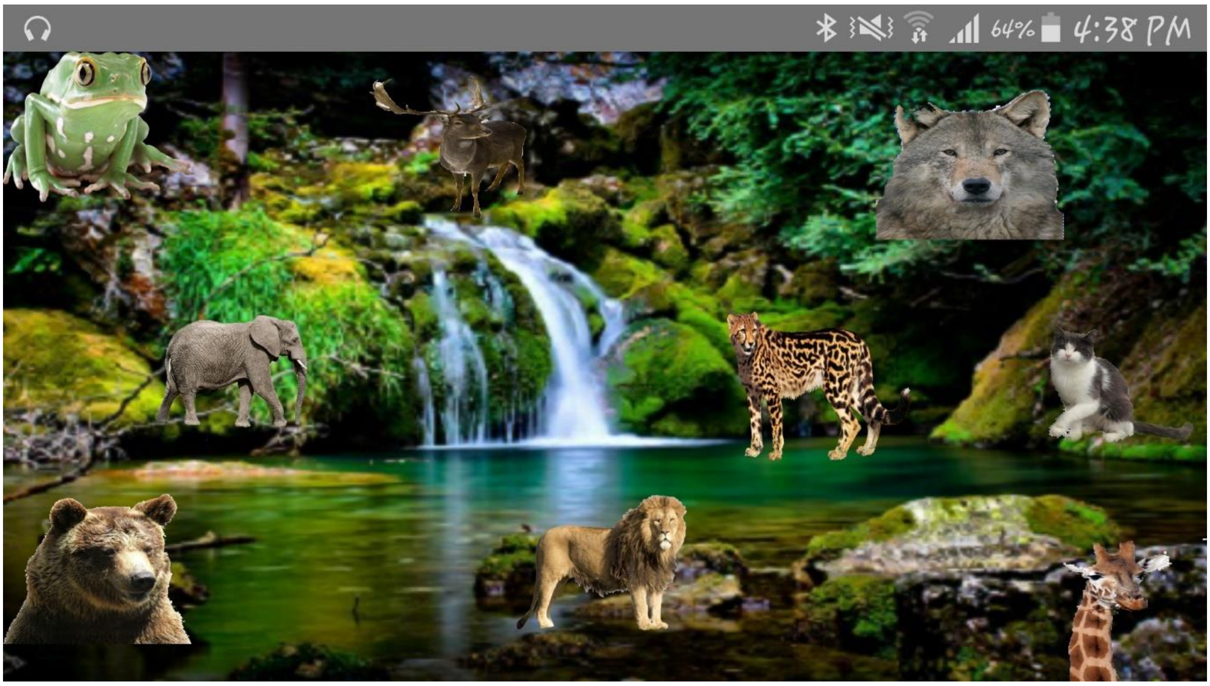


FIGURE TEN SCREENSHOT OF 'JUNGLE APP' (COPPOLA ET AL. 2013)

This brought about the preliminary design of 'Pesky-Penguins' which involved 2D shapes and colour variations of a penguin face, pictured below, that needed to be 'caught' by the player. The hypothesis was that this would specifically challenge the players shape and colour perception.

FIGURE ELEVEN PESKY PENGUIN SHAPE ASSETS FOR PERCEPTION

The beginning of a digital video game of Pesky-Penguins was developed, but due to time constraints Pesky-Penguins was not included in the Brainplay package. Code that was developed involved the action of spawning (making them appear and disappear on the screen) the penguin assets in random array within the play space. A screenshot of Pesky Penguins is given in Figure twelve to highlight how the game may have looked.

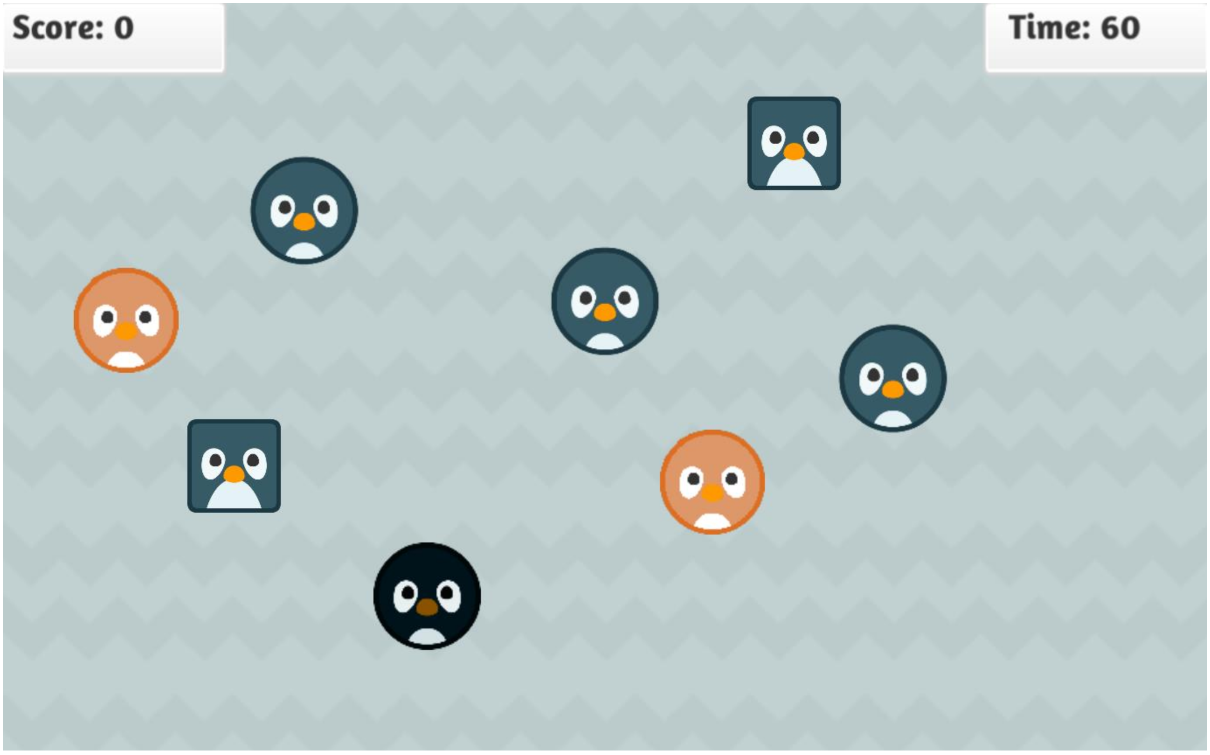


FIGURE TWELVE PESKY PENGUINS CONCEPT

5.4.5. LONG TERM MEMORY GAME: MEMORY MATTER

Section 3.2.2.1 in the previous work chapter suggested that there were few ventures by video games into assessing long term memory. This could have been due to the challenge of creating a game that accurately simulated long-term memory or with a retention element to bring players back.

The examples given in the previous work chapter suggested using common knowledge, that is knowledge gained from environment and primary education, should be known to a player to challenge long-term memory as suggested by the game ‘The Ryokansan’ (Ohtsu Computer cited by Fukui et al. 2015). The researcher hypothesised that a game developed for long term memory should carry out a demographic test to observe the knowledge of users before developing a video game to model long term memory. If a demographic test was carried out to understand an audience’s educational background and common knowledge, then a video game could attempt to create a game that would test or measure the knowledge gained over time. This observation of knowledge is seen in game-based learning (Prensky, 2001).

This research proposed that a video game developed from the cognitive process of long term memory should:

- Include some longevity in its game play, or long-term retention/recollection
- Challenge the player with previously recorded data (i.e. Remembering an answer or action and recalling it in a future play-through)
- Justify whether a passage of time accounts for long term memory, and not short-term memory or whether the recalling of knowledge is coming from long term memory or working memory

Testing common knowledge could have been potentially difficult to test and measure through a video game without a complex input and AI to select relevant questions to an individual’s knowledge. It was hypothesised that attempting to test an individual’s game-based learning experience is highly complex and beyond the scope of this immediate research.

Instead, this research suggested testing common knowledge; the player would have been tested on previously recorded data that could be obtained from a previous play-through. The video game *Hello Neighbour* by Dynamic Pixels & tinyBuild (2017) was an example of a game that uses an AI opponent that learns from the players mistakes. With each attempt *Hello Neighbour* changed with the actions that have been conducted by the player. This iterative form of play in video games could have potentially presented a method for creating a game on long term memory with the player having to remember their actions however the development of such a video game prototype is beyond the scope of this immediate research.

When thinking of the suite of games for this research, the researcher conceptualised the idea of creating a long-term memory game that was simpler than the potential requirement of an AI. This led to an idea where the player would return to play the game across the duration of a few months. The concept was that the player would create a pattern on a 15x15 grid that required them to use between 7 and 15 blocks on the grid. The player would then by presented with a blank grid after a set time (hours, days, weeks or months) and challenged to recreate the pattern they had created. The interactive grid would form the primary mechanic of this game, referred to as Memory Matters. The dynamic would be the player recording and recalling their pattern. With every correct answer where they remembered their pattern, the player would be encouraged to add another block to their pattern.

The image below shows the basic layout of how the game would look.

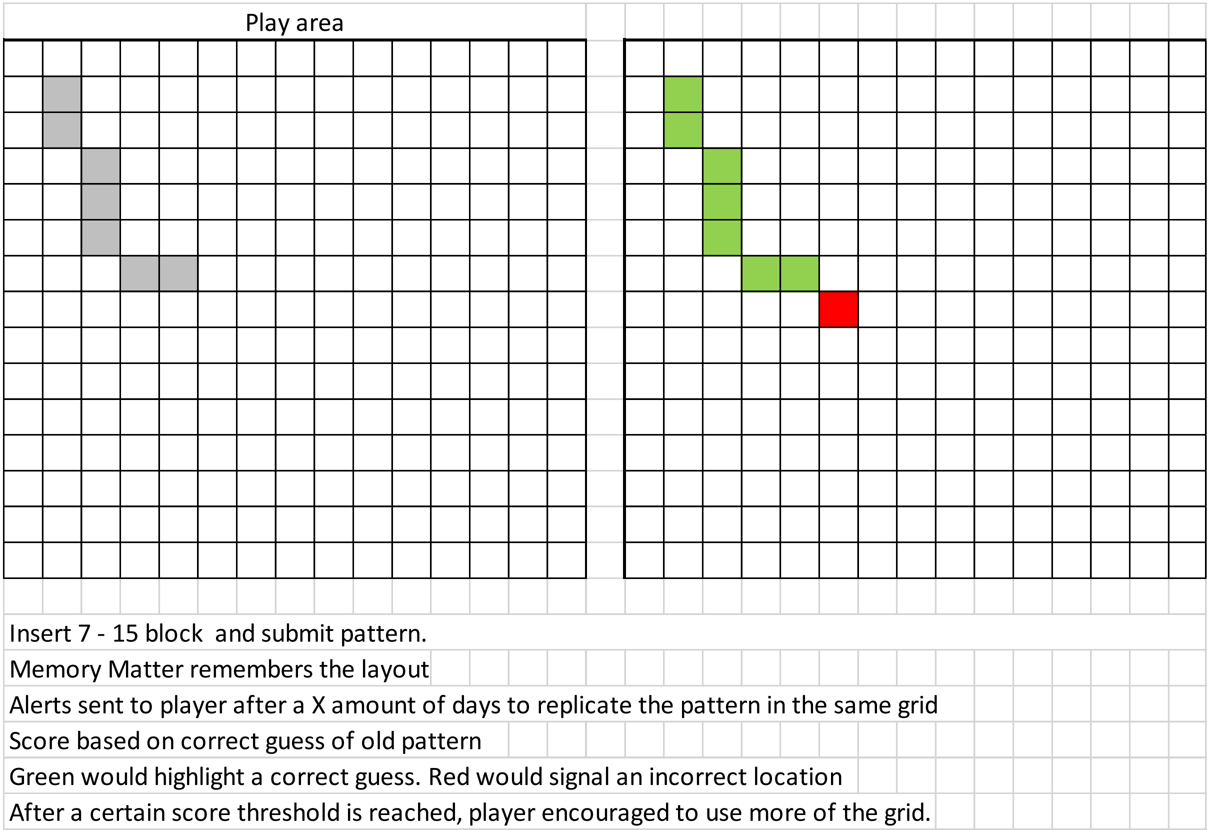


FIGURE THIRTEEN MEMORY MATTER DRAFT DESIGN

Memory Matters took inspiration from Memory Matrix (155 Games, 2016) which involved the player remembering a layout of shaded squares on a grid and then selecting them once they were hidden. Player succession at Memory Matrix results in the grid size and number of tiles increasing to present a tougher puzzle. Where Memory Matrix required immediate feedback, Memory Matters would test the player's ability to retain information through long term memory.

The further development of this game was not carried over into digital format due to the time constraints of this research. Creating and testing a long-term memory game would require a longitudinal study and the retention of the same test group to observe if changes occurred over time.

5.4.6. ATTENTION GAME: CHARACTER CATCH

The previous work chapter in section 3.2.2.1 suggested games that were assessing the cognitive process of attention had the features of multitasking and creating distractions within the game. There was often an element of trying to mislead the player and challenge them to work out what the correct objective is.

Many of the games referenced by Baniqued et al. (2013b) in their study of casual games referenced a game that featured a scored progression system while attempting to avoid incorrect answers or dangers to the player.

The previous work chapter presented existing games associated with the cognitive process of attention; this research proposed that the design of a game for the cognitive process of attention should include:

- Multiple tasks or objectives. Perhaps starting off easy and gradually introducing more complex scenarios
- A form of distraction or challenge. The distraction challenges the plays ability to separate the correct objective and the incorrect objective

An early concept of a 2D catch game was hypothesised where the player must navigate a net along the X axis along the bottom of the screen. The objective was to catch the desired objects/entities and avoid the object and entities that were regarded as incorrect answers.

This mechanic would utilise a tilt function within tablet device to position the net to catch desired objects. The researcher conceptualised the video game prototype of 'Character Catch' which would involve the mechanic of the tilt function to manoeuvre a net to catch the desired character. Catching an undesired animal would result in the player losing score.

The dynamics would have involved the player actively searching the play space for correct ‘characters’ and manoeuvring the net under the desired character while avoiding the undesirable characters.

No early prototype was developed for Character Catch, but a concept image has been provided in Figure fourteen.

FIGURE FOURTEEN CHARACTER CATCH CONCEPT IMAGE

Developing the tilt function or a swipe input would stray from keeping the game easily accessible to individuals with no experience of video games; this was the main reason why Character Catch was not carried forward to final development in Brainplay.

5.4.7. PROCESSING SPEED GAME: KNIGHT RUSH

As stated previously in 5.4.4 of the prototype development for perception, perception shared basic cognitive processes that are often associated with processing speed. Processing speed in existing games often involved an individual’s reaction time, both physical and mentally.

An early concept in development was an endless runner genre game to test processing speed. An endless runner game requires quick input to score/progress the game. A single input can be developed to create the main mechanic of an endless runner game.

The primary example identified in the existing game literature was Aquasnap that assessed processing speed through the mechanics of limited time, test of reaction time to fast moving images and tracking multiple objects at one (Van de Weijer et al. 2016).

This research proposes that a game for processing speed will share similar design qualities of a perception based video game. However, a video game for processing speed should:

- Make use of a time based/score based system
- Be fast based, with a reliance on reaction time
- Possibly introduce multiple elements for the player to track

In reference of early concept design, an endless runner style game like *Bit Trip Runner* (Choice Provisions, 2015) and *Jetpack Joyride* (Halfbrick, 2011) could be developed with a different approach to the mechanic. Where these games challenged the player’s reaction time and by tapping at the correct time to manoeuvre over obstacles, the processing speed endless runner would use lanes to manoeuvre around obstacles. An early sketch of how the lanes would work in an endless runner is given below in Figure fifteen.

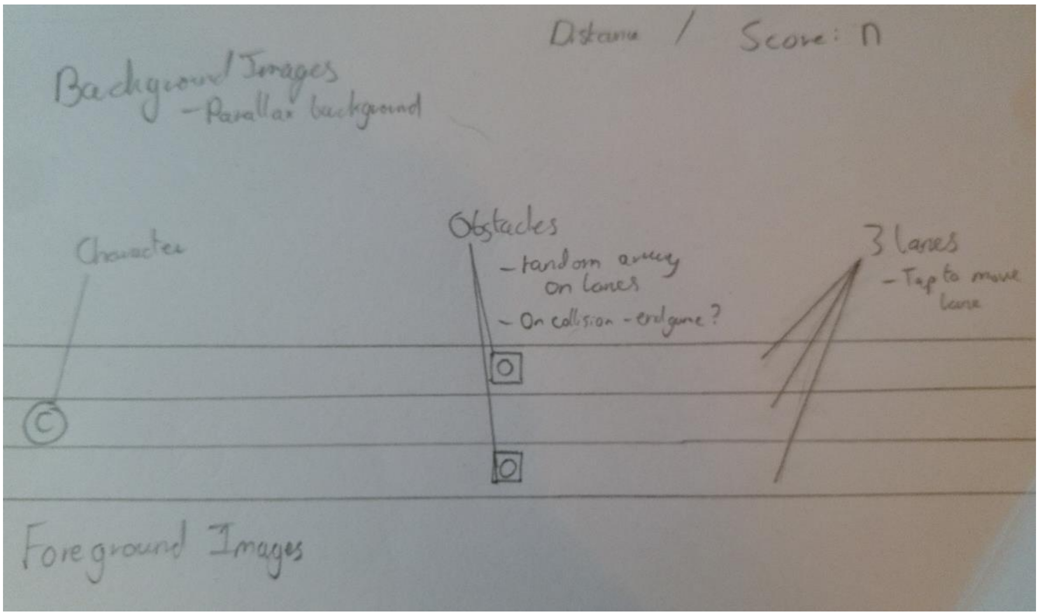


FIGURE FIFTEEN ENDLESS RUNNER, MECHANICS OF LANES

The lanes would allow the player to use a single input of a tap to switch lane and avoid an incoming danger. The idea developed an aesthetic of a knight storming a wall and running down a wall fortification, the longer a player lasted before failing, the more points they accumulated. The name Knight Rush was conceptualised for a video game with the potential to assess processing speed.

Knight Rush would become gradually quicker with the knight accelerating his movement speed and new obstacles would be introduced to challenge the player. This formed the basis of the mechanics with the dynamics of the player reactions through a single touch input to move into a different lane and avoid danger. The expected aesthetics would be notions of sensation, eliciting enjoyment from the game. Not only that, the aesthetic descriptor of challenge would be expected as the game is framed ‘as an obstacle course’ (Hunicke, LeBlanc & Zubek, 2004). A concept image is given below in Figure sixteen to help communicate the concept of Knight Rush. However, there was no scope to develop Knight Rush during the length of this research since Knight Rush would have required considerably more development time for animation, art asset generation and procedural map generation in comparison to the other games of Brainplay.

FIGURE SIXTEEN KNIGHT RUSH CONCEPT IMAGE

5.5. DIGITAL PROTOTYPES DEVELOPED

5.5.1. MATCH UP – WORKING MEMORY

Match Up was the video game designed with the potential to assess the cognitive process of working memory. Match Up was matching cards game that challenged the player to match identical cards and remember the locations of previously flipped cards. The player wins when all card pairs have been matched and faced up. A video of match up can be accessed in appendix seven.

Through the application of the MDA framework, the mechanics of Match Up were faced down cards and the process of revealing a matching pair. A matched pair would then remain faced up. The player was timed on how long they take to complete the game. The player is given the total number of matches that they have left to find as a guide for progression through Match Up.

The dynamics are the players touch input to select and reveal a cards image, the first card revealed remained faced up until another card is selected. If this is an incorrect match, the cards returned face down. A correct identical match would reduce the number of matches to find. The other dynamic at play is the players' ability to remember card patterns and position on the display.

The expected aesthetics of play will be that Match Up is regarded as an enjoyable experience and that the hidden elements offered a challenge to the players' memory (Hunicke, LeBlanc & Zubek, 2004).

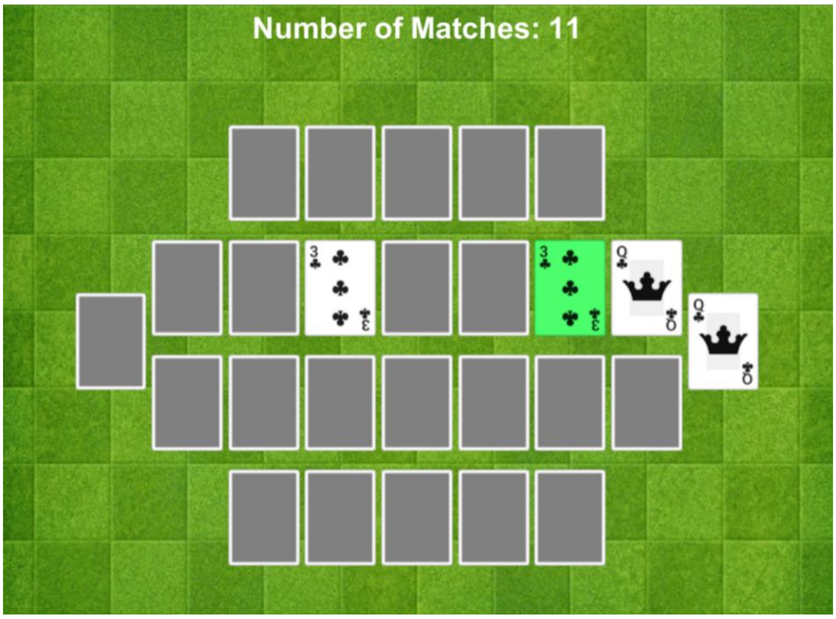


FIGURE SEVENTEEN MATCH UP EARLY DEVELOPMENT

Figure seventeen showcases the first digital adaptation of the working memory card matching game that used royalty free card assets (Kenney, 2017) to create Match Up. The mechanics of cards flipping, matching an identical pair and then presenting the correct pair faced up were all in place. The dynamic interaction of the single touch input, whether a mouse click or finger tapping once, was incorporated for use on tablet technology.

There was only one method of tracking score which was through the number of matches. Time taken was used to track how long it took a participant to complete the Match Up game with thirteen potential matches. The number of matches was selected as twenty-six cards in the given screen space did not clutter or present an overwhelming challenge.

In addition, this research developed two other levels of difficulty that were not used in testing as it would have created a long duration of play time that would have kept participants far too long. The other difficulties featured eight matches and twenty matches. A new set of visual assets were used as well as the addition of background music (developed by Benedetti, 2017). New artwork was added to create a universal art style that could potentially appealed to a wider audience. The addition of feedback audio cues meant that players received both audio and visual feedback when a match was made to guide the player that a match was the correct action. An image of Match Up, seen in Figure eighteen, displays the implemented new art assets.

The researcher carried out quality assurance for any bugs (errors in the video game) that appeared. The bug report checked for problems in the mechanics or errors that appeared from playing Match up on device. The bug report for Match Up can be seen in appendix six.

FIGURE EIGHTEEN MATCH UP FINAL PROTOTYPE

5.5.2. ODD ONES

The early prototypes of thinking and reasoning led to the development of 'Odd Ones', a spot the difference style video game with the mechanics of identifying the differences between assets that appear on the screen and which one appears different. This was built with the addition of a time limit to create the objective of achieving the highest score possible in the given time. This design choice was to elicit a competitive nature from players. A screenshot of Odd Ones is given in Figure nineteen below.

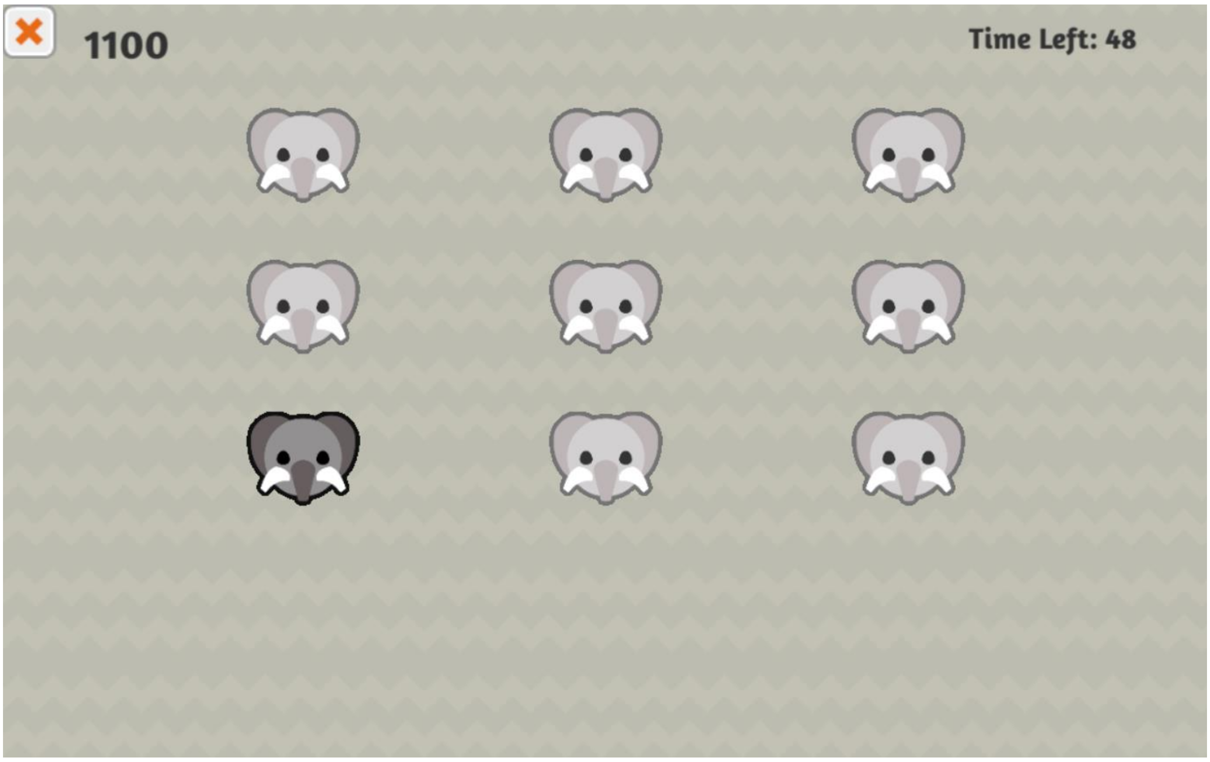


FIGURE NINETEEN ODD ONE'S BRAINPLAY

'Odd Ones' featured a number of animals with one of the animals differing from the rest, either by colour, feature or being an entirely different animal. Odd Ones had originally featured an array of animals with one animal a distinct colour from the rest but early feedback from the supervisory team suggested colour difference would suggest a cognitive colour test, which suggests a test related to perception rather than thinking and reasoning. An attempt to assess thinking and reasoning involved the addition of different creatures and shapes to the Odd Ones layout. This change would mean players would need to determine the differences between the assets rather than just the specific colour, which was still included.

The foundation mechanics are a grid of animals that originally presented three randomly generated assets with one that differs. As the player progressed and achieved a higher score, the layout size increased to show four assets, then nine and finally sixteen assets. The dynamic was the process of working out which animal is the odd one out and tapping the odd one. This resulted in a feedback of a score increase.

Quality assurance was carried out on Odd Ones in the same process as it was for Match Up. The researcher identified no bugs through quality assurance of Odd Ones.

5.5.3. WHICH WORD

As explored in section 5.4.3, the trivia genre of game and word-play were associated with the potential assessment of language. The researcher kept the trivia genre and moved towards word association within the trivia genre. The prototype trivia game was named Which Word.

The main mechanics of Which Word were the trivia genre layout, with a question area and four possible answers. To create the questions the researcher viewed current word association games such as *Word Association!* (Zelnut LLC, 2017) and *Lateral* (Zdbzd, 2009) for examples of word association puzzles. Using the examples, the researcher created the questions and answer trivia game where one answer stood out as the associated answer and the rest were highly unlikely to be related to the question. Correct answers resulted in a reward to score.

The dynamics would be the players input on selecting the answer they best believed was associated with the word in the question. After 60 seconds, the player is given their score for Which Word. Figure twenty displays a screenshot of Which Word.

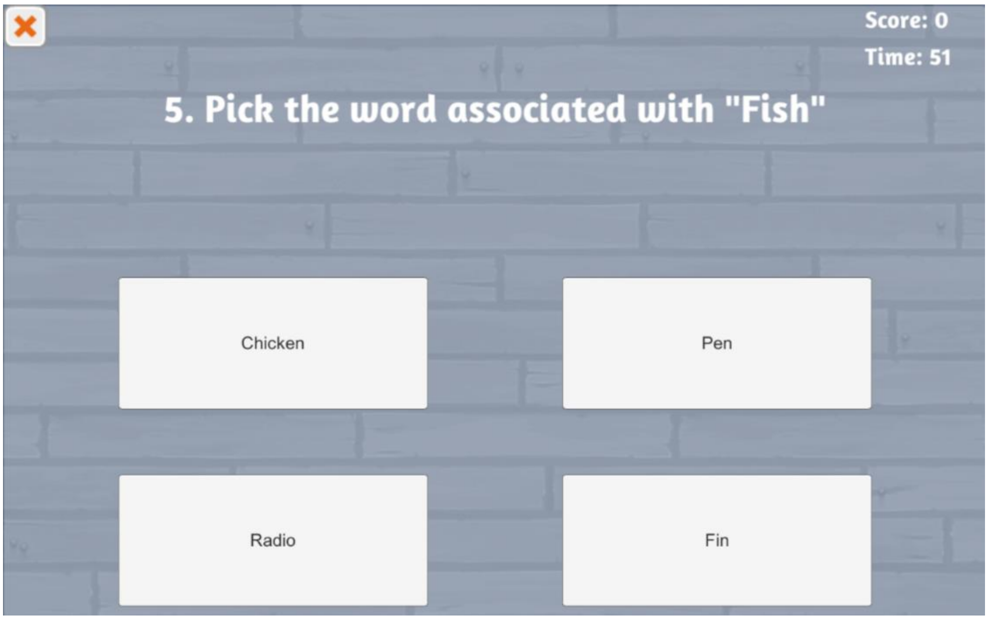


FIGURE TWENTY WHICH WORD - BRAINPLAY

The style of the game was based off trivia game shows seen on daytime television, such as ‘The Chase’ and ‘Who wants to be a Millionaire?’ (ITV, 2014).

5.6. PROTOTYPE DEVELOPMENT SUMMARY

As seen in this chapter, this research has proposed a game for each of the cognitive processes (Match up for Working Memory, Odd Ones for Thinking & Reasoning, Which Word for Language, Pesky-Penguins for Perception, Memory Matter for Long term memory, Character Catch for Attention and Knight Rush for processing speed). This chapter highlighted features seen in existing video games and suggested a mechanic(s) or genre for each of the cognitive processes:

- **Working memory** games:
    - involved short term recall of a position or detail of an object and rewarding the player for their success
    - Or, displayed a matching action, where the player must ‘match’ two identical images, patterns, or sounds to succeed
- **Long term memory** games suggested:
    - remembering or reciting objects from a long duration of play
    - testing common knowledge
- **Perception** games:
    - involved players having to find and select the desired object
    - Or, displayed fast paced games where the player must perceive a danger to their character and react in time
- **Attention** games suggested the action of avoidance and multitasking
- **Processing speed** games were often a test of reaction and commonly assessed in perception games.
- **Thinking & Reasoning** games suggested:
    - the mechanic of problem solving
    - Or, learn a pattern / solve a puzzle
- **Language** games suggested the act of writing or guessing a word to succeed

As detailed in 5.5, the researcher developed three of the games designed for Brainplay. The next step of this research was to explore whether ‘Odd Ones’, ‘Which Word’, and ‘Match Up’ actually conveyed the cognitive processes they were developed for (or not) using the MDA framework to design the games and whether the games of Brainplay were still perceived as games.

The scope of the research meant this research was limited in the number of games that could be developed for Brainplay. As a result, only three of the seven designed games were developed for these further studies.

Each of the video games developed has supplied an explanation of the mechanics, dynamics and aesthetics, adhering to the MDA framework. This provided a design rationale for Brainplay.

The next step of this research was to discover whether Odd Ones, Match Up and Which Word were still perceived as games as defined in the chapter two of the background. This research would explore whether these games could be used with assessment, diagnosis or treatment of cognitive impairment. The methods for these studies were provided in chapter four of the methods, the results are detailed in chapter's seven to nine. Further details on the implementation of Brainplay are detailed in the next chapter.

6.1. CHAPTER SIX: IMPLEMENTATION

This following chapter discusses the implementation of Brainplay. In summary, this chapter details information on the programming language selected, resources used, tools used and how Brainplay was developed onto a tablet device. The digital submission also contains the files for viewing Brainplay.

The source code and assets for Brainplay are available in Appendix seven**.**

6.2. DEVELOPMENT TOOL

To create the base prototypes that would become Brainplay, Unity 5 (Unity, 2017) was used as it was a familiar tool to the researcher and freely available to use. Unity 5 allowed for the creation of 2D and 3D which meant the design choices were not limited. Unity 5 also offered a marketplace for royalty free assets which could be used to rapidly develop prototype. The two programming languages used in Unity 5 were C# and JavaScript, with the development of Brainplay using C# as the preferred programming language. The scripting for Brainplay was written within MonoDevelop, an associated scripting program packaged with Unity 5.

Alternative tools such as Gamemaker (YoYo Games, 2017), Construct 2 (Scirra, 2017) and Unreal Engine (Epic Games, 2017) could have been used in place of Unity 5. However, Unity 5 provides a large amount of key documentation to aide with programming the desired product along with a marketplace to access royalty free assets.

6.2.1. OTHER TOOLS

To aide with the development of Brainplay, other tools were used in the creative process. The main secondary tool used was Paint.net (DotPDN LLC, 2017), a freely available image editor tool which allowed assets to be modified or created for Brainplay.

6.3. IMPLEMENTATION PATHWAY FOR BRAINPLAY

This section of the chapter highlights how Match Up, Odd Ones and Which Word were created in the Unity 5 editor. Specifically showcasing some of the more complex mechanics which make the three games different. As all the games are two-dimensional, Brainplay was created in the 2D format of the Unity editor.

6.4. MATCH UP

Match Up was a tile/card game that was designed to potentially assess the cognitive process of working memory. As evidenced from the prototype development chapter in section 3.2.2.1, other developers and researchers had developed similar games to Match Up and this research attempted to replicate the genre of game but through the design process of the MDA framework. The researcher used the available unity documentation, tutorials and asset packs to help develop Match Up.

Match Up was the first game within Brainplay to be implemented into a digital prototype. Match Up relied on a script called *CardGameManager* which controlled main functions with Match Up.

Match Up utilised a user interface layer to observe the time taken and the number of matches left for the player to find. Two empty text boxes are placed on the user interface layer which would be updated by the *CardGameManager* script.

Before any functions are scripted within the *CardGameManager*, the public and private variables were laid out. For Match Up, there are two public Sprites, *cardBack* and *cardFace*, which allowed the upload of a sprite in the inspector with what would display on a card. The other variables declared here were the text boxes for the number of matches, as well as the time remaining. Finally, the variable for the total number of matches that were available was set.

The first function within this script that was used was the ‘update’ function which ran every frame (every second). Within this function, an ‘if’ statement initialized the cards that would appear in the scene. The update functions also detected for a mouse button (or touch) when a card was selected, it then ran the separate function of *checkCards*, which looked for a match between the two cards. Finally, the update function was responsible for the timer in Match Up, using real time to count seconds up from zero. The update function can be seen below in Script one.

```
void Update () {

        if (!_init)
            initializeCards ();

        if (Input.GetMouseButtonUp (0))
            this.gameObject.AddComponent<AudioSource>();
            checkCards ();

        timeStart += Time.deltaTime;
        timeText.text = "Time:  " + Mathf.Round (timeStart);
    }
```

SCRIPT ONE UPDATE FUNCTION FOR MATCH UP

This leaded into how the cards were initialised. The *initializeCards* script ran a while loop to randomise the cards in the scene. It also called an external script called *CardScript*, which was attached to a prefab of a face down card asset and is explained further on in this chapter.

FIGURE TWENTY-ONE BEAR CARD IMAGE

The key component for Match Up to work was the *checkCards* function. It took the image of the card face up, for example a bear image as seen in Figure twenty-one. The bear image remained face up and the function assigned the face up bear image to a list with a value of 1. All other images were now in a list with a value of 0. These lists are added together so an incorrect match will equal 1 however if both bear cards were flipped then the total would equal 2, resulting in a correct match. If the ‘card count’ equalled 2, a match was made and the *cardComparison* function is called.

The *cardComparison* function ran when a match was made. It then took the total number of matches and removed 1 from the total match count, indicated by two minus signs attached to the match’s reference. It also checked for when the number of mates equals zero, where if it did, the game over screen loads. The card comparison code is displayed below in Script two.

```
void cardComparison(List<int> c)
    {
        CardScript.DO_NOT = true;

        int x = 0;

        if (cards [c [0]].GetComponent<CardScript> ().cardValue == cards [c [1]].G
etComponent<CardScript> ().cardValue) {
            x = 2;
            _matches--;
            correctSound.Play ();

            matchText.text = "Number of Matches: " + _matches;
            if (_matches == 0)                                          //When all
matches are found, boot to main menu
                SceneManager.LoadScene ("CardGameOverScreen");
        }

        for(int i = 0; i < c.Count; i++)
        {
            cards [c [i]].GetComponent<CardScript> ().state = x;
            cards [c [i]].GetComponent<CardScript> ().falseCheck ();              /
/checking state of cards (pausing to select another card)
        }
    }
```

SCRIPT TWO CARD COMPARISON CODE

Finally, the last function that ran within the *CardGameManager* scripts was the update of the time which stringed the current time to the text box created in the user interface.

The *CardScript* which was called upon in this script contained the functions for the behaviour of cards with Match Up. This script was attached to every prefab of every card that is spawned within Match Up.

The start function of the *CardScript* first found the game manager using a find function. It looked for the *CardGameManager* that was discussed above. This created a reference for functions used within that script.

Within the *CardScript* was a public function called *setupGraphics* which gathered the image or asset for the back of the card and the front of the card, the front of the card was a script called *cardValue*.

The function for flipping a card in Match Up was also contained within this script. There was no animation of the card turning, it was an instant switch from face down to face up to create a quick feedback system to the player. The *flipCard* function uses 'if' and 'else' functions to determine the card state and detect a match through the images.

The *cardValue* as mention before determined the images of the face up cards. This allowed for multiple images to be uploaded where the *CardGameManager* can call from to determine the images to use.

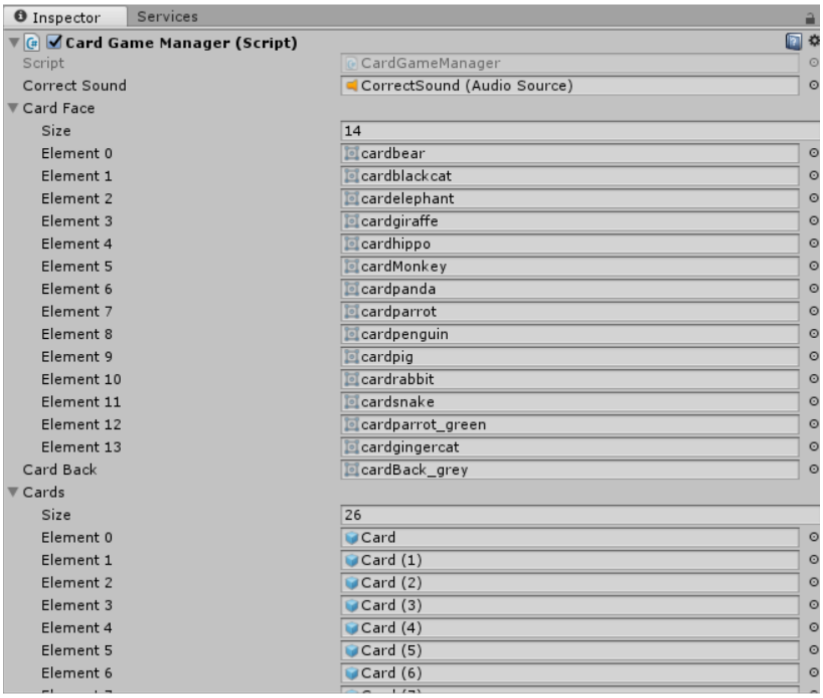


FIGURE TWENTY-TWO INSPECTOR OF CARD GAME MANAGER FOR MATCH UP

Figure twenty-two above shows what the developer can see when the *CardScript* and *CardGameManager* were used to create the game. The public variables entered here showed the assignment of a correct sound audio file that was to be played when a correct match was made. The card face variable allowed the developer to change the number of characters the player would find. As Match Up defined thirteen matches, there needed to be thirteen or more different images. The card back variable can be seen with the image of *cardBack_grey* assigned. Finally, the list of cards used in the scene. Each of the cards was a prefab created in an Assets folder. As mentioned before, the prefab for the Card contained a *cardscript*, a button script (for when clicked or touched) and an image script for the card back. If the prefab were to be changed, then all the spawned (created objects in the interactive game space) cards seen in the inspector pictured above would change as well.

These prefabs and public variables allowed for potential future study to edit the images as well as the number of matches a player must find. When Match Up was used in the user experience test, only one level was used which had a total of thirteen matches. One level was used to keep the total testing time for participants to a minimum. Two other levels were developed, one with six matches and one with eighteen matches, pictured in Figure twenty-three.

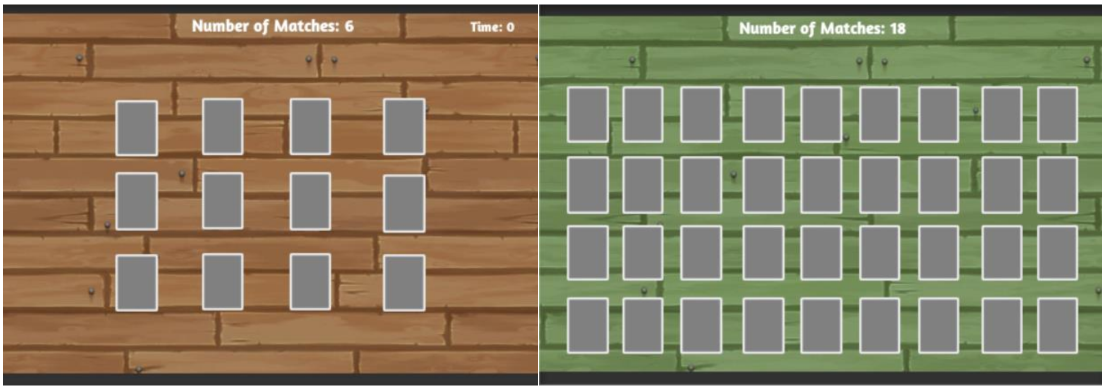


FIGURE TWENTY-THREE MATCH UP'S OTHER LEVELS OF DIFFICULTY

Like the other games of Brainplay, Match Up utilised a scene management script to move between the main menu, the game itself and the game over screen. The menu utilised a switch function where each ‘scene’ is assigned a number and that number is assigned to a button within the menu as seen in Script three below.

```
public void StartGame(int i)
    {
        switch (i) {
        default:
        case (0):
            SceneManager.LoadScene ("CardGame 1");
            break;
        case (1):
            SceneManager.LoadScene ("CardGame");
            break;
        case (2):
            SceneManager.LoadScene ("CardGame 2");
            break;
        case (3):
            SceneManager.LoadScene ("landingpage");
            break;

        case (6):
            Application.Quit ();
            break;
        }
    }
```

SCRIPT THREE SCENE MANAGEMENT FOR MATCH UP

Both the other two levels of Match Up are visible here, ready to be used in future work. Their buttons were disabled when carrying out the user experience of Brainplay.

6.5. ODD ONES

As section 5.4.2 and 5.5.2 of the prototype development chapter outlined, Odd Ones was developed from the cognitive process of thinking & reasoning. The first design of a game to challenge thinking and reasoning was developed similar to Which Word using an interactive user interface (UI) to create a true or false game.

Building upon the true or false style, the idea for an odd one out game was developed. To develop the basics of Odd Ones the researcher used Unity 5 and C# programming languages.

To create the scene (video game level or play space) where Odd Ones was viewed, a main camera was created that was focused to a two-dimensional scene around the origin (0,0). A foreground layer was added of a user interface that would serve as a method of keeping track of score and time left.

Keeping track of the time and score was done by creating empty text boxes in the user interface layer within Unity. These text boxes were scaled to the size required and then a script was added to each of the score and time text boxes as seen in Script four.

```
public class OddOneOutScoreController : MonoBehaviour {

    public Text scoreText;

    void Start(){
        scoreText.text = OddOneOutController.currentScore.ToString ();
    }
}
```

SCRIPT FOUR SCORE TEXT FOR ODD ONES

Script four above was attached to the empty text box and called (invoked a script) the '*OddOneOutController*' for the updated score in the game. The time text box also called the '*OddOneOutController'* for the current time in the game.

The *'OddOneOutController'* was an empty *GameObject*, base class for all entities in unity (Unity, 2017), in the scene that had a C# script attached called '*OddOneOutController*'. The purpose of the 'Controller' was to manage all the other scripts in the scene, or the whole game. This main script was how most of Odd Ones functions.

The '*OddOneOutController*' used a mixture of public and private variables to edit and control the scores, time limit, images created, number of characters, difficulty, and audio. At the

'Start' of every game of Odd Ones, the start function was called where it would reset the current score to zero, call the '*DifficultyController'*, reset the win condition to false (reset the time limit) and then create the level (layout of characters). This can be seen below in Script five.

```
void Start () {

        fx = gameObject.AddComponent<AudioSource>();
        difficultyController = gameObject.GetComponent<DifficultyController>();
        gameOver = false;
        currentScore = 0;
        createLevel ();

    }
```

SCRIPT FIVE START FUNCTION FOR ODD ONES

Each of the games within Brainplay displays a similar 'Start' function in order to reset the score for every play-through.

The next function in the script was the update function which updates every frame (second) in Odd Ones. This means the update function ran the code within the update function every second. Within this function, the time limit was updated and then stringed (sent to) the empty text box in the user interface. The time was dictated by a float value set by the developer, in this case sixty and then every frame, the delta time (real time) was taken away. In lay terms, each frame represents one second and when each frame was updated, one second was removed from the total float value of sixty. When the float time was equal to, or less than zero, the update function would end the game and load the scene, '*OddOneOutGameOver'* which presented the final score to the player.

The '*OddOneOutController'* also tracked the interaction with the characters on the screen. When a character was tapped or clicked there were two functions, a correct click and an incorrect click.

The first function, *OnCorrectClick*, plays the *correctSfx* audio cue, updated the score and then created a new level of 'Odd Ones' to find (*createLevel*).

The second function, *OnWrongClick*, acted the same as the other function with the exception that no score was awarded and the *wrongSfx* plays instead. A wrong click resulted in a new level of 'Odd Ones to find (*createLevel*). Both functions act as public functions which meant they were changed within the inspector of Unity, rather than having to edit the C# script.

The *createLevel* script however, was a private function that created the random level layout seen in Odd Ones. The comments in Script six below describes how the function works in some detail.

```
private void createLevel() //create a random generated level set by the parameters
 of time, difficulty and coordinates of images
    {
        destroyLevel (); //destroys current layout of characters
        currentcharacter = getCharacterType (); //grab images of characters
        timeLimit = 100; //*Score -> Adds 100 to score
        imagesCreated = 0;
        Vector3[] levelCoordinates = difficultyController.getLevelCoordinates ();
//Grabs coordiantes for where characters spawn
        imagesForLevel = new GameObject[levelCoordinates.Length]; //creates charac
ters as new GameObjects in scene
        int badIndex = GetRandomIndex (levelCoordinates.Length); // Randomly arran
ge coordinates for character spawns
        for (int imageCounter = 0; imageCounter < levelCoordinates.Length; imageCo
unter++) {
            if (imageCounter == badIndex) {
                createImageObject (levelCoordinates [imageCounter], "Bad" + diffic
ultyController.getOddAsset ()); //grabs one 'bad' asset. The odd one out
            } else {
                createImageObject (levelCoordinates [imageCounter], "Good"); //gra
bs one 'good' asset. The predominantly seen asset in the scene.
            }
        }
    }
```

SCRIPT SIX CREATELEVEL FUNCTION FOR ODD ONES

The call made in the *createLevel* function called '*getCharacterType'* grabbed the available images, or assets, to use within the scene. The '*getCharacterType'* function contained a '*GetRandomIndex* (N)' function where N was the number of assets (characters) Odd Ones can use to create the scene. Odd Ones had a total of seven odd one out scenarios when used for testing. Of these seven scenarios there was a 'Good' asset and then three versions of an odd one out, '*Badeasy*', '*BadMedium'* and '*BadHard'*. The three versions of the 'Odd Ones' were to add a suggestion of randomness to Odd Ones so that players were not predicting the same odd one out scenario. The Odd Ones differed in colour but sometimes in a complete different character asset.

The '*createImageObject'* also seen in the *createLevel* function was crucial to the spawning of the characters within Odd Ones. '*createImageObject'* function gathered the coordinates from the *difficultyController* script and then instantiates (clone) the character assets as *GameObjects* in the scene. This created the character assets as interactive objects within the scene as well as renders the layout of the 'good' and 'bad' character assets.

As mentioned before, the '*OddOneOutController'* called another script used to develop Odd Ones, the '*DifficultyController'*. The Difficulty Controller was a separate script used to create the levels (layouts of characters).

All the functions within the '*DifficultyController'* were private functions that cannot be edited in the Unity 5 inspector.

```
private uint levelId = 0; //Number of images that will appear at their coordinates
    private int imageDifficulty = 0; //which image it pulls from the asset/materia
ls folder
    private float timeDecaySpeed = 0.2f; //Not used in Odd Ones final version. It
would create a time limit on finding the odd one out
    private bool imagesCanRotate = false; //Not used in Odd Ones final version. Al
lows assets to rotate, making it more difficult.
    private string[] assetDifficulties = { "Easy", "Medium", "Hard" }; //looking f
or asset character difficulty levels
    private Vector3[] threeImages = {new Vector3(-
5,1,0),new Vector3(0,1,0),new Vector3(5,1,0)}; // The coordinates of three images
in the scene
    private    Vector3[] fourImages = {new Vector3(-4,1,2),new Vector3(-4,1,-
1),new Vector3(4,1,2),new Vector3(4,1,-
1)}; //The coordinates of four images in the scene
    private    Vector3[] nineImages = {new Vector3(-
4,1,1),new Vector3(0,1,1),new Vector3(4,1,1),new Vector3(-4,1,-
1),new Vector3(0,1,-1),new Vector3(4,1,-1),new Vector3(-
4,1,3),new Vector3(0,1,3),new Vector3(4,1,3)}; //the coordinates of nine images in
 the scene
    private    Vector3[] sixteenImages = {new Vector3(0,1,0),new Vector3(0,1,-
2),new Vector3(0,1,2),new Vector3(0,1,4),new Vector3(-2,1,2),new Vector3(-2,1,-
2),new Vector3(-2,1,0),new Vector3(-2,1,4),new Vector3(2,1,0),new Vector3(2,1,-
2),new Vector3(2,1,2),new Vector3(2,1,4),new Vector3(4,1,0),new Vector3(4,1,-
2),new Vector3(4,1,2),new Vector3(4,1,4)}; // Sixteen images in the scene
```

SCRIPT SEVEN DIFFICULTY CONTROLLER FUNCTION FOR ODD ONES

The private functions above in Script seven help create the difficulty and layout for Odd Ones. The comments attached are self-explanatory, but this section delves further into how this script works.

Like the '*OddOneOutController*', the 'Start' function reset the scene and removed any old layout or prefixed coordinates. The 'Update' function ran '*getsLevelCoordinates'* every frame, which gathered the list of coordinates that was inserted. In this case, the *threeImages*, *fourImages*, *nineImages* and *sixteenImages* are the list of coordinates that were used. The next function referenced within the *DifficultyController* was an updateDifficulty function.

The update difficulty function is how Odd Ones determined which level coordinates layout to use. Odd Ones starts with three images, but to increase to four, nine and sixteen the player must reach a certain threshold in score. To do this, the researcher used the players score to create and ‘if’, ‘else’ statement that relied on the players score to change the difficulty as seen in Script eight below.

```
public void updateDifficulty(int score)
    {
        //uses the players current score to activate and increase difficulty value
s
        if(score > 1800)
        {
            imageDifficulty = GetRandomIndex (3);
            imagesCanRotate = false; //turn this to true to make images rotate, in
creasing difficulty
            levelId = 3;
        }
        else if(score > 1600){ //change these scores to change when the level gets
 more difficult
            imageDifficulty = 2;
            levelId = 3;
        }
        else if(score > 1000){
            imageDifficulty = 1;
            levelId = 2;
        }
        else if(score > 400){
            imageDifficulty = 0;
            levelId = 1;
        }
    }
```

SCRIPT EIGHT SCORE DIFFICULTY FUCTION FOR ODD ONES

The ‘else if’ statement is better understood by reading it backwards, where if the score was greater than 400 the difficulty will not increase but the level ID will, which meant the number of images would change from three to four. When the score reached greater than 1000, the image difficulty would increase, using the more difficult odd one out characters, and the layout would increase from four to nine. Again, when the score reached 1600, the difficulty would increase, and the layout would increase from nine to sixteen images. The final ‘if’ statement, for if the score was greater than 1800, meant the difficulty of the odd one image was random within the sixteen-image layout. The statement also had a ‘*imagesCanRotate’* script set to false. This was an idea to rotate images randomly to make spotting the odd one out more difficult however it caused some distortion in images, which could have made the objective of spotting the odd one out confusing.

The rest of the '*DifficultyController'* script was a public string to gather the 'Odd' asset determined by the difficulty of the level and tested scripts to the rotate function of the images.

Both the '*OddOneOutController'* and the '*DifficultyController'* were the main scripts that make Odd Ones function. The rest of this section describes some of the other features that were used to implement Odd Ones.

For example, within the '*OddOneOutController'*, a script called a *go.GetComponent* '*ImageHandler'* when creating a level of Odd Ones. The '*Imagehandler'* was a prefab *GameObject* that acted as a host for the instantiated images cloned by the *OddOneOutController*. A prefab meant that every image would adopt the same characteristics found embedded in the *ImageHandler*. In this case, *ImageHolder* prefab contained its own script that detected when it had been clicked/tapped (called *ImageHandler.cs*) and a script called '*OddOneOutScaleTween'* which created the growing animation when each level spawns in. This straightforward script scales the x, y and z axis by their own value until they reached the desired size set out in the prefab inspector editor.

Another script implemented were the buttons in place which took the player from the menu, or game-over screen, to Odd Ones or the Brainplay main menu. Each of the games, and Brainplay itself, hosted a menu script which allowed the buttons to navigate the player between each game.

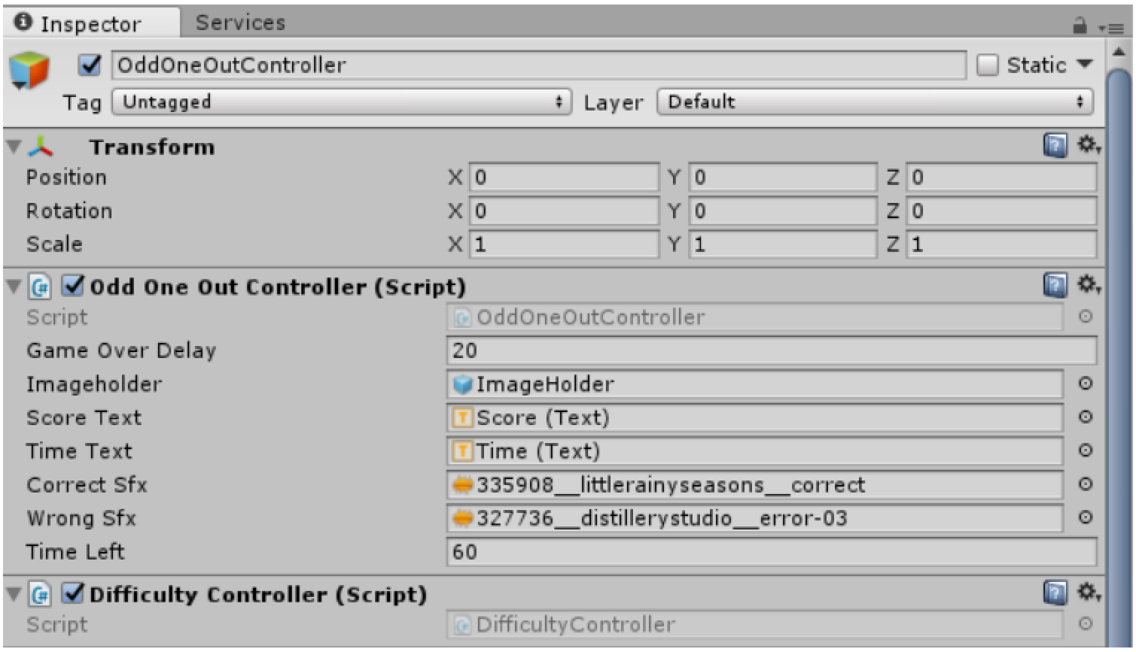


FIGURE TWENTY-FOUR INSPECTOR OF ODD ONES GAME CONTROLLER

Figure twenty-four above showcased how the scripting in C# is reflected in Unity's inspector, the *OddOneOutController* created a public variable area where the developer could assign, text boxes, audio and alter the duration of Odd Ones.

6.6. WHICH WORD

The genre of Which Word fell under the genre of a quiz/trivia video game. The development of Which Word was a lot more complex than initially thought. After the background and previous work chapters revealed very few video games had been developed for the cognitive process of language. As described in the prototype development chapter, Which Word was inspired by assessments of language but also trivia game shows seen on television.

With help from Unity tutorials, the development Which Word was completely different to the rest of the games within the Brainplay suite of games. Where the other games of Brainplay involved the use of Unity scenes and objects within the play area, Which Word operated and displayed through only the user interface layer.

To begin, the researcher created a user interface canvas layer from which all the buttons and text would display. This would be created in its own scene. The canvas layer included anchored text boxes that would display the time, score and question. These text boxes were left blank. Another text panel was used and constrained to a certain area, this would be the display area for the answers. Added to the answer text box were two Unity scripts, the *Content Size Fitter* which kept the content within the present size and the Grid Layout Script which displays the answers in a desired layout. The Hierarchy display for how the canvas looked in unity is given in Figure twenty-five below;

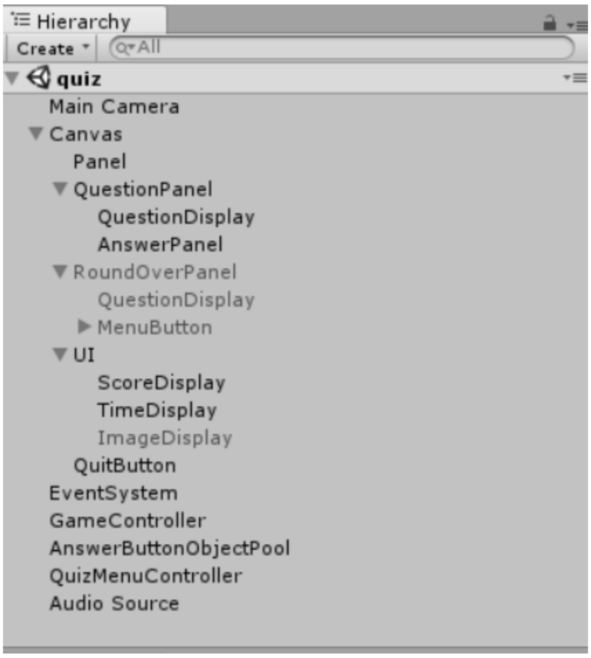


FIGURE TWENTY-FIVE HIERARCHY ILLUSTRATING WHICH WORD'S DISPLAY

Once this was done the researcher could begin on scripting how Which Word would function. Again, the scripts were written in C# like the rest of the games. Which Word possessed two main scripts from which other scripts worked from, the *GameController* script and the *DataController* script.

The *GameController* script was attached to an empty *GameObject* within the scene of the game, where all the empty text boxes and UI was placed. The declarations within this script created the public variables where the text boxes in the scene could be assigned. The *GameController* also called the *DataController* as well as two other scripts, *RoundData* and *QuestionData*.

Upon starting, the *GameController* found the *DataController* script and the information stored in it. It then gathered the question data as well as the answer data. It gathered the *timeRemaining* variable and restarted the countdown for Which Word. Finally, the player score was reset to 0.

For Which Word to display a question it first ran a function that removed any old answer buttons that had been spawned into the scene. It then called the *QuestionData* for the first question to Which Word. Within this script, the *QuestionData* provided the answers for the specific question which are then parented as buttons to the constrained layout that was created in the scene. The code that executed this function is displayed in Script nine below for reference;

```
QuestionData questionData = questionpool[questionIndex];
        questionText.text = questionData.questionText; //reach into our pool of qu
estions and display using the question text ui element.
        questionImageDisplay.sprite = questionData.questionImage; //adds an image
to the question

        for (int i =0; i < questionData.answers.Length; i++)
        {
            GameObject answerButtonGameObject = answerButtonObjectPool.GetObject (
);
            answerButtonGameObject.transform.SetParent (answerButtonParent); //par
ent the button to the panel and create the nice layout in the UI
            answerButtonGameObjects.Add(answerButtonGameObject);

            AnswerButton answerButton = answerButtonGameObject.GetComponent<Answer
Button> (); //get a reference to the answerbutton script
            answerButton.Setup(questionData.answers[i]); //set the text of the but
ton to the relevant answer
    }
```

SCRIPT NINE QUESTION DATA FUNCTION FOR WHICH WORD

Script nine above illustrated that there was the potential to add an image to each question. This was an instance of ‘feature creep’ where the researcher was going to add images for each of the questions as a reference. However, the images caused numerous bugs and were not used when the studies were conducted.

The next functions that occurred in the *GameController* for Which Word are the *RemoveAnswerButtons* function that clears all old answers before the next question is asked and the *AnswerButtonClicked* function that checked the answer. The *AnswerButtonClicked* function runs an 'if' statement to check if the answer is correct and if so, adds to the total player score. It was also at this point where the text for "Score:" was printed in the scene. As the question has been answered, the *AnswerButtonClicked* script then loaded the next question in the list, in the event there was no next question it runs the function '*EndRound'*.

The *EndRound* script was a straightforward script that used a 'true or false' statement to detect whether the round has ended. If the round has ended, then the question display was returned to false (disappeared) and the *endscreen* display was presented to the player.

The interesting mechanic in developing Which Word comes from how the questions and answers are pooled into Which Word. A new scene was made which was referenced as 'persistent'. The reason for this was due to the nature of the script which would continuously run no matter how many times the player moved between different scenes (games or levels). For the script to be persistent, the following code was written in the *DataController (Script ten)*;

```
void Start () {
        DontDestroyOnLoad (gameObject);

        SceneManager.LoadScene ("landingpage");

    }
```

SCRIPT TEN PERSISTENT SCRIPT FOR WHICH WORD

The *DontDestroyOnLoad* prevented the *gameObject's* (the *gameObject* that contained all the questions and answers) from being destroyed when the player loaded another scene. The researcher was able to create the questions and answers in the inspector viewport in unity within the empty *gameObject* with *DataController* attached as a script. The *DataController* called the *RoundData*, which determined the number of round the game can have, this in turn called the *questionData* script which created a public variable where the questions can be wrote and the *questionData* called the *AnswerData* script which created public variables where the answers could be wrote. It also contained a public bool to toggle which answers were determined as correct. This created the menu which can be seen below in Figure twenty-six;

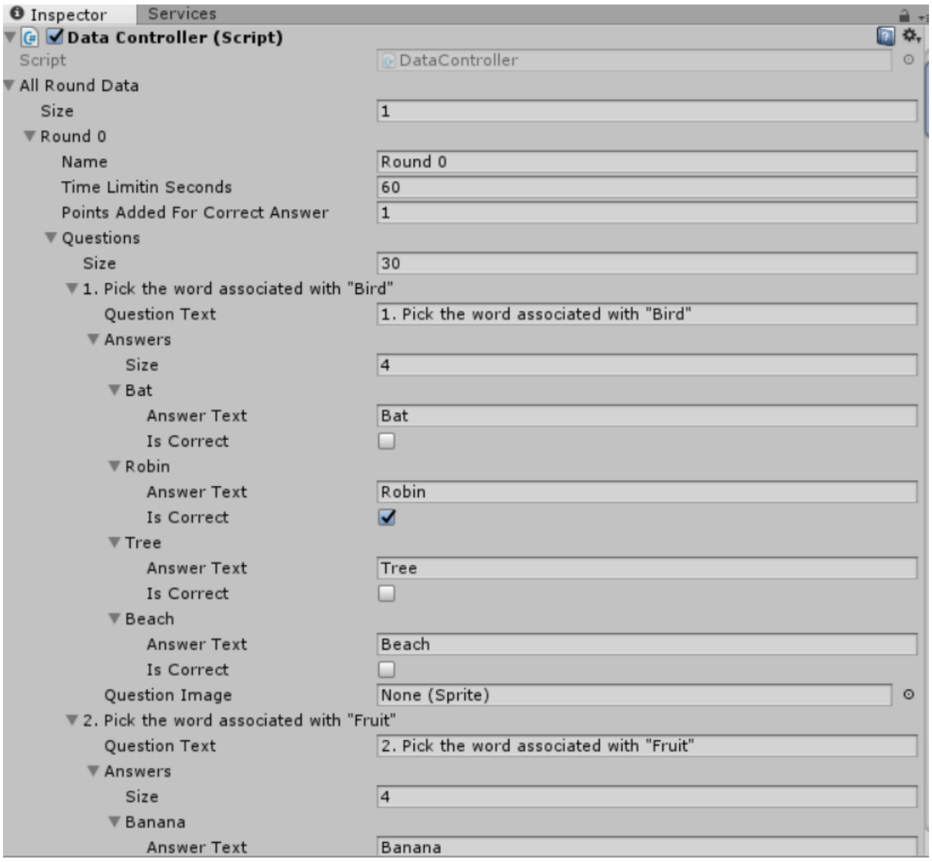


FIGURE TWENTY-SIX INSPECTOR VIEW OF THE DATA CONTROLLER

The utilisation of a persistent scene meant Brainplay had to be launched from the persistent scene for Which Word to display the questions wrote in the *DataController*.

6.7. BRAINPLAY NAVIGATION IMPLEMENTATION

As it has been mentioned before, Brainplay acted as the suite that held Odd Ones, Match Up and Which Word. However, to package the games together into one suite this research had to format each game, so it worked independently but could be quit and switched to another game with relative ease.

To do this, numerous scenes were added to help direct the player through Brainplay. As mentioned in the implementation of Which Word (section 6.6), Brainplay started from the persistent page to load the question and answer list for Which Word. However, as these lists were persistent, the player did not have to be immediately taken to Which Word. Instead, the researcher created a '*landingpage'* scene where the games could be selected from a menu. The menu was created in the user interface and canvas layers that have been previously discussed. Text boxes and buttons were used to direct the player to where they wanted to go. The menu also contained a 'quit' button, as Brainplay was designed for Tablet devices, there needed to be a path to exit the application.

The script for the main menu utilised a switch function as seen in the Match Up section, 6.4. Using scene management in scripts, the researcher created a menu system for the player to navigate through.

Each of the games of Brainplay contained their own menu screen which served as a tutorial for each game. This was necessary to explain the rules of each of the games. Not adding any form of tutorial could have led to confusion in the games and would most likely have affected the results of the user experience study.

6.8. PORTING TO ANDROID TABLET

Another step for Brainplay was to export from the Unity 5 editor to an android tablet device. To do this, the researcher installed the Android software development kit (sdk) command line tools. The Android sdk command line tools allowed the researcher to install individual sdk files for specific android versions. For the Samsung 10.1 Galaxy tab, the researcher had to install the sdk files for the Android 4.2 'Jelly-Bean' software.

Using the tutorials provided by Unity, the researcher had to also install the latest version of Java. Java and the Android sdk root folder was then imported into the Unity editor through the external tools menu.

When the android device was connected, in this case the Samsung 10.1 Galaxy tab, the device had to be enabled into developer mode where then it could be connected to the PC running unity and Brainplay could be ‘built’ onto the tablet device. This was how builds (versions of Brainplay) were generated for tablet device. Numerous test builds were generated until a working build was produced. This was due to number of exporting issues seen in the tablet build of Brainplay such as assets rendering at the wrong position or size.

6.9. QUALITY ASSURANCE

Prior and during the user experience study, see section 7, bug testing or quality assurance was conducted. Using the researchers experience in quality assurance it was important to test builds of Brainplay for functionality before being used in the study.

The quality assurance carried out was to test whether there were many major bugs (errors or faults in the running of Brainplay) occurring during gameplay, either in the Unity 5 player or on the tablet device. A major bug would constitute an incident where Brainplay was unplayable.

Appendix 6 outlines the test case used when Brainplay was tested. The build that was used for the user experience study had two known bugs. One where the cards in Match Up would not flip correctly. Another instance was where there was a delay in the player being unable to interact with Match Up for an estimated 7-10 seconds. The delay was exclusive to the Samsung tablet build and was most likely due to the hardware of the device struggling to load and display the assets.

7. CHAPTER SEVEN: GAME-PLAY EVALUATION

7.1. METHODS AND PROCEDURE

7.1.1. OVERVIEW

The game-play evaluation study was carried out to explore the answer to the first research question proposed in this research;

Are serious video games that are designed to assess or diagnose cognitive processes, still perceived as 'fun' video games?

The understanding and perception of a 'game' in this study, is that a 'game' is perceived as fun, immersive and engaging.

The game-play evaluation study used the user experience survey utilised in the hedonic-motivation system acceptance model (HMSAM) (Lowry et al. 2012). The user study was conducted with 20 people aged 18 to 31' to evaluate the user experience of Brainplay. This explored whether Brainplay was perceived as a 'game' or not.

7.1.2. HYPOTHESIS

What is the user experience of each of the three games of Brainplay (Which Word, Match Up and Odd Ones)?

This hypothesis is drawn because each of the games were designed using the same method, the MDA framework. However, an individual's personal preference to playing Brainplay may result in different results in the user experience test.

7.1.3. DESIGN

The design of the game-play evaluation is a quantitative survey method using the hedonic motivation system acceptance model (HMSAM) method of analysing user experience after a period of game play (Lowry et al. 2012; Madrigal & McClain, 2012). The quantitative survey method gathered ordinal data (Likert scale) on the experience of a product, in this case Brainplay.

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

FIGURE TWENTY-SEVEN LIKERT SCALE FOR USER EXPERIENCE SURVEY

The Likert scale provided a seven-point scale where median participants would indicate their view towards Brainplay. A score greater or equal than five would suggest an agreement and liking of Brainplay's experience, a score between three and five would suggest a participant is impartial on their opinion of Brainplay and a score less than or equal to three would suggest disagreement and a dislike of Brainplay.

The researcher would calculate the median with upper and lower quartiles of all twenty participants as detailed in section 7.2.2. The median of all participants would suggest the disposition participants felt about each of the games of Brainplay (Jamieson, 2004).

HEDONIC MOTIVATION SYSTEM ACCEPTANCE MODEL (HMSAM)

This study utilised the HMSAM as a basis for conducting the user experience test. Lowry et al. (2012) established a user experience survey that was measured on a seven-point Likert scale for analysis of the HMSAM model. The HMSAM is a variation of the technology acceptance model (TAM) (Davis, Bagozzi & Warshaw, 1989), commonly used in human computer interaction (HCI) studies and information systems (IS) studies. The HMSAM was created to better measure interactive experiences such as gambling and video games. The structure of the user experience survey was comprised of eight elements: joy, curiosity, immersion, control, temporal dissociation, perceived ease of use, behavioural intention to use and perceived usefulness. Each of these elements has a certain number of questions.

- Joy is comprised of six questions
- Control is comprised of six questions
- Focused Immersion is comprised of five questions
- Temporal dissociation is comprised of three questions
- Curiosity is comprised of three questions
- Perceived ease-of-use is comprised of eight questions
- Perceived usefulness is comprised of five questions
- Behavioural intention to use is comprised of three questions

Each of the questions in the user experience survey was measured by a seven-point Likert scale, from strongly disagree (value of 1) to strongly agree (value of 7) as seen in Figure twenty-seven. The questionnaire can be found in appendix eight.

Each of HMSAM elements is concerned with how a game is perceived by a participant.

- Joy gathered the participants enjoyment of the game, whether they found the experience enjoyable or not
- Control gathered the participant's opinion on the controls of the game. Whether they are constrained in their ability to play the game or not.
- Focused Immersion gathered information on whether the participants were distracted when playing or completely absorbed in the experience.
- Temporal dissociation measured the phenomenon of when time appears to go by quicker when participating in an engaging activity (or in Flow).
- Curiosity gathered the participant's opinion on whether the experience was inventive or something they have experienced before.
- Perceived ease of use inquired whether the participant found the experience accessible. Whether the interactions (or dynamics) were easy to use or not.
- Perceived usefulness gathers data on whether Brainplay provided a useful escape or destressing environment.

- Behavioural intention to use determined whether the participant would play Brainplay again or whether they would use it recurrently in the future.

The data provided by the HMSAM explored whether Brainplay was perceived as a game.

7.1.4. EQUIPMENT & APPARATUS

- Tablet (Samsung Galaxy Tab 10.1)
- Brainplay installed on tablet device
- Digital copy of demographic questionnaire
- Physical copy of demographic questionnaire
- Paper HMSAM test
- Digital HMSAM test
- Pen

7.1.5. ETHICS

To protect the participant's personal identity, a reference number was given to participants.

The study was approved by the University of Strathclyde Computer Science department ethics committee (approval number/application ID: 609).

7.1.6. LOCATION

The study took place from the 24th July 2017 until the 29th July 2017. The venue of the study was at the University of Strathclyde. The researcher and participants met at room 12.13 of the Livingstone tower at the University of Strathclyde or at a prior agreed location within Glasgow such as Strathclyde student union and common rooms within the Livingstone Tower.

7.1.7. PARTICIPANTS

Participants were recruited through fliers and posters (see appendix nine) within the city of Glasgow, specifically located on the University of Strathclyde, Braehead shopping centre and Glasgow Caledonian University. Emails were sent to groups such as Creative Scotland, Alzheimer's Scotland and Glasgow City Council for a call for participants.

The game-play evaluation study was open to anyone over the age of eighteen - male, female or other. Participants were required to fill out a demographic questionnaire (see appendix ten) to observe the participant sample.

People who were interested in participating in the study were given a date and time that was convenient to both the researcher and the participant once consent forms (see appendix eleven) had been returned.

The study endeavoured to conduct an opportunity sample approach, attempting to gather a mix of gender, age, and educational background.

The aim of the study was to gather twenty participants that will complete the study. Twenty participants gave a sample suggestion of whether the games of Brainplay were perceived as a 'game' to suggest that Flow and 'play' was elicited.

The demographic results can are discussed in 7.2.1 and the complete survey results are in appendix twelve.

7.1.8. LIMITATIONS OF THE STUDY

The user experience data was recorded through a questionnaire which may have restricted how participants expressed how they felt about the game as detailed as they may have through an interview. However, gathering quantitative data was a faster method to explore whether the games were viewed as enjoyable. Recording data through a Likert scale with the HMSAM gave a clear quantifiable reference for data analysis.

Another limitation was that the data was a sample study and not representative of the population. The data should be able to provide validity whether Brainplay was perceived as a 'game' or not.

7.1.9. DATA COLLECTION

User experience data was collected through a questionnaire hosted on Qualtrics (2017). The data was saved both locally on the tablet device and within the researchers University account of Qualtrics. Local data was erased when the researcher committed data to safe secure online storage of the researchers Strathclyde ShareFile service.

7.1.10. DATA ANALYSIS

The data from the user experience questionnaire provided a discussion for whether Brainplay maintained the perception of a game. Each element of the questionnaire was evaluated individually to discuss the response to Brainplay.

When calculating the significance of the data, the scores from the questionnaire user experience (which are the dependent variable) were compared between each of the games (the independent variables). Each of the elements of the HMSAM questionnaire were examined individually. Descriptive statistics, Friedman tests (Laerd Statistics, 2017a), Shapiro-Wilk and Wilcoxon signed-rank test (Laerd Statistics, 2017b) were used in data analysis and detailed in sections 7.2.1 and 7.2.2 of this chapter.

7.1.11. PROCEDURE

1) Explanation of the study and introduction to Brainplay
2) Participant completed demographic questionnaire (5 minutes) (See Appendix ten)
3) Participant played each of Brainplay's games three times (10-15 minutes)
4) Participant completed the user experience questionnaire for their experience of Brainplay (estimated 5-10 minutes) (See Appendix eight)
5) Researcher thanked participant and presented the participant with £10 love-to-shop voucher for their time. (2 minutes)

Appendix thirteen represents how the study was conducted.

7.2. RESULTS AND DISCUSSION

The following section presents the results and discussion regarding the game-play evaluation study conducted to observe whether Brainplay was still perceived as a video game, as defined in section 2.3.3 of the background chapter.

7.2.1. STUDY POPULATION DEMOGRAPHICS

A sample of twenty participants was recruited to explore the user experience of Brainplay.

Prior to the user experience survey and playing Brainplay, participants completed a demographic survey to better understand the sample that would be completing the study. The results of the demographic survey can be found in appendix twelve. Demographic survey revealed that the population of twenty participants, fourteen (70%) were male and six (30%) were female.

The age range of participants was eighteen to thirty-one with the most frequent occurring age of twenty-two. The mean of the age for this study was twenty-three.

The population had completed a minimum of secondary school education with the most frequent (36.4%) form of education as undergraduate level. No participant disclosed no education or only a primary level of education.

POPULATIONS RELATIONSHIP WITH TECHNOLOGY

The second section of the demographic survey was to establish the knowledge and frequency that participants use modern technology. The survey also wanted to know if participants used a tablet and what they used them for.

The first question in this section asked participants on their familiarity with technology (such as mobiles, tablet technology and computers). The question gave five statements that the participant could select from to best describe their familiarity with technology. Of the twenty participants, nine (45%) stated they were highly proficient in the use of mobiles, tablets and computers. The other eleven (55%) participants stated they were frequent user of mobile, tablets and computer technology.

The next question asked which devices and technologies the participants owned. Table five indicated that every participant owned a smartphone. Table five also indicated that thirteen (65%) of the participants owned or had access to a tablet device.

TABLE FIVE TECHNOLOGY OWNED BY PARTICIPANTS

	What technology do you own, or have access to, in your home? (Select multiple answers if applicable)								
	Selected Choice Desktop Computer	Selected Choice Games Console (Xbox, Playstation, Nintendo)	Selected Choice Handheld Console (Nintendo DS, Playstation Portable)	Selected Choice Laptop	Selected Choice Smartphone (Mobile)	Selected Choice SmartTV	Selected Choice Sound System	Selected Choice Tablet device (e.g. iPad)	Selected Choice Other
Frequency	12	15	9	16	20	7	7	13	2

The participants were then asked if they had used a tablet before to which nineteen (95%) of participants stated, ‘definitely yes’ and one (5%) stated ‘probably yes’. They were then asked to select multiple-choice answers on what they have used a tablet device for.

The most frequent response to this question was using a tablet device to send or receive email. A total of fourteen (70%) participants answered that they used a tablet device to send or receive email. Only nine (45%) participants stated they played games on a tablet device.

FAMILIARITY WITH VIDEO GAMES

The last section of the demographic section proposed questions regarding the participant's familiarity with video games. Participants were asked if they have ever played video games on any platform. Eighteen (90%) of participants answered, 'Definitely Yes' with one (5%) other participant stating they had 'definitely not' and one (5%) other stated they 'Might or might not' have played video games before.

When asked how many hours each participant spent playing video games a week, the most frequent response was '10 hours or more' by seven (35%) participants. A total of four (20%) participants stated that do not play video games. The mean average of the population played between four to six hours a week. This indicated that most of the sample should have been familiar with the controls and interactions of Brainplay.

TABLE SIX TIME PLAYING VIDEO GAMES

In the past 7 days, roughly how many hours have you spent playing video games (e.g. gaming consoles, mobile phones, computers, etc.)?

	Frequency	Percent	Valid Percent	Cumulative Percent
None	4	20.0	20.0	20.0
1 to 3 hours	3	15.0	15.0	35.0
4 to 6 hours	5	25.0	25.0	60.0
7 to 9 hours	1	5.0	5.0	65.0
10 hours or more	7	35.0	35.0	100.0
Total	20	100.0	100.0	

7.2.2. USER EXPERIENCE DATA RESULTS

The study needed to first determine whether the data is normally distributed or not. The study conducted a Shapiro-Wilk test in SPSS to understand whether the data was normally distributed or not. This test was chosen over the Kolmgorov_Smirnov test as the Shapiro-Wilk test is more appropriate to small samples (Laerd Statistics, 2017a).

If the Sig. value of the Shapiro-Wilk test is greater than 0.05 then the data gathered from the user experience test is normal. However, if the Sig. value is lower than 0.05 then the data deviates from normal distribution.

As seen by Table seven and Appendix fourteen, each of the elements of the HMSAM user experience questionnaire showed that the distribution of the values was non-normal. Data was not normally distributed. Normally distributed data is seen as a bell-shaped curve, see Figure twenty-eight. The symmetrical distribution of scores has most values falling in the centre of the curve (near the mean) (Miller, 1996). Normally distributed data can be used to help predict future studies in similar fields and draw assumptions on values such as median and mean. Data that is not normally distributed suggests the opposite.

FIGURE TWENTY-EIGHT BELL SHAPED CURVE (MILLER, 1996)

TABLE SEVEN NORMAL DISTRIBUTION OF DATA

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Game	Statistic	df	Sig.	Statistic	df	Sig.
Joy	Odd Ones	.196	20	.043	.872	20	.013
	Match Up	.153	20	.200*	.868	20	.011
	Which Word	.215	20	.016	.791	20	.001
Control	Odd Ones	.203	20	.030	.756	20	.000
	Match Up	.244	20	.003	.849	20	.005
	Which Word	.189	20	.059	.869	20	.011
Immersion	Odd Ones	.209	20	.022	.876	20	.015
	Match Up	.123	20	.200*	.939	20	.232
	Which Word	.138	20	.200*	.944	20	.281
Temporal_Dissociation	Odd Ones	.149	20	.200*	.913	20	.071
	Match Up	.151	20	.200*	.903	20	.048
	Which Word	.185	20	.072	.879	20	.017
Curiosity	Odd Ones	.200	20	.035	.931	20	.160
	Match Up	.149	20	.200*	.927	20	.138
	Which Word	.168	20	.141	.946	20	.306
Perceived_Ease_of_Use	Odd Ones	.205	20	.028	.914	20	.076
	Match Up	.190	20	.055	.894	20	.032
	Which Word	.258	20	.001	.866	20	.010
Perceived_Usefulness	Odd Ones	.158	20	.200*	.959	20	.524
	Match Up	.158	20	.200*	.951	20	.389
	Which Word	.143	20	.200*	.975	20	.856
Behavioural_Intention_to_Use	Odd Ones	.284	20	.000	.875	20	.014
	Match Up	.261	20	.001	.855	20	.006
	Which Word	.187	20	.066	.947	20	.318

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

To determine the significant difference, this research needed to choose a statistical method to determine the significance of the data gathered. The researcher used the Friedman test to determine the difference between the dependent variables (the games). To correctly use the Friedman test, four assumptions needed to be made (Laerd Statistics, 2017a):

1. *One group (participants) that is measures on three or more occasions (the games)*
2. *That the group is a random sample of the population*

3. *Dependent variables should be measured at the ordinal level (Likert scale of the user experience questionnaire)*
4. *Not required to be normally distributed.*

As the data met the requirements of these assumptions, Friedman tests were completed on each of the elements of the HMSAM questionnaire. The Friedman tests (Appendix fifteen) showed that there was a significant difference in the scores of the HMSAM between the games, but it was not yet known where exactly those differences were. To explore where the differences were, the study conducted post-hoc tests using the Wilcoxon signed-rank tests.

The Wilcoxon signed-rank test was carried out with each of the elements of HMSAM between the three games. To examine the where the differences in significance occur; the study ran separate pairs on the different pairs of the games.

- Match Up -> Odd Ones
- Which Word -> Match Up
- Which Word -> Odd Ones

Because there are multiple comparisons in the data, a Bonferroni adjustment was required to understand if the data was still significant. The adjustment took the initial significance level of 0.05 and divided it by the number of comparisons.

Number of comparisons = (n*n-1)/2 = (3*2)/2 = 3

Correct *p* = 0.05/3 = 0.017

Table eight below showcased the median value and result of the Wilcoxon signed-rank test for each of the HMSAM elements investigated.

TABLE EIGHT WILCOXON TEST ACROSS HMSAM ELEMENTS AND PAIRS

Test Statistics

	Pair	Median	Z	Asymp. Sig. (2-Tailed)
Joy	MatchUp & OddOnes	6.17 & 6.67	-1.706[b]	.088
	WhichWord & MatchUp	6.25 & 5.17	.000[c]	1.000
	WhichWord & OddOnes	6.25 & 6.67	-3.219[b]	.001
Control	MatchUp & OddOnes	5.84 & 6.25	-1.288[b]	.198
	WhichWord & MatchUp	6.42 & 5.84	-1.355[d]	.176
	WhichWord & OddOnes	6.42 & 6.25	-.455[d]	.649
Immersion	MatchUp & OddOnes	5.9 & 6.3	-2.103[b]	.035
	WhichWord & MatchUp	6 & 5.9	-.794[d]	.427
	WhichWord & OddOnes	6 & 6.3	-1.630[b]	.103
Temporal Dissociation	MatchUp & OddOnes	5.67 & 6	-2.023[b]	0.43
	WhichWord & MatchUp	6 & 5.67	.000[c]	1.000
	WhichWord & OddOnes	6 & 6	-1.892[b]	0.58
Curiosity	MatchUp & OddOnes	5.2 & 6	-2.383[b]	.017
	WhichWord & MatchUp	5.84 & 5.2	-1.122[d]	.262
	WhichWord & OddOnes	5.84 & 6	-1.409[b]	.159
Perceived Ease of Use	MatchUp & OddOnes	6 & 6.38	-2.666[b]	.008
	WhichWord & MatchUp	6.44 & 6	-2.240[d]	.025
	WhichWord & OddOnes	6.44 & 6.38	-2.120[b]	.034
Perceived Usefulness	MatchUp & OddOnes	5.5 & 5.8	-2.252[b]	.024
	WhichWord & MatchUp	5.7 & 5.5	-1.642[d]	.101
	WhichWord & OddOnes	5.7 & 5.8	-2.066[b]	.039
Behavioural Intention to Use	MatchUp & OddOnes	6 & 6	-1.857[b]	.063
	WhichWord & MatchUp	5.84 & 6	-.261[d]	.794
	WhichWord & OddOnes	5.84 & 6	-1.367[b]	.172

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

c. The sum of negative ranks equals the sum of positive ranks.

d. Based on negative ranks.

The Asymp. Sig. (or *p* value) represents where there was a significant statistical difference in the data. In this case, the significance level was $p = 0.017$, so any *p* value that was larger than 0.017 was not a statistically significant result.

The process of determining statistical differences was applied to all elements of the HMSAM to observe if there were any statistical significant differences in the data. Appendices fifteen & sixteen showcase the results of the Friedman tests with post-hoc analysis using the Wilcoxon signed-rank test with Bonferroni correction.

From that data analysis, the following statements can be made for each of the elements of the HMSAM.

JOY

The median values on the score for the games of Brainplay in Joy were;

TABLE NINE MEDIAN VALUES FOR JOY

Game	Median Values
Odd Ones	6.67 (6.17 to 7)
Match Up	6.17 (5.5 to 6.83)
Which Word	6.25 (5.83 to 6.63)

There are no significant differences in perceived joy between Match Up and Odd Ones ($Z = -1.706$, $p = 0.88$) as well as Which Word and Match Up ($Z = 0$, $p = 1$). However, there was a significant difference seen between Which Word and Odd Ones ($Z = -3.219$, $p = 0.001$).

The results of the post hoc analysis showed that in terms of perceived enjoyment from the HMSAM, Odd Ones was enjoyed more when compared to Which Word. Even though all the games were scored positively, there was a significant difference that suggests Odd Ones was enjoyed significantly more compared to Which Word.

CONTROL

The element of control in the HMSAM was to gather the opinion of how Brainplay was accessible or not. The population was asked how the controls of the game felt, and whether they felt that they had the correct amount of input to play the games of Brainplay.

Data analysis revealed that all the games scored positive with median values of;

TABLE TEN MEDIAN VALUES FOR CONTROL

Game	Median Values

Odd Ones	6.25 (5.37 to 7)
Match Up	5.84 (5.33 to 6.79)
Which Word	6.42 (5.54 to 7)

Friedman tests revealed that there was no statistically significant difference between the three games with regard to control, $X^2(2) = 1.042$, $p = 0.594$.

IMMERSION

The questions for immersion were concerned with how absorbed an individual was in the experience of playing Brainplay. When analysing the scores from the HMSAM user experience questionnaire, Odd Ones, Match Up and Which Word were scoring positively with the median value displayed below in Table eleven;

TABLE ELEVEN MEDIAN VALUES FOR IMMERSION

	Median Values
Odd Ones	6.3 (5.45 to 6.95)
Match Up	5.9 (5 to 6.55)
Which Word	6 (5.25 to 6.75)

The Friedman test revealed that there was no statistically significant difference between the three games with regard to immersion, $X^2(2) = 1.947$, $p = 0.378$.

TEMPORAL DISSOCIATION

The questions within category of temporal dissociation were focused on the phenomenon when time appears to go by faster when the player is engaged in a game. With Brainplay designed as a short arcade suite of games, the research expected mixed responses on the HMSAM questionnaire.

The scores reflected for Odd Ones, Match Up and Which Word were again scoring positively with a median value of;

TABLE TWELVE MEDIAN VALUE FOR TEMPORAL DISSOCIATION

Game	Median Values
Odd Ones	6 (5.33 to 6.92)
Match Up	5.67 (5 to 6.5)
Which Word	6 (5.1 to 6.2)

This suggested that the population did experience some form of temporal dissociation when playing Brainplay. A Friedman test on the scores of temporal dissociations revealed there was no evidence of a statistically significant difference between the three games, $X^2(2) = 4.846$, $p = 0.089$.

CURIOSITY

The element of curiosity within the HMSAM focused on how different the experience was for the population. Whether the experience piqued their interest or not, or whether the experience was nothing different they had seen before. The design of Brainplay was influenced by what other researchers had created when assessing cognitive processes in games. The researcher hypothesised that there would be a very neutral response to the scoring of curiosity where the population would feel indifferent towards Brainplay.

The median scores, including upper and lower quartiles, were;

TABLE THIRTEEN MEDIAN VALUE FOR CURIOSITY

Game	Median Values
Odd Ones	6 (5.1 to 6.2)
Match Up	5.2 (4.67 to 6)
Which Word	5.84 (4.75 to 6)

Although the results suggest a positive response, in that the population found Brainplay curious and it piqued their interest, the lower quartile values suggest that some of the population were indifferent as hypothesised by this research. When the results were evaluated through a Friedman Test, a statistically significant difference can be seen from the results, $X^2(2) = 6.353$, $p = 0.042$. As the p value was less than the significance value (0.05), the researcher carried out a Wilcoxon signed-rank test to explore where the difference occurs.

The results of the Wilcoxon signed-rank test showed that there were no statistically significant differences between Which Word and Match Up ($Z = -1.122$, $p = 0.262$) and no difference between Which Word and Odd Ones ($Z = -1.409$, $p = 0.159$). However, a borderline difference can be seen between Match Up and Odd Ones ($Z = -2.383$, $p = 0.017$).

PERCEIVED EASE OF USE

Perceived ease of use was concerned with the accessibility with each of the games of Brainplay. Accessibility refers to the design of games, whether they were usable by participants of different abilities and knowledge of technology, without the need of modification (Lidwell, Holden & Butler, 2003).

The median scores, including upper and lower quartiles, were;

TABLE FOURTEEN MEDIAN VALUE FOR PERCEIVED EASE OF USE

Game	Median Values
Odd Ones	6.38 (5.91 to 6.75)
Match Up	6 (5.32 to 6.38)
Which Word	6.44 (5.88 to 6.6)

The descriptive statistics (see appendix seventeen) suggested that the dynamics of Brainplay were accessible to the population.

When analysing the results through the Friedman test, there is evidence of a significant statistical difference between the three games of Brainplay, $X^2(2) = 12.412$, $p = 0.002$. Conducting a Wilcoxon signed-rank test as a follow up, revealed that there was no statistically significant difference between Which Word and Match Up ($Z = -2.240$, $p = 0.025$) as well as Which Word and Odd Ones ($Z = -2.120$, $p = 0.034$). However, a significant statistical difference could be seen when comparing Match Up to Odd Ones ($Z = -2.666$, $p =$

0.008). This suggests that Odd Ones was favourably a more accessible game compared to Match Up.

PERCEIVED USEFULNESS

The questions for perceived usefulness explored the suggestion of Brainplay providing a useful ‘escape’ and providing a distraction.

The median scores, including upper and lower quartiles, were;

TABLE FIFTEEN MEDIAN VALUE FOR PERCEIVED USEFULNESS

Game	Median Values
Odd Ones	5.8 (5.25 to 6)
Match Up	5.5 (4.65 to 5.95)
Which Word	5.7 (4.9 to 6)

Odd Ones, Match Up and Which Word each displayed indifferent to mostly positive perceptions of perceived usefulness. The Friedman test carried out showed that there was a significant statistical difference in the result, $X^2(2) = 6.2$, $p = 0.045$.

Conducting a Wilcoxon signed-rank test as a follow up, revealed that there was no statistically significant difference between any of the games. Which Word and Match Up ($Z = -1.642$, $p = 0.101$), Match Up and Odd Ones ($Z = -2.252$, $p = 0.024$) and Which Word and Odd Ones ($Z = -2.066$, $p = 0.039$) displayed no p value less than 0.017 to show any statistical significant difference.

BEHAVIOURAL INTENTION TO USE

The behavioural intention to use questioned whether the population would value any replay-ability or future use of Brainplay. Whether a participant who owned Brainplay would come back and play Odd Ones, Match Up and Which Word.

The median scores, including upper and lower quartiles, were;

TABLE SIXTEEN MEDIAN VALUE FOR BEHAVIOURAL INTENTION TO USE

Game	Median Values
Odd Ones	6 (5.75 to 6.5)
Match Up	6 (4.4 to 6.5)
Which Word	5.84 (5 to 6.25)

The results suggested mostly positive results which suggested the populations would continue to use Brainplay if they owned it.

A Friedman test conducted on the scores of the three games of Brainplay showed that there were no statistically significant differences between the games for their future intention of use, $X^2(2) = 4.189$, $p = 0.123$.

7.3. DISCUSSION OF THE GAME-PLAY STUDY

Referring to the hypothesis for this user study in section 7.1.2, the research hypothesised the question of “What is the user experience of each of the three games of Brainplay (Which Word, Match Up and Odd Ones)?” The games of Brainplay would be perceived as a game in that they elicit ‘play’ or fun in the player. In this part of the hypothesis, it can be suggested each game was scored relatively positively in the user experience survey. In addition, the participants viewed the games of Brainplay as ‘games’ and not as an assessment.

Although the majority of user experience scores were positive, the games of Brainplay were not all experienced the same. When compared, a statistical significant difference was seen between Odd Ones and Which Word which suggests that there was a difference in experience.

However, the statistical analysis of the user experience scores showed that Odd Ones scored higher over three of the elements of the HMSAM. The participants found Odd Ones more enjoyable in comparison to Which Word and Match Up. This could be to do with the mechanics or genre of the games. Tile based games, like Match Up are a lot more frequent in existing games seen in the previous work chapter and Which Word is a text-based arcade game. Odd Ones may have been more enjoyable to the population as there were not a lot of existing games similar to Odd Ones, so it offered a new challenge to the population. Compared to Which Word, Odd Ones visuals are based on images opposed to text. Where Which Word used the mechanics of a trivia game, involving reading and processing the language challenge, Odd Ones utilised the mechanic of rapid changing images to test problem solving within the process of thinking & reasoning.

The participants also found Odd Ones to be more interesting and curious in comparison to Which Word and Match Up. As stated above, Odd Ones mechanics and dynamics are not seen in existing games, which could be why the population found the experience of Odd Ones more interesting in comparison to Which Word, a trivia game, and Match Up, a matching tile game.

The other significant difference was seen in perceived ease of use. This measured the accessibility of Brainplay, specifically how difficult or easy the interaction (or dynamics) with Brainplay were. Although all the games scored positively which suggested that the games were easy for the population to interact with, possibly due to the design decision of single input, there was a significant statistical difference seen in Odd Ones. Again, Odd Ones showed that the population found the interaction better when compared to the other two games. Although all the games utilised a single input for interaction, the input is possibly more simplistic when compared to Match Up and Which Word. In Match Up the player was required to select two different cards in attempt to match them, however players can flip incorrect tiles and cannot flip new tiles until the previous selected tiles have returned face down, this design may have caused ease of use issues in Match Up. Which Word requires a single input for selecting an answer, but perhaps the lack of complex interaction or challenge was why Odd Ones was favourable when compared to Which Word. Odd Ones does use the same single input as which word, but the location of new odd one out problems was randomised, which meant the player needed to determine the location of the odd one out and quickly respond with input.

Overall, the game play evaluation study has shown that Brainplay was perceived as a game. The scores reflected in the mean, median and quartile values show that the response to each element of the HMSAM across all three games is predominantly positive. This showed that Brainplay was still enjoyed as a game; it was easy to use and accessible. Brainplay also displayed a sense of temporal dissociation and immersion when played by the sample.

The importance of this study suggested that Brainplay was still perceived as a game compared to a potential exercise or test. The results of the game-play evaluation have suggested that the games of Brainplay elicited play from the sample and the participants did not view Brainplay as a test or assessment. It can be suggested that the design of Brainplay can create a play experience which could be used in further study to potentially measure a specific cognitive domain.

With Brainplay displaying the perception of a game, the assessment or potential measuring of a player using Brainplay could potentially provide an ‘honest’ assessment of the player. Where assessments can elicit response bias as an individual can feel that they are being assessed, a play-based approach could package assessment through play and provide an ‘honest’ answer.

Where the literature on serious games discussed the definition and difference between a game and a serious game, the results of this study suggests that games used in research can still be viewed as entertaining. Michael and Chen (2005) stated that the primary purpose of serious game is not to entertain but the games of Brainplay present an enjoyable experience. A concern during the investigation was that the games would be an assessment as the nature of recruiting participants to play a game could be viewed as instructional. However, the results of the HMSAM indicated that Brainplay elicited joy, immersion and curiosity that suggest play was elicited. The significance of Brainplay viewed as an entertaining game partially supports the suggested definition of a serious game where “the voluntary attempt to overcome a set of rules, systems and challenges that are presented to the player that result in negotiable quantifiable outcomes which can impart knowledge or skill.” Brainplay retained the voluntary experience of play as suggested by Suits (1978). Brainplay was designed through the MDA game design framework that presented connotations of rules, systems and challenges proposed by Salen & Zimmerman (2003) but further analysis would be required from external game developers to whether a game design framework was, or is, necessary for serious game development. The imparting of knowledge or skill defined by Zyda (2005) could be investigated through repeated play of Brainplay. Instead, Brainplay was presented to healthcare professionals to whether there was any potential serious purpose Brainplay could be used for. The contribution of defining a serious game adds to the ongoing discussion towards a universal definition of a serious game and a game. The study conducted has suggested that games in research can be viewed as a game with the potential to be used for a serious purpose.

The next studies in chapter eight explored whether Brainplay could be replicated by professional game developers using the design process and whether the MDA was necessary to the development of a serious game. Chapter nine details a study where Brainplay was introduced to healthcare professionals and discusses the potential serious purpose for Brainplay.

8. CHAPTER EIGHT – MDA EVALUATION

8.1. METHODS AND PROCEDURE

8.1.1. OVERVIEW

The study presented in this chapter aimed to evaluate the whether a game design framework was necessary to the development of serious games for healthcare by commercial game developers.

The study explored whether professional game developers had utilised game design frameworks before and whether they could understand the process of using the MDA framework to develop games with a potential to assess cognitive processes.

To evaluate the use of the MDA framework for designing the games (as well as the design decisions), the researcher approached three professional game developers with Brainplay. After a video of Brainplay (See appendix seven) was shown to the game developers, interviews were conducted to gather their opinions on Brainplay's design and the use of the MDA framework.

The interviews were recorded and then transcribed into digital format, so the researcher could conduct a thematic analysis (Cote and Raz, 2015 citing Braun and Clarke, 2006) on the transcripts. This study explored whether professional game developers could understand the design decisions made, as well the use of the MDA but also expected to explore any insights the professional designers/developers would have regarding the development of serious games for health within assessment, diagnosis or treatment of cognitive impairment.

8.1.2. HYPOTHESIS

The hypothesis is that the population interviewed should have been able to understand the relevance and advantage of using the MDA in developing video games that could potentially be used for cognitive assessment, diagnosis or treatment. In addition, the commercial game developers would also understand the design decisions and would be able to replicate or create new games using the framework and design decisions described in the prototype development chapter (5.1).

8.1.3. DESIGN

The method for this study followed the in-depth interviews as described in *Game Research Methods* (Cote & Raz, 2015). Three interviews were conducted one-to-one, so the researcher could help steer the conversation towards the use of the MDA and design choices made. The three interviewees were comprised of two professional game designers and one professional game developer. Interviews were recorded so that the researcher could analyse transcripts of the interviews. A thematic analysis was then conducted to highlight the themes in the participant's responses.

EQUIPMENT & APPARATUS

- Video of Brainplay's gameplay (https://youtu.be/LWNESlYqjWE)
- Interview Guide and Questions (see Interview Guide and Interview questions below)
- Recording device (or software for online interview)
- Access to video calling software (Skype) and computer/laptop

ETHICS

As the interviews were conducted one-to-one. To protect the participant's personal identity, a reference number or pseudonym was given. The study was approved by the University of Strathclyde Computer Science department ethics committee (approval number/application ID: 616).

LOCATION

The study took place from the 11th August 2017 until the 12th September 2017. The studies were conducted remotely, using video calling software and sharing the gameplay video through an email.

8.1.4. PARTICIPANTS

Participants were recruited through emails (invitations seen in appendix eighteen) within the Scottish game development network as well as through contacts known by the researcher's games industry connections.

People who were interested in participating in the study were given a date and time that was convenient to both the researcher and the participant once consent forms (see appendix nineteen) had been returned.

The target sample size was to gather three professional game developers as participants for the qualitative study. These professional game developers could have been from independent development or commercial development and would provide their background details to the researcher. Demographic questions, were conducted in early contact to establish whether the participant qualified as a game development professional (a minimum of 2 years in game development and a record of game development experience such as academic qualifications).

8.1.5. LIMITATIONS OF THE STUDY

Interpretation of the interviews is subjective to the researcher. Interviewers can unintentionally show bias when conducting an interview (Cote & Raz, 2015).

The data is a sample of the population and not representative of the population however it should offer a sample from the opinion of games developers. The small number of participants presents the limitation that the data gathered may not present a broad opinion towards the MDA evaluation. Due to the short scope of data gathering time, it was unlikely that the study was to reach saturation of participants. Future study would benefit from capturing a larger group of game design representatives to present a broader knowledge base.

The impact of the study conducted remotely carried the possibility of communication errors when the interviews were conducted. The video of the Brainplay could have also detracted from the interactive experience that could be experienced if the participant could play the game. The video only offered insight into the shown footage of the video game; this may have affected the discussion surrounding Brainplay’s design. Video footage was used so that the research could gather the qualitative data quickly; having participants play the game would have required meeting professionals in person which would not have been feasible for some participants. Brainplay could have been distributed as a downloadable application, however it was not known how Brainplay would have run on personal devices, and this could have created a different response to Brainplay.

8.1.6. DATA COLLECTION

Data was collected in the form of an audio recorded interview. The recorded interview was then transcribed through an intelligent verbatim method. Intelligent verbatim transcription involved the transcription of the interviews to omit words or actions that did not contribute to the value of the qualitative data.

8.1.7. DATA ANALYSIS

To analyse the transcribed data, a thematic analysis was conducted with the transcripts. *Game Research Methods* describes the process of thematic analysis as:

"Thematic analysis is a method for identifying, analysing, and reporting patterns (themes) within data, which minimally organizes and describes the data set in rich detail" (Cote and Raz, 2012 citing Braun and Clarke, 2006)

The researcher followed this method when analysing the interviews, highlighting key themes and any recurring themes in each of the transcripts from participants.

8.1.8. PROCEDURE

1. Explanation of the interview (2 minutes)
2. Participant described their role in game development (2 minutes)
3. Introduction of Brainplay and feedback (3 minutes)
4. Five questions on the development of Brainplay using the MDA (10-20 minutes)

Total Procedure length: 15-20 minutes.

Common Interview Guide Components	**Purpose**	**Description/Questions**
Introductory Script	To open the interview and cover necessary information with the participant. To remind the researcher of the study goals.	Summarise the study and the objective
		Discuss the following procedure. Clarify consent
Warm-up Questions	Put the participant at ease and build rapport	"What is it you do within game development?"
		"What games have you made?"
		"What are your favourite games?"
Substantive questions	Collect deeper data that answers the questions posed by the study	Open ended questions
		Encourage discussion and follow up questions
		See Appendix twenty for questions
Demographic questions	Gather data to describe the participants in the final thesis	Tie in with warm-up questions
		Evidence on "game professional" participant

8.2. RESULTS AND DISCUSSION

The following section of this chapter presents the findings of the qualitative interviews carried out with professional game developers.

The purpose of this study was to answer the second research question which was;

Are game design frameworks necessary to the development of serious games for healthcare by commercial game developers?

It also explored the commercials game developers view on the development process and whether they would be able to develop games with the potential to assess cognitive processes/

8.2.1. STUDY POPULATION DEMOGRAPHICS

TABLE SEVENTEEN DEMOGRAPHICS FOR MDA EVALUATION STUDY

Participant (X)	Age (Range)	Gender	Profession	Years in professional video game development
A	21-25	Male	Game Designer	3
B	26-30	Male	Game Designer	5
C	21-25	Male	Game Developer	3

A total of three participants were gathered for the sample group for this study. Of this demographic, each participant displayed a background of between three and five years of experience in game development. All the participants had been in commercial game development as well as experienced independent game development.

Two of the sample regarded themselves as video game designers where the other participant described themselves as a game developer, which suggested a programming, or technical background.

One of the first questions asked was if they understood or knew of the MDA framework. Both the game design participants had heard of the MDA framework and understood its features as a game design framework. The game developer had not heard of the MDA.

8.3. DATA RESULTS

A thematic analysis was conducted on the responses in the interview transcripts. This involved the researcher highlighting recurring themes or statements (positive and negative). Illustrative quotes of interest that add to the discussion will be presented per theme. To identify themes in the qualitative data, coding was conducted to identify key areas of interest emerging from the data.

8.3.1. CODING

The first step to analyse the data was to code the data. Coding the data helped categorise, summarise the qualitative data (Lapan, Quartaroli & Riemer, 2012). The process of coding involved the researcher interpreting and analysing the data for what it is trying to be communicated. How the researcher interpreted the data is a limitation to the study as other researchers may have interpreted the data differently.

The researcher carried out coding on each of the participants to observe the raw data and highlight areas of interest in participant's responses to the questions (Coding data can be found in appendices twenty-one, twenty-two and twenty-three).

8.4. THEMATIC ANALYSIS

To better understand and analyse the data, the researcher grouped answers under a list of themes. These themes highlighted what the participants were communicating as well as what the study wanted to find. The researcher suggested the six themes as the best method for grouping and discussing the results of the interview data.

Table eighteen below describes the themes and grouping of codes.

TABLE EIGHTEEN THEMATIC ANALYSIS OF GAME DEVELOPER PARTICIPANTS

Theme	**Description**	**Example of Codes grouped within theme**
Knowledge of MDA Framework	This theme encompassed codes where the participant had demonstrated knowledge of the MDA framework	Used the MDA previously
		Confirmation that they have heard of the MDA
		Knowledge of MDA
		MDA helpful to focus development
Familiarity with Game Design Frameworks, models & methods	Whether the participants had, or had not, heard of or used other game design frameworks or models.	Used framework in independent development
		Freeform approach to design
		Use of another methodology (fail faster)
		Test new ideas quickly
		Gain feedback quick
		Lack of clarity of game design frameworks
Utility of Frameworks	Where a participant had used game design frameworks in their experience	Iterative development
		Other suggested framework used for narrative
		Iterative processes normally, focused on functionality.
		Streamline design process
		Brainstorming methodology
Comprehend Design Process	Participants understand the design process for Brainplay. Where participants acknowledged they could have replicated the study	Supports the design process
		Unsure what they would do differently
		Goal' is met
		Vague agreement with the interviewer’s development of Brainplay
Brainplay Design Critique	The participant has provided good or bad feedback on the design of Brainplay	Investigate what mechanics or dynamics could be further added in association with the art style
		Feedback from Brainplay would be improved, both visual and auditory.
		Targeting the specific audience
		design for the end 'goal' or 'aim'

		Using previous titles may limit the process (creativity)
		Regardless of use or process, it still needs to remain a game
Development insight	Where participants have expressed they would do things differently	Who needs games like Brainplay
		Gather thoughts and opinions on games for cognition
		Market research as a stage of development
		Background research into processes
		Observe their methods
		Prototype and test
		Approach an expert
		gather external advice
		playtesting would be important

8.5. DISCUSSION

The hypothesis outlined that the population interviewed should have been able to understand the relevance and advantage of using the MDA in developing video games that could potentially be used for cognitive assessment, diagnosis or treatment.

The coding of participant A, B and C transcripts can be found in appendices twenty-one, twenty-two and twenty-three respectively.

8.5.1. KNOWLEDGE OF MDA FRAMEWORK

The knowledge of MDA framework theme collected codes that highlighted a participant use, discussion or statement regarding the MDA framework. Whether the participant had heard of the MDA was the first question to ask before leading into whether the participant had used the MDA framework before.

Two out of the three participants appeared to understand and possess knowledge or understanding of the MDA. Where participant A affirmed they had heard of the MDA and then followed up and stated that they had utilised the MDA for analysing games as seen in Quote one. Participant B had a few more years' experience as a professional game developer than the other two participants and presented experience in both independent game development and commercial game development. They had heard of the MDA and had utilised it within their own project as seen in Quote 2. In addition, participant B used the MDA to create their own framework derived from the MDA, something that is regularly done within the study of game design as seen with the CCAE by Oceja & Fernandez (2016), who created their framework after analysing the MDA framework.

Interviewer: First off, have you heard of the MDA?
Participant: Yes
Interviewer: (MDA explanation) And have you ever used the framework before?
Participant: I have used it a couple of times when analysing games as part of previous work but have not used it in nearly a year.

QUOTE ONE QUESTION 1, PARTICIPANT A'S RESPONSE

Interviewer: I suppose my first question is, have you heard of the MDA framework?
Participant: Oh yeah.
Interviewer: Have you used the framework in any game development?
Participant: I have used it as a light basis for the design. The project I worked on *Independent title* that was, I actually created a framework from the mda framework to help streamline the process of *Independent title* .
I think, the mda framework works well, it helps to add focus. I think that, Especially with games like *independent Title* , the style of play is much more themed of the game, rather than the mechanics dynamics…it's good to focus development.

QUOTE TWO QUESTION 1, PARTICIPANT B'S RESPONSE

Participant C identified themselves as a video game developer opposed to a video game designer which suggested that they were not from a design background. This could be a reason to why participant C did not display any knowledge of the MDA. When they were asked if they had heard of the MDA framework they stated "*No*" firmly. However, participant C stated that they had used some other frameworks which is discussed in the next theme.

The theme of 'Knowledge of MDA Framework' was important to this research to understand whether game design frameworks were known to commercial developers. This research wanted to know if professional game developers would recognise the value in using a game design framework as a 'recipe' for making games that could potentially assess cognitive processes. Discovering that participant C had not heard of the MDA framework suggests that the knowledge of the MDA framework is mainly apparent to those from a game design background. This suggested that the design and development of video games is not a uniform process.

8.5.2. FAMILIARITY WITH GAME DESIGN FRAMEWORKS, MODELS & METHODS

Following on from the 'Knowledge of the MDA framework theme', the theme of 'familiarity with game design framework, models and methods' grouped codes where a participant demonstrated knowledge of other frameworks. Participants A & B displayed a knowledge for other frameworks or more accurately methods that they had used as seen in Quote three & four. Participant A had also stated in the first question, "*I have used it a couple of times when analysing games*" referring to the use of the MDA. From participant A's quote, it is suggested they had used the MDA as a post-mortem tool for analysing a published game opposed to using the MDA framework as an iterative design tool.

Interviewer: Have you used any other game design framework/model/methods in the development of video games? Participant: Yes, the fail faster methodology. *Interviewer: What purpose did you use that?* Participant: When designing and developing the game it was important to test new ideas quickly and to get feedback on them as soon as possible due to the time constraints on the project. Fail Faster is a methodology that was ideally suited for the project and we ended up picking it up fairly quickly. A lot of the ideas we tried out were shot down quickly but the rapid fire of different ideas for mechanics led to some interesting mechanics the we normally may have not been able to try or implement.

QUOTE THREE QUESTION 2, PARTICIPANT A'S RESPONSE

Interviewer: Have you used any other game design framework, methods or models for other titles you have worked on? Participant: I'd say that many of the things I have worked on I have not really used a framework, it's been a lot more freeform. So it was looking at how the game functioned, there was no set framework. Very much an iterative process.

QUOTE FOUR QUESTION 2, PARTICIPANT B'S RESPONSE

Participant B highlighted that in commercial development, they had rarely followed any design framework or methodology as seen above in Quote four.

Again, with participant C, there was only one uncertain suggestion to a game design framework as seen in Quote five. Although participant C demonstrated the knowledge of the 'narrative framework', their use of the phrase "you can make an argument" does not sound like participant C values the use of a design framework. This suggested that participants C's background was not focused towards design.

Interviewer: Have you used any other game design frameworks, models or methods in the development of video games? Participant: It depends somewhat what you mean, if you count narrative framework such as the concept of the hero's journey or Dan Harmon's story circle then perhaps you can make an argument that those are "frameworks" intended to design narratives, which I've applied to games before. But the best answer I suppose, is no.

QUOTE FIVE QUESTION 2, PARTICIPANT C'S RESPONSE

The theme of 'familiarity with Game design frameworks' showed that participant A displayed a knowledge of the 'fail faster methodology' whereas participant B stated that commercial development had been "a lot more freeform". The findings of this theme highlight that although other frameworks and methodologies exist, it is suggested from the interviews that frameworks and methodologies are not perceived as important to game development. Participant B's experience with commercial development suggests that commercial environments do not utilise a framework but do follow an iterative process. Where participant C has three years of professional game developer experience, they have not used game design frameworks in their experience. This theme can suggest that game design frameworks are not regularly adopted by professional game developers and are perhaps only used for academic development, such as this research, and in post-mortem analysis of games as suggested by participant A.

8.5.3. UTILITY OF FRAMEWORKS

Inquiring further into where participants had used a framework allowed the researcher to group codes where participants demonstrated using a framework to help design a video game. The theme of 'utility of frameworks' grouped codes identified in the transcripts that were specifically identifying where the participants had applied a framework, or iterative design process to game development.

All participants suggested iterative development to deliver a final product where participant A discussed the use of the 'fail faster methodology' and stated;

"*When designing and developing the game it was important to test new ideas quickly and to get feedback on them as soon as possible…"*

QUOTE SIX PARTICIPANT A ON FAIL FASTER METHODOLOGY

When Participant B was asked about the use of other frameworks or models they stated they had not adopted a framework, but the development was an iterative process.

When participant C was asked about how they would approach the design of video games for cognitive assessment, they stated 'iterative experiments in gameplay' would be used to compare results to 'established methods' which suggested that they would adopt their own iterative development and compare the development process to a game design framework like the MDA. Overall it appeared that each participant valued iterative development process over the application of a framework, with a focus on testing as suggested by participant C's comment on "*Playtesting would be important"* and participant A's process of adopting 'fail-faster'.

This theme also attempted to help answer the hypothesis of whether a game design framework is useful in creating a video game product. Where participant A and B have given examples of using game design frameworks in their line of work, participant A had not recently used a framework in their work (see quote one) and participant B (see quote four) had not used any framework within commercial development. This suggested that the use of a game design framework was not necessarily important within the game development community sampled.

8.5.4. COMPREHEND DESIGN PROCESS

Another aim of this study was to determine whether professional developers and designers could understand and comprehend the design process of Brainplay, whether they would be able to replicate the study if given the resources and MDA framework as a method of development.

The theme of 'Comprehend design process' was established by grouping codes where participants had displayed confidence in the ability to replicate the development of Brainplay.

When asked whether if they could replicate the development of a game like Brainplay, Participants A and B suggested they would confidently be able to carry out a similar project and produce video games that could potentially assess cognitive processes. Where participant A stated "Yeah, I'd say so", it is suggested they are confident in their ability to replicate the study. Quote seven shows the response participant B gave to last question regarding the participant's ability to create their own games for cognitive impairment, cognitive training etc. Participant B highlighted that the mechanics may prove an issue to replicate in a study as the interaction may be different, resulting in a different overall experience.

Could you follow application of the MDA framework to the table to create new games for cognitive impairment, cognitive training, cognitive therapy..? Participant: I'd say so. The tables seem detailed and it would be fairly easy to pick mechanics from it to create new games. Only issue might be how the different mechanics would interact in the overall experience but that would be noticed and resolved in testing.

QUOTE SEVEN QUESTION 5, PARTICIPANT B'S RESPONSE

The barrier for participant C was due to exposure to the MDA evident in the interview with their knowledge in iterative development and not specifically in frameworks. When participant C was asked the final question they stated, "*Having no exposure to the mechanics of MDA, I would find it difficult".* The lack of exposure to the MDA framework suggests that participant C is less likely to use a framework but will still utilise iterative development to create games.

This theme suggested that professional game designers could replicate the study but there is a barrier for other professional developers to replicate the study due to the lack of knowledge surrounding game design frameworks, such as the MDA. What this theme can suggest is that the comprehension of a design process, specifically the MDA, is known to a specific niche (game designers) and not likely known by those who are not experienced in design. For those professional developers outside of design, there would need to be a guide that would lead the professional developer through the process of the MDA.

8.5.5. BRAINPLAY DESIGN CRITIQUE

The researcher was curious to gather feedback from professional game designers and developers on the design of Brainplay and where improvements could have been made. Participants were shown a video of Brainplay and were encouraged to comment on what they thought of Brainplay. This theme encompassed any codes that critiqued Brainplay.

The main feedback from the participants was to improve the audio and visual feedback and potentially tailor the game to a specific audience as seen in quotes below. Each participant displayed a different opinion on the design of Brainplay. When Participant A was asked for the feedback on Brainplay, they supported the design of Brainplay, except for developing further mechanics after the art style was developed. However, the suggestion was vague and reserved onto the specific improvement that could be made. Participant B's focus was on establishing the market. It was interesting to see the different views come from each of the professional developers and how their individual experiences reflect on the feedback of Brainplay.

> *"maybe having an extra step after choosing the art theme to see if there was anything either mechanically or dynamic that could be added or changed to tie in with the art theme though this seems unlikely with this type of game."*

QUOTE EIGHT PARTICIPANT A'S BRAINPLAY DESIGN CRITIQUE

> *"asking individuals who need to use these games, how they feel about games for cognition, seeing what these people (healthcare staff and patients) want to see. The market if you will."*

QUOTE NINE PARTICIPANT B'S BRAINPLAY DESIGN CRITIQUE

> *"I might question the level of adherence to previous titles on a mechanical level."*

QUOTE TEN PARTICIPANT C'S BRAINPLAY DESIGN CRITIQUE

Another critique was how the design had adhered to previous titles works as seen above in Quotes eight, nine and ten. This critique regarded the review of existing games that assessed cognitive processes, questioning how much Brainplay had followed a similar design to the existing games reviewed or had it created its adopted its own process.

8.5.6. DEVELOPMENT INSIGHT

Finally, the interviews revealed a developer insight to how they would conduct the design of video games that could assess cognitive processes. This theme encompassed codes where the participant expressed how they would do things differently or the process they would take to develop a product like Brainplay.

The main finding here was that each of the participants would approach an expert for advice or speak to stakeholders such as healthcare staff and patients seen in Quotes eleven, twelve and thirteen.

> *"After a few rounds of prototyping I would like to get an expert in cognitive assessment involved to take a look at the game and see if they feel it is either doing something wrong or is missing something"*

QUOTE ELEVEN PARTICIPANT A'S DEVELOPMENT INSIGHT

> *"…asking individuals who need to use these games, how they feel about games for cognition, seeing what these people (healthcare staff and patients) want to see"*

QUOTE TWELVE PARTICIPANT B'S DEVELOPMENT INSIGHT

> *"…Likely I would approach an expert and seek guidance"*

QUOTE THIRTEEN PARTICIPANT C'S DEVELOPMENT INSIGHT

Playtesting was also a priority for this development process as participants A and C both mentioned playtesting would be important to the development of games in general as discussed in previous themes.

The development insight highlighted that there was a shared development agreement in that each of them would approach an expert in cognition to help guide the development of games for cognitive development. There is a lot of guidance suggested from the sample study which suggested that an expert in cognition would be required to guide the development of a commercial set of games to assess cognitive processes.

8.6. GAMES 4 CHANGE 2017 CONFERENCE FEEDBACK

Brainplay and the associated research was submitted to the Games4Change annual conference as a short talk to present the development process of serious games for those with MCI. The submission process was to submit a short talk and presentation within serious games. There were three tracks that the conference held: neurogaming and health, games for learning and civics and social issues. A presentation on the development of Brainplay was submitted to the neurogaming and health track. Both a telephone and video (skype) interview was undergone as a method of peer review by the Games4Change team. The presentation was accepted in May 2017 to be presented as a short talk on the second day of the conference alongside other speakers on serious games and health. The conference was held during the 31st of July to the 2nd of August 2017 at the New York school of design.

The presentation of Brainplay discussed the feasibility of designing Brainplay from the MDA framework and its potential use to model cognitive processes. The opening of the presentation introduced the motivation of the project and defined the key terms of what a serious game is before discussing the use of the MDA framework as a design and development process. Footage of Brainplay was shown while the design and upcoming user studies were described. The definition of serious game suggested was presented which gained some discussion to the use of Suits (1978) definition combined with more modern theories on serious games (Juul, 2003; Zyda 2005). The main interest formed around the design approach of using the MDA framework to design a game that could potentially model cognitive processes and could be utilised in healthcare.

The outcome of the talk presented opportunities to talk with developers and researchers involved in serious games. A former developer of Fit Brains (Rosetta Stone, 2007) presented work on accessibility of games and designing emotional intelligence. The former developer of Fit Brains discussed the design of their brain training games that shared some similarities with Brainplay. Match Up and Which Word shared similarities in design but when asked about design processes they had not utilised a game design process. Instead, they had observed competitors such as Brain Training (Nintendo, 2006) and Lumosity (2018) to identify how the games should be developed. The feedback from the former Fit Brains developer was that further accessibility options could be implemented. In addition, they were interested in the development process justified through a game design framework but sceptical to the time needed to research and utilise a game design framework or model.

There were two others key conversations had at the Games4Change conference, a producer at a digital comic narrative PriyaShakti (2014) and the other a founder and creative director of the independent development company. The producer at PriyaShakti (2014) utilised augmented reality to challenge sexual violence and was interested to discuss how the game design framework approach could be utilised to develop linear narratives in augmented reality. How adopting a game design framework for a related medium could be used to explore other ‘serious issues’. The interest lied in how Brainplay could be used in a medical purpose further down development to help inform whether there was a health or wellbeing issue with the player. However, the concern put forward was that game development and research move at two different speeds. The concern was that game development time of a working prototype is often measured in months, whereas research can take over a year. The difference in time created the concern that game developers could not afford to adopt a serious games approach to healthcare as the necessary research may too long to gather before any development or earnings on a product could be made.

The founder and creative director discussed game mechanics and future directions to the use of Brainplay in both a commercial setting and a health & wellbeing setting. Their interest lied in how Brainplay’s mechanics could be adopted into a larger and more complex game where each action of the player could be measured and recorded to observe changes in playstyle and current wellbeing while playing. In addition to the feedback towards Brainplay and the design process, the Games4Change conference featured influential speakers whose work has been referenced within the thesis. For example, the key note of the presentation discussed Green & Bavelier’s (2012) research article on action games and cognition as a key paper in serious games and cognition research (Steinkhuehler, 2017). The critical play framework author Flanagan (2009) presented work on evidence-based design, similar to what was discussed in section 5.3.1. such as patient person involvement or co-design approach.

8.7. SUMMARY OF MDA EVALUATION STUDY

Focusing on the prior objective of the hypothesis; whether a game design framework was relevant or required for the development of video games for cognition, the thematic analysis results presented that a framework was not required. It was not solely a lack of understanding as two of the participants had demonstrated knowledge of the MDA. The results of this sample study suggested that the game development industry is not dependent on utilising game design frameworks within a commercial sense. This suggested that the use of a game design framework may only be contained to video game studies in academia as a method of describing a design process or analysing games as a post-mortem to observe the mechanics, dynamics and aesthetics of a published game. The sample has suggested that the development of video games is 'freeform' or highly iterative. However, it should be noted that a much larger study would be required to gather an idea of how commercial development works, as it was only suggested from this small sample. In addition, each participant demonstrated a critique of Brainplay and a summary of how they would design something like Brainplay and did not reference a framework to help complete the design process.

Relating to the discussion on defining a serious game in section 2.3.1 and 7.3, the results suggest that a game design framework is not needed to create serious games. However, the key elements to designing a game or serious game involving rules/mechanics and systems are still discussed by the professional game developers. Although the MDA framework (Hunicke, LeBlanc & Zubek, 2004) presented the best method for the design of Brainplay to model cognitive processes, the sample interviewed could have replicated the design process. Furthermore, the sample suggested their own method of game development which supports the discussion in section 2.3.2 surrounding the gap between game design theory and game design practice. Where theories and frameworks of design have been proposed and tested by research, professional game developers are going to rely on the development knowledge they understand before embracing a new theory or approach. The design of games in industry is suggested to be open without the constraints of following a model or framework. It is evident that the contribution from the MDA evaluation study is that the gap between theory and practice exists. The game developer interviewed did not know of game design frameworks and although the game designers had heard of the MDA framework, they had not utilised the framework in their professional capacity. Instead, production or business models of waterfall or scrum take precedence. Further investigation with a larger sample may highlight additional barriers and reasons to the gap between design theory and practice.

This analysis suggested that MDA would not be required to illustrate the design process for creating a game like Brainplay. With the suggestion that commercial game development does not utilise game design frameworks, it would be perhaps more useful to provide a background of mechanics and dynamics that can be used to design games that assess a specific cognitive process. Perhaps the use of a framework would be better suited to the academic study of games to help communicate design processes and replicate studies, opposed to the use within commercial development.

9. CHAPTER NINE – POTENTIAL APPLICATION IN HEALTHCARE

9.1. METHODS AND PROCEDURE

9.1.1. OVERVIEW

The study presented in this chapter aimed to evaluate whether Brainplay could be perceived as useful in a healthcare environment to answer the research question, “What are the potential uses of a serious video game in healthcare?”

To answer this question, the researcher introduced Brainplay to three healthcare professionals. The healthcare professionals were asked about their discipline in healthcare to establish a demographic background. The healthcare professionals were interviewed on the utility of Brainplay, inquiring into whether they felt Brainplay could be used for assessment, diagnosis, recreation etc. to determine whether Brainplay had a potential application within healthcare or whether it was only viewed as an entertainment game.

This study would explore the purpose of Brainplay within healthcare. Like the MDA evaluation, the recorded interviews were analysed for themes using thematic analysis. Thematic analysis was conducted to reveal insights from the healthcare professionals and any suggestion to where Brainplay could be used with a healthcare setting.

9.1.2. HYPOTHESIS

The hypothesis for this study was that the healthcare professionals would able to understand the cognitive processes modelled by each of the games included within Brainplay. Where the healthcare professionals would identify that Match Up was modelling working memory, Odd Ones was modelling thinking & reasoning and Which Word was modelling language. It was hypothesised that the healthcare professionals would suggest a potential use for Brainplay within healthcare and not just perceive Brainplay as an entertainment game.

9.1.3. DESIGN

A qualitative method of an in-depth interview was conducted with healthcare professionals. Interviews were conducted one-to-one and recorded so that the researcher could transcribe later.

Interviews were between 20-35 minutes as the healthcare professionals were busy professionals and difficult to secure a time frame between work and life commitments.

EQUIPMENT & APPARATUS

- Video of experimental prototype video game Brainplay
- Interview Guide and Questions (see Procedure, section 9.1.8 and Interview questions, section 9.1.9 below)
- Recording device (Skype for online interview)
- Access to video calling software (Skype) and computer/laptop

ETHICS

As the interviews were conducted one-to-one, only the researcher knew the names and identity for each of the participants. To protect the participants' personal identity, a reference number or pseudonym was given.

LOCATION

The study took place from the 11th August 2017 until the 15th September 2017. The study was conducted remotely, for the convenience of both the participant and researcher.

The researcher and each participant spoke via skype for approximately 20 - 30 minutes.

9.1.4. PARTICIPANTS

Participants were recruited through emails (see appendix 23) to NHS England and Scotland specifically areas such as Angus and Fife, North East England, North Wales, Central London and North-West England as the researcher had contacts in these areas. These initial emails were calls for participants asking for their input on the use of Brainplay within a healthcare environment.

The researcher received replies from twelve healthcare professionals within the contact areas of the NHS who were interested in participating. In correspondence, these twelve healthcare professionals were sent the participant information form (appendix twenty-five). Three of the participants replied to the correspondence and agreed to an interview. The three healthcare professional representatives were a mental health nurse, a director of nursing and general practice manager. The study was open to all healthcare professionals as the research sought to gather different viewpoints from different professional backgrounds.

9.1.5. LIMITATIONS OF THE STUDY

Interpretation of the interviews was subjective to the researcher. Interviewers can unintentionally show bias when conducting an interview.

The data was sample of the population and not representative of the population however it was able to provide an insight to where Brainplay could be used.

The impact of the study conducted remotely carried the possibility of communication errors when the interviews were conducted. The video of the Brainplay could have also detracted from the interactive experience that could be experienced if the participant could play the game. The video only offered insight into the shown footage of the video game; this may have affected the discussion towards the potential purpose of Brainplay as the healthcare professionals were unable to interact with Brainplay.

9.1.6. DATA COLLECTION

Data was collected in the form of an audio recorded interview. The recorded interview was then transcribed through an intelligent verbatim method. Intelligent verbatim transcription involved the transcription of the interviews to omit words or actions that did not contribute to the value of the qualitative data.

9.1.7. DATA ANALYSIS

To analyse the transcribed data, a thematic analysis (Cote and Raz, 2012 citing Braun and Clarke, 2006) was conducted with the transcripts. The thematic analysis highlighted interesting themes and opinions from each of the participants.

9.1.8. PROCEDURE

1. Explanation of the interview (2 minutes)
2. Participant described their role in Healthcare (2 minutes)
3. Introduction of Brainplay and feedback (3 minutes)
4. 5 questions on the potential use of Brainplay (10-20 minutes)
5. Researcher thanked participant and presented the participant with £10 love-to-shop voucher for their time. (2 minutes)

Total Procedure length: 25-35 minutes.

Common Interview Guide Components	**Purpose**	**Description/Questions**
Introductory Script	To open the interview and cover necessary information with the participant. To remind the researcher of the study goals.	Summarize the study and the objective
		Discuss the following procedure. Clarify consent
Warm-up Questions	Put the participant at ease and build rapport	“What is it you do within healthcare?”
		“What do you do in your job?”
Substantive questions	Collect deeper data that answers the questions posed by the study	Open ended questions
		Encourage discussion and follow up questions
		See Appendix twenty-six for questions
Demographic questions	Gather data to describe the participants in the final thesis	Tie in with warm-up questions
		Evidence on “healthcare professional” participant

9.1.9 INTERVIEW QUESTIONS

The interview questions can be found in detail in appendix twenty-six. However, in summary the questions were to understand the opinions of healthcare professionals on a video game to be potentially used in healthcare and what use that would be.

The questions first enquired whether the healthcare professionals used, or knew of, video game technology in their discipline of healthcare. They were then asked to comment on whether they thought Brainplay could be used within a health setting.

They were then specifically asked for each of the games of Brainplay, to describe what cognitive process they thought each of the games was potentially trying to assess.

Finally, the healthcare professionals were asked whether they would use Brainplay within their discipline of healthcare and detail reasons why.

9.2. RESULTS

The following section described the results of the study into the potential of Brainplay. The study conducted three interviews with healthcare professionals to ascertain the potential of Brainplay within a healthcare process.

The three interviews were all carried out via video calling software (Skype) and were guided by questions seen in appendix twenty six.

9.2.1. STUDY POPULATION DEMOGRAPHICS

Prior to the questions that focused the interview; the researcher began with warm up questions to determine the demographic of each healthcare professional. The three participants were from diverse backgrounds, as illustrated in the Table nineteen below. The names and ages have been kept hidden to protect their identities.

TABLE NINETEEN DEMOGRAPHICS FOR STUDY 3

Participant (X)	Age (Range)	Gender	Profession	Years in healthcare
D	21-25	Female	Mental Health Nurse	3
E	31-35	Female	Practice Manager (GP)	15
F	46-50	Female	Clinician (Acute and Mental health services)	30+

As seen by the Table nineteen above, each participant came from a different area of healthcare and each had a different length of experience. It should be noted that participant *E* had previous experience as a GP and participant *F* had previous experience in nursing however further details have been omitted to protect the identities of participants.

9.2.2. DATA RESULTS

The study used thematic analysis as the qualitative method of observing the interview data. Each of the interviews was transcribed and then the process of coding was applied to identify areas of importance, recurring details and frequencies within the data.

9.2.3. CODING

The first step was to analyse the data by coding. Coding the data helped categorise, summarise and account the qualitative data (Lapan, Quartaroli & Riemer, 2012).

Coding involved the researcher identifying insights and areas of interest in the participant's transcripts. The coding focused on identifying the main concern of the participant (or subject matter), the assumption of the participant and patterns in the data.

The researcher carried out coding on each of the participants to observe the raw data and highlight areas of interest in participant's responses to the questions (Coding data can be found in appendices twenty-seven, twenty-eight and twenty-nine).

9.2.4. THEMATIC ANALYSIS

The interviews were relatively short, between 20-30 minutes, with five questions to focus the subject of the study. A thematic analysis was used to group and categorise the codes into themes. The researcher believed the themes described below best communicated the main insights that came across from the interviews.

TABLE TWENTY THEME'S FROM TRANSCRIPTS (STUDY 3)

Theme	Description	Example of Codes grouped within theme
Desire for Interactive Technology	Where a participant had shown interest in the desire to see interactive technology in healthcare	The need for smartphone access
		Opinion of finding them useful
		Enthusiasm for interactive technologies
		Desire to use technology within health
Uncertainty on Demand	A participant had shown uncertainty to the need for games with healthcare.	Uncertain on the demand for video games in health.
		Sceptic surrounding video games in health
		Require evidence
		There isn't a demand from practices.
Potential of Brainplay	The participant had suggested a potential for Brainplay. Inclusive of where a participant has provided an idea for where each game could have been used.	Match up assessing Memory
		Opinion on the potential of Brainplay as a memory test
		Odd Ones to assess colour blindness
		Positive use for Brainplay. patient care?
Technology Underused	Participant suggested that technology is underused with Healthcare. Or that the current technology is outdated.	Alternative and not addition
		Similar test done, spoken instead of interactive.
		Technologies underused in healthcare
		Technology use in healthcare rising.
Concern of Cost	Concern of cost, whether it was the cost of time, staff, money or available technology.	Concern on cost (financial)
		Dependent on finished product. Concern for ease of use and cost
Time Saving, assist with daily tasks	Participants expressed that time needs to be saved, or technology to help with day to day tasks.	Save time, and not money
		The need for smartphone access (save time)
		Help with daily tasks of a nurse

9.3. RESULTING THEMES

The purpose of this study was to understand the potential for Brainplay within a healthcare environment. Questioning whether games like Brainplay could be used in healthcare, if it all. The study also wanted to know if healthcare professionals interpreted the cognitive processes that the video games were designed to potentially assess or whether they interpreted different cognitive processes modelled by the video games.

Towards understanding the potential of Brainplay within healthcare, the thematic analysis identified a total of six themes in the qualitative data. These themes were generated to represent the insights of the healthcare professionals and the codes presented from raw data analysis (see appendices twenty-seven to twenty-nine).

9.3.1. DESIRE FOR INTERACTIVE TECHNOLOGY

One of the unanimous themes found across all three participants was the desire to see interactive technology used in healthcare. Each participant suggested a desire for technology, whether it was "*they could see how it (Brainplay) would be useful"* or "*where we are trying to define and diagnose cognitive impairment"*.

When each participant was asked if they had an interest to see more interactive technology such as video games used in healthcare, each participant responded positively as seen in Quote fourteen to sixteen.

Interviewer: After watching Brainplay, do you think that Brainplay could be used in a healthcare setting?
Participant: I think that Brainplay would ultimately be used in a healthcare setting. This would be use in waiting rooms to relieve feelings on anxiousness or to take their (patients) mind off the environment that they are in. This app could also be good for occupational therapy intervention

QUOTE FOURTEEN PARTICIPANT D'S INTEREST IN INTERACTIVE TECHNOLOGY

Interviewer: After watching Brainplay, do you think that Brainplay could be used in a healthcare setting?
Participant: Yes- if it were connected to the clinical system and data inputted using a tablet. Not sure if better suited to secondary or primary care though. It would depend on the finished product, ease of use and cost etc.

QUOTE FIFTEEN PARTICIPANT E'S INTEREST IN INTERACTIVE TECHNOLOGY

Interviewer: Do you think there is demand for interactive application such as Brainplay within your area of healthcare?
Participant: Absolutely

QUOTE SIXTEEN PARTICIPANT F'S INTEREST IN INTERACTIVE TECHNOLOGY

Participants were enthusiastic to the use of interactive technologies, especially surrounding mobile and tablet technology. Participant D suggested that the main users of technologies would be;

"*staff such as GPs, nurses and patients _ service who have access to smartphone technology"*.

QUOTE SEVENTEEN PARTICIPANT D'S SUGGESTION TO MAIN USERS OF TECHNOLOGY

This suggested that the desire was not just for games technology for patients but also healthcare professionals.

9.3.2. UNCERTAINTY ON DEMAND

Although there was a desire for the technology of video games with healthcare, there was uncertainty to the demand for interactive technologies such as games. Both participant *D* and *E* were unsure of any demand for interactive technology within their area of work as seen in the quotes below.

Interviewer: Do you think there is demand for video games, such as Brainplay, within your area of work?
Participant: I'm unsure if there is a demand, although I can see how they could be useful

QUOTE EIGHTEEN PARTICIPANT D'S OPINION ON DEMAND

Interviewer: Do you think there is demand for video games, such as Brainplay, within your practice? Participant: The use of technology is increasing in the healthcare sector and this type of videogame is an excellent alternative to traditional ways of assessing cognitive function. I wouldn't say there is particular demand from practices at present but CCG's (Clinical Commissioning Groups) and NHS England are increasingly looking at ways to better utilise technology and this is then rolled out across practices. Some practices are resistant to begin with (online consultations is the current initiative meeting resistance from many practices!) but usually there will be some that are interested and lead the way in terms of piloting such projects and often they do end up saving time for practices in the long term.

QUOTE NINETEEN PARTICIPANT E'S OPINION ON DEMAND

The identification of codes of uncertainty suggested that the healthcare professionals as individuals were enthused to see interactive technologies in the workplace but could not speak for their workplace. It also suggested that their maybe hasn't been a significant video game that has created a demand within healthcare, so there was no demand from healthcare professionals to see a desirable interactive technology in their workplace.

Participant E stated that they "*would like to see other practices and CCG adopt video games, to better to see what video games can do for the NHS*", which supports the suggestion that there hasn't been a significant breakthrough by video games to create a demand within healthcare.

When participant F was asked for their opinion on the demand they stated "*Absolutely*". It's suggested that the single answer is a response more associated to desire for technology than demand. However, participant F did suggest the area of where the demand could come from.

9.3.3. POTENTIAL OF BRAINPLAY

Part of the research was to understand if the cognitive processes had been communicated effectively through the design of Brainplay. Healthcare professionals were asked what they believed each game monitored or assessed in terms of cognitive process. Table twenty-one showcases the participant's responses below. It was important to know if Brainplay could be used to assess the cognitive processes that the games were designed for in chapter six of the prototype development.

Overall there were three suggestions to where Brainplay could be used. It was suggested that Brainplay could assist with boredom or loneliness, which suggests a potential for Brainplay to be used for quality of life purposes. In addition, it was also suggested that Brainplay could be used as a distraction tool for waiting rooms and individuals in hospital. Participant D even suggested Brainplay as a use in occupational therapy. Finally, participant F suggested a potential use of Brainplay as an assessment tool as seen in Quote twenty.

This would be use in waiting rooms to relieve feelings on anxiousness or to take their (patients) mind off the environment that they are in. This app could also be good for occupational therapy intervention

Interviewer: What setting would you see for Brainplay? Like diagnosis or assessment?
Participant: Diagnosis. Using it to determine any mental or physical capabilities, especially with younger patients.

I think there is real worth in using something such as this in areas where we are trying to define and diagnose cognitive impairment, acute confusional states and behavioural aspects of health – it could be used either in front line services such as primary care or in a secondary setting such as mental health or care of the elderly. Or the diagnosis of dyslexia, dyspraxia..

QUOTE TWENTY PARTICIPANT F'S COMMENTS ON THE POTENTIAL USE OF BRAINPLAY

TABLE TWENTY-ONE HEALTHCARE PARTICIPANT RESPONSES TO BRAINPLAY

Brainplay	**Cognitive Process**	**Participant D's interpretation**	**Participant E's interpretation**	**Participant F's interpretation**
Which Word	Language	Dyslexia	Knowledge	Perception, encoding and retrieval processes, memory, decision making
Match Up	Working Memory	Memory Photographic memory	Comprehension	Visual attention, motor skills, praxis
Odd Ones	Thinking & Reasoning	Colour Blindness, face recognition	Analysis tasks	Short term memory, attention, concentration

Table twenty-one above showed how each of the participants interpreted each of the games within Brainplay. In the case of Which Word, participant *D* suggested that it could assess dyslexia, as seen in Quote twenty-one, which was not far removed from the cognitive process focus of Language as dyslexia is a cognitive impairment of language (Eysenck and Keane, 2010).

Which word would assess dyslexia, from my own personal experience

QUOTE TWENTY-ONE PARTICIPANT D'S OPINION ON WHICH WORD

Participant E suggested Which Word acted as a game for knowledge as seen in Quote twenty-two. Interpreting this from the background literature, the challenge of knowledge would fall under solving problems and puzzles, an area of thinking and reasoning (Eysenck and Keane, 2010).

I would say that which word assesses Knowledge, gathering a person's basic mental capacity.

QUOTE TWENTY-TWO PARTICIPANT E'S OPINION ON WHICH WORD

Participant F's opinion of Which Word was that it didn't just challenge one cognitive process, but many cognitive processes encompassing perception, memory and decision making but not language which can be seen in Quote twenty-three.

Various cognitive components are tested in this task which I believe comprise of scanning, matching, switching, and writing operations that are reflective of several higher cognitive functions like perception, encoding and retrieval processes, transformation of information stored in active memory and decision making

QUOTE TWENTY-THREE PARTICIPANT F'S OPINION ON WHICH WORD

The samples potentially suggested that the interactive nature of video games cannot be limited to assessing an individual cognitive process. A video game typically requires multiple forms of input and thought processes depending on genre, therefore it could be suggested that creating a game with mechanics specific to one cognitive process was not feasible.

The view on Match Up showed a support for the development around working memory, participant *A* stated memory (and photographic memory) as the suggested assessed cognitive process. Participant *E* suggested comprehension which could relate to task analysis. It was also suggested that Match Up could be used to measure visual attention (perception and attention), as seen in Quote twenty-four, which could be feasible due to the design of Match Up. The player had to remember separate locations, an act of divided attention, which was most likely why participant F suggests Match Up as a method for assessing or measuring visual attention.

Interviewer: What do you think Match Up assesses?
Participant: Visual and colour representations alongside image and due to compromise to almost any brain system this includes aspects like visual-visual attention, language, praxis, motor, to see if other brain systems are basically intact

QUOTE TWENTY-FOUR SUGGESTION OF MATCH UP ASSESSING VISUAL ATTENTION

Odd Ones showed the most variety in responses as it was suggested it could be used to assess colour blindness or face recognition, both aspects of perception as seen in Quote twenty-five. Participant *E* believed that Odd Ones would be used in analysis tasks which could be interpreted as a function of thinking & reasoning, involved in solving problems or again, as a function within perception. Participant *F* suggested differently as well stating Odd Ones could be used for short term memory analysis or even attention.

Odd Ones could be used to assess colour blindness, maybe even face recognition through the ability to recognise familiar animals and when they have been altered.

Interviewer: What do you think Odd Ones assesses?
Participant: Analysis tasks, definitely. Analysing the images and choosing the correct answer.

Interviewer: And finally, what do you think Odd Ones assesses?
Participants: It appears to measure processing speed deficits. It's about short-term auditory memory; also, attention and concentration. Weak attention capacity can have an effect on language, memory, listening and recall abilities. For me it is important to differentiate between memory for meaningful and non-meaningful abilities as well as the difference between auditory and visual memory. This helps me to understand strengths and weaknesses.

QUOTE TWENTY-FIVE MIX OF RESPONSES TOWARDS ODD ONES

The wide body of interpretation could be down to the design of video games, unable to avoid incorporating other cognitive processes in the 'interactive experience'. Everyone has displayed a distinct perspective and understanding of cognitive processes which could be why there was a lot of difference in interpreting Brainplay's suite of games.

The results seen in Table twenty-one highlighted that each participant interpreted each of the games within Brainplay differently. There were a couple of instances where a healthcare professional participant identified the cognitive process that the game was designed to assess, as seen with Which Word and Match Up. However, for many of the games, there were a wide range of opinions on what cognitive processes were communicated by each game in Brainplay. This could be due to the interactive nature of video games. The action of interacting with a video game could have communicated numerous cognitive processes and the process of trying to design for a specific and single process could be highly difficult. As stated before, it could also be due to the different knowledge of each participant. As the background chapter established, there were multiple theories on cognitive psychology which could suggest why there were such different interpretations and wording used to describe what the games of Brainplay were trying to communicate.

There was also the limitation that the healthcare professional participants viewed a video due to remote interviews opposed to playing the interactive experience on the tablet device.

9.3.4. TECHNOLOGY UNDERUSED

The fourth theme observed from the interviews was that there was an underutilisation of technology with healthcare. Dyslexia tests, for example, are still conducted through spoken word and pen & paper opposed to an online assessment or utilising modern mobile phone technology such as video calling as suggested by participant D seen in Quote twenty-six.

I undertook a dyslexia and dyspraxia test with an educational psychologist and a test like this was done, only is was spoken and not done interactively.

QUOTE TWENTY-SIX REFERENCE TO PARTICIPANT D'S SPOKEN DYSLEXIA TEST

There was evidence that the use of technology was improving though, where participant D described the use of apps as a nurse they use, such as to aide with time keeping and retaining details as seen in Quote twenty-seven.

In regard to apps some nurses may use the NHS BMI tracker app for clinics, appointments or on a ward. These are also an app called my local NHS. This app allows patients or service users to keep track of appointments or locate various services such as A&E or pharmacies and allows you to store notes ready for when you visit your GP or attend a hospital appointment.

QUOTE TWENTY-SEVEN PARTICIPANT D'S REFERENCE TO CURRENTLY USED TECHNOLOGIES AND APPS IN HEALTHCARE

This theme provided the evidence that there was a potential market for technology to develop within healthcare, to help both patients and staff. The importance of this finding is that there is not only a suggested desire as previously discussed, but there is an attempt being made within healthcare to expand into technology. The theme of technology underused also touched on that there are still tests conducted through paper or spoken methods which suggests there is the opportunity to digitalise and improve on these existing methods with the possible implementation of video games.

9.3.5. CONCERN OF COST

A stand out theme from the interviews was the concern of cost which primarily came from participant E. They showed an overall enthusiasm for interactive technologies to be used within their healthcare setting, but their biggest concern was ‘cost’ as seen in Quote twenty-eight.

Interviewer: Are there any reasons to why you would not use Brainplay within a healthcare setting? Participant: If the cost were prohibitive. *Interviewer: So it needs to be affordable for the practice?* Participant: Yes, the cost of buying an app and distributing would be a fundamental factor to use within the practice.

QUOTE TWENTY-EIGHT PARTICIPANT E’S CONCERN OF COST

The cost could be interpreted as the financial cost to healthcare; the cost of installing, affording devices or buying the application. But there was the cost of implementation in training staff to use new interactive technologies for example. This would create a large cost the healthcare sector training multiple staff members to use a new interactive technology.

Though this theme emerged specifically from one participant, there was the suggestion from the sample that cost would need to be considered when developing a video game as a healthcare intervention. Where the participants D and F suggested the potential use of Brainplay as a “*use in waiting rooms to relieve feelings on anxiousness*” or for “*Patients who need support and something that is provided in a ‘fun form’*”, these potential applications would need to consider the cost to implementing video games into waiting rooms and the cost of training staff how to use or administer video games to patients.

Future studies should consider that the development of an interactive technology for healthcare should supply a cost to implementation; how accessible would the product be? What would the cost to healthcare be regarding training time or the cost of the technology required using Brainplay? The importance of this finding could suggest that the main barrier to games gaining approval to be used with healthcare could be the lack of consideration towards cost and benefits. Whether the costs of implementing a video game into healthcare are less than the benefits a video game intervention could provide.

9.3.6. TIME SAVING

The last theme identified was the interest regarding the use of interactive technology. When asked about existing technologies that the participants used, examples such as apps on mobile technology which kept appointments, details and information were readily available to save time as seen in Quote twenty-nine below.

> *Some practices are resistant to begin with (online consultations is the current initiative meeting resistance from many practices!) but usually there will be some that are interested and lead the way in terms of piloting such projects and often they do end up saving time for practices in the long term.*
>
> *This app allows patients or service users to keep track of appointments or locate various services such as A&E or pharmacies and allows you to store notes ready for when you visit your GP or attend a hospital appointment.*

QUOTE TWENTY-NINE PARTICIPANT E'S AND D'S TIME SAVING SUGGESTIONS

The quotes above state that projects have previously ended up saving time and the suggestion that being able to 'store notes' in advance would allow for time to be saved at a "*GP"* or "*Hospital appointment"*. The notion of 'saving time' seemed highly important to two of the participants interviewed. This posed the question of whether interactive technologies such as Brainplay on a tablet device would provide a faster diagnosis or assessment of cognition in comparison to current methods. This finding was important for this research as it brings the development of video games into healthcare another area of feasibility and whether the addition or substitution of a game-based intervention would free up more for healthcare professionals so that they could apply themselves to specific areas that would need their attention or expertise.

9.4. SUMMARY

This potential application in healthcare study was conducted to answer the research question of;

What are the potential uses of a serious video game in healthcare?

The result of this study has shown that there was a desire for interactive technologies such as Brainplay within the Healthcare setting. However, it was still unclear as to where the use could be used as each participant interpreted the cognitive processes differently. If Brainplay were to be implemented into healthcare, an external healthcare board would need to advise how Brainplay could be used to observe or assess cognition.

As discovered by this study in section 9.3.5, future study should consider the cost to healthcare when designing video games such as Brainplay. Describing the potential costs and resources required to effectively distribute and utilise an interactive product. In addition, when future game development within this body of research is conducted, the preliminary research and design should consider whether the interactive technology provides an element of 'time saving' for healthcare professionals or patients.

This study also revealed that there was a desire for interactive technologies to be used more within healthcare as the opinion of this study's participants was that technology was underused within healthcare. This suggested that there was a potential market to develop video games for healthcare purposes.

There is also the suggestion that there needs to be further research into the demand as there was a lot of uncertainty whether the healthcare professional population in the UK has a demand for interactive technology or not. Whether or not patients have a demand to see interactive technology approaches to healthcare as well. This uncertainty needs to be addressed if video game development is going to expand into the healthcare sector.

However, the significance of these findings is that there is a potential for Brainplay to be used for a serious purpose. The contribution of this study means that the definition of a serious game discussed in 2.3.1 carries further validity. Brainplay has the potential to be used in a healthcare setting therefore the definition by Zyda (2005) that refers to imparting knowledge or skill could be confirmed by these results. If Brainplay were to be used as a distraction tool or time saving tool, it would be imparting knowledge to health professionals. Furthermore, the additional contributions of the potential application study have highlighted further areas of research in the cost of implementation and the uncertainty towards games in healthcare.

10. CHAPTER TEN: FURTHER STUDY AND CONCLUSION

10.1. FURTHER STUDY

This research served as an exploratory venture into where video games could move into the healthcare sector where video games could potentially be used to assess or diagnose cognitive processes or cognitive impairment.

Although the studies conducted were with small samples, the insights have the potential to open further study. For example, within the previous work chapter (section 3.2.2), the previous work highlighted that existing games appeared to have not specifically targeted cognitive training/assessment in a healthcare environment, hence the direction of this research. This could suggest that further development and exploration of video games for cognitive training/assessment would be needed to understand the impact on literature within this cross-discipline field. In addition, the previous work chapter highlighted that existing games associated with cognition had not primarily focused on quality of life. Individuals with mild cognitive impairment could benefit for a game-based approach to assessing cognition but there should be some exploration into how a game-based approach would impact an individual's quality of life.

The main area of further study however, would be into the design of video games that potentially assess cognitive processes. When the researcher reviewed the previous work in existing games and cognition, it was suggested that one game can be used to assess one specific cognitive process. However, the assessment of one cognitive process would be highly difficult to conduct as, paraphrasing Eysenck and Keane (2010), each action involves multiple cognitive processes working at the same time. As seen in chapter nine of the Potential Application in Healthcare study (section 9.3.3), each participant perceived different cognitive processes from the games of Brainplay.

Further study could consider deconstructing video games that portray cognitive processes and observing the interaction that occurs in different genres of video games. Or would suggest that further research consider the development of one game that could potentially monitor or assess multiple cognitive processes through multiple techniques and methods. Another area of further study could consider an exploration into potential costs of developing games for healthcare. This area of further study could highlight the potential costs and benefits a video game intervention should be aware of when developing into an area of serious purpose like healthcare. Furthermore, the scoping review and proceedings presented a variety of different approaches that could be taken to designing and developing games that model cognitive processes. Alternative directions could explore collaboration, single-player vs multiplayer, observing behaviour or flow as well as observing the effects of introducing artificial intelligence into a video game prototype.

Further study into video game frameworks and their global use would also be an area of interest to further study. In the MDA evaluation study, two out three of the sample group had heard of the MDA framework, where they mentioned their use of the framework. Likewise, other frameworks were suggested not to be adopted in commercial industries. A review to understand the global design and development of games would provide a bench mark to understand what designers and developers are using. Then a common design process could be suggested and applied to a serious purpose solution.

The next step of this research would be to iterate on the development of Brainplay, taking the current prototypes to a mixed background of healthcare professionals and enquire to the measures that would be desired and the method of implementation. Brainplay could then adopt an iterative process to develop video games that elicit play in its users, aim to save time for healthcare professionals, provide a cost benefit analysis for the implementation of Brainplay within different areas of healthcare and provide data that could be used to assess multiple cognitive processes.

10.2. CONCLUSION

This research set out to answer three research questions;

1. Are serious video games that are designed to assess or diagnose cognitive processes, still perceived as ‘fun’ video games?
2. Are game design frameworks necessary to the development of serious games for healthcare by commercial game developers?
3. What are the potential uses of a serious video game in healthcare?

To answer these, the researcher carried out three user studies. The first study conducted in chapter seven was undertaken to discover whether Brainplay was still perceived as a game and that it retained the notion of play and that it was a voluntary experience.

The hypotheses of the game-play evaluation study were that all of the games would be viewed positively which would suggest some notion of play was elicited from the participants. The second hypothesis was that each of the games would be scored and viewed similarly as the development of each of the games followed the same design framework.

The first hypothesis turned out correct and each game of Brainplay generated positive results from the game-play evaluation study. The results suggested that play was elicited and that the participants viewed Brainplay as a voluntary experience and not as an exercise. As discussed in the game-play evaluation study discussion (section 7.3), if Brainplay had not been perceived as game (not enjoyable and no intention to use) then it would be suggested that the serious purpose of Brainplay (potentially assessing cognitive processes) would have created the perception of a carrying out an exam or a compulsory application. Simply, Brainplay would not elicit play and would not be considered a game.

However, regarding the second hypothesis, all three games of Brainplay were not viewed the same. The results of the game-play evaluation study highlighted that Odd Ones was perceived differently to the other two games which suggested that the participant sample preferred the gameplay and experience Odd Ones offered. As each of the games was designed using the same game design framework of the MDA, it was surprising to see the population favour one game over the others. Theories on the difference in score can be found in section 7.3 referring to the design of Brainplay.

The second study aimed to answer the second research question on whether game design frameworks were necessary to the development of serious games for health. The MDA evaluation study (section 8.1) revealed that the MDA framework was not known to the whole sample. In addition, the user study suggested that game design frameworks and models are not used in commercial development. However, the two designers in the sample of three were confident in their ability to follow the design decisions that created Brainplay and attempt their own games to potentially assess cognitive processes. Each participant shared the opinion of contacting a healthcare professional to assist in the development. Thus, it can be concluded that the sample suggested a willingness to develop serious game for health, without needing the MDA framework. There may be a potential future study into understanding the barriers to development of serious games of health, whether it could be developers interest, risk to new market or lack of transparency between disciplines of game design and health.

Finally, to answer the last research question regarding the potential use of a serious game, the third study explored the potential use of Brainplay within a healthcare environment (section 9.1). The potential of healthcare study suggested that there were different interpretations of what Brainplay was trying to portray, however each participant showed a desire to see technology such as video games develop into a healthcare environment. It was suggested that games could be used to save time rather than money and that there is a concern on cost of implementation into a healthcare environment. One participant suggested the potential of Brainplay to be used within an assessment area but the inconsistency of how the games were interpreted leads to further research. Another suggestion was made that Brainplay could suit as a distraction tool in waiting rooms or potentially for those awaiting care.

This research has created a number of avenues for further study which have been suggested in this conclusion. Each avenue of research has the potential to add to the body of knowledge, evidence and literature if so desired.

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13. APPENDICES

13.1. APPENDIX 1 - SEARCH TERMS FOR GAME DESIGN FRAMEWORK REVIEW

Advanced search on NCBI

(("video games"[MeSH Terms] OR ("video"[All Fields] AND "games"[All Fields]) OR "video games"[All Fields] OR ("video"[All Fields] AND "game"[All Fields]) OR "video game"[All Fields]) AND design[All Fields] AND frameworks[All Fields]) AND "open access"[filter]

Advanced search on ACM

(+video +game +design +framework)

Search strategy for ResearchGate – MDA Citations, Video game design Frameworks

13.2. APPENDIX 2 – OVERVIEW OF FRAMEWORKS

	Paper	Author(s)	Abstract/Summary	Area of research?
1	Cognitive behavioral game design (CBGD): a unified model for designing serious games	Starks	Cognitive behavioral game design (CBGD) is a new framework that incorporates SCT, the theory of MIs, and game design elements into a unified model that guides designers through a process to create games for learning and behavioral change.	Cognition Education Serious Games flow
2	Gamification: What It Is and Why It Matters to Digital Health Behavior Change Developers	Cugelman	This editorial provides a behavioral science view on gamification and health behavior change, describes its principles and mechanisms, and reviews some of the evidence for its efficacy. Furthermore, this editorial explores the relation between gamification and behavior change frameworks used in the health sciences and shows how gamification principles are closely related to principles that have been proven to work in health behavior change technology. Finally, this editorial provides criteria that can be used to assess when gamification provides a potentially promising framework for digital health interventions.	Game Design Digital Health Behaviour
3	Engaging Elderly People in Telemedicine Through Gamification.	Vette et al	Gamification frameworks have been developed from different backgrounds-business and academia-but rarely target the elderly user. The effectiveness of user classifications for tailored game content in this context is not yet known. As a next step, we propose the development of a framework based on the hypothesized existence of a relation between preference for game content and personality.	digital Health Engagement

4	Development, Usability, and Efficacy of a Serious Game to Help Patients Learn About Pain Management After Surgery: An Evaluation Study.	Ingadottir et al	The aim of this study was to describe the development of a computer-based game for surgical patients to learn about postoperative pain management and to evaluate the usability, user experience, and efficacy of the game.	healthcare video games Digital Health
5	ENED-GEM: A Conceptual Framework Model for Psychological Enjoyment Factors and Learning Mechanisms in Educational Games about the Environment	Fjaellingsdal & Klockner	Based on a thorough review of psychological literature, this article seeks to develop a model of game enjoyment and environmental learning (Environmental Educational Game Enjoyment Model, ENED-GEM) and delineate psychological processes that might facilitate learning and inspire behavioral change from educational games about the environment.	Psychology Education flow
6	A Framework for Evidence Based Visual Style Development for Serious Games	McLaughlin, Smith & Brown	In this paper, we describe a framework for connecting computer graphics techniques and visual style in video game design with targeted learning outcomes for students. The relationship is organized on a table depicting Bloom's taxonomy of the cognitive process and categories of computer graphics	Serious Games Cognition Education

			imagery from simplified to realistic. This framework is presented as a useful way to economize design development efforts and incorporate visual development in addition to player immersion as an indicator of expected effectiveness for serious games.	
7	User Centered Game Design: Evaluating Massive Multiplayer Online Role Playing Games for Second Language Acquisition	Rankin, McNeal, Shute & Gooch	The challenge is to design and develop serious games that simultaneously create an enjoyable experience for the player as the player develops or improves her skill set as a result of game play and applies these newly developed skills in a real world setting. Because transfer of learning represents the primary goal of serious games, it is crucial that game designers understand the interactions associated with game tasks and their impact on players prior to game development. Borrowing heavily from interaction design, we introduce the user centered game design methodology as the framework for serious game design and apply this technique to the evaluation of the social interactions between Player Characters in a commercial Massive Multiplayer Online Role Playing Game.	Game Design Interaction design Serious Games
8	Game Design for Social Networks: Interaction Design for Playful Dispositions	Järvinen	Through a number of Facebook games as case studies, the author extracts a set of design principles into a design framework where interaction, social, service, and game design meet. The framework aims to support the inherent sociability, spontaneity, narrativity, and playfulness that permeate online social networks.	Game Design Interaction design Social media
9	A Framework for	Smith, Cha	Our framework provides a common vocabulary for these items and provides	level design

	Analysis of 2D Platformer Levels	& Whitehead	level designers with a method for thinking about elements of platformers and how to compose them to create interesting and challenging levels.	Game Design Game Analysis
10	Instructional Objectives to Core-Gameplay: A Serious Game Design Technique	Hall, Wyeth & Johnson	The paper describes the use of this design framework in the context of a small section of gameplay from an educational game currently in development. This demonstration of the framework demonstrates how instructional objectives can be embedded into a serious games core-gameplay	Game Design, HCI Serious Games
11	Toward an Understanding of Flow in Video Games	Cowley, Charles, Black & Hickey	The relationship between player and game, characterized by learning and enjoyment, is central to our analysis. We begin by framing that relationship within Cowley's user-system-experience (USE) model, and expand this into an information systems framework, which enables a practical mapping of flow onto game-play. We believe this approach enhances our understanding of a player's interaction with a game and provides useful insights for games' researchers seeking to devise mechanisms to adapt game-play to individual players.	design flow video games
12	Actors, elements, and innovative interfaces in game experiences: CCAE as a model for analysing game elements	Oceja & Fernandez	Our model proposes four categories (conventions, components, actions and emotions). The reason why they are represented in a 1+3 formula is that conventions historically associated with gaming (such as points, badges, rankings, but also other elements such as time constraints represented by a countdown), even though they tend to appear less often in current games (besides maybe casual games) are, paradoxically, the most frequently used elements in gamification. They are the most basic and evident elements in video game culture and their mere presence reminds users of game experiences.	Gamification Serious Games

13	From Game Design to Service Design: A Framework to Gamify Services	Klapztein & Cipolla	This article presents and describes the development of the Gamification Service Framework, an IT artefact designed to solve a class of problems related to the service field: the gamification of services. The central aim is to provide a new tool for service designers to use game design concepts in their practices, by structuring services in an analogous way to games.	Game design Services User experience
14	Player–Game Interaction and Cognitive Gameplay: A Taxonomic Framework for the Core Mechanic of Videogames	Sedig, Parsons & Haworth	We present a taxonomic framework named INFORM (Interaction design For the core Mechanic) to address this gap. INFORM employs twelve micro-level elements that collectively give structure to any individual interaction within the core mechanic. We characterize these elements in the context of videogames, and discuss their potential influences on cognitive gameplay. We situate these elements within a broader framework that synthesizes concepts relevant to game design. INFORM is a descriptive framework, and provides a common vocabulary and a set of concepts that designers can use to think systematically about issues related to micro-level interaction design and cognitive gameplay.	Cognition video games
15	Educational Game Models: Conceptualization and Evaluation	Amory & Seagram	The Game Object Model (GOM), that marries educational theory and game design, forms the basis for the development of the Persona Outlining Model (POM) and the Game Achievement Model (GAM). POM provides researchers with a means to more easily match software development with the intended audience and expected outcomes. The concrete GOM interfaces are realized in GAM which provides a convenient way to develop and document educational games. These models were developed to better understand the relationships between story, play and learning.	Game design Education Game development

16	Digital game-based learning: Towards an experiential gaming model	Kiili	Thus, in this paper an experiential gaming model that is based on experiential learning theory, flow theory and game design is presented. The model stresses the importance of providing the player with immediate feedback, clear goals and challenges that are matched to his/her skill level. The flow theory is used as a framework to facilitate positive user experience in order to maximize the impact of educational games. Especially, the factors that contribute to flow experience are discussed. The experiential gaming model can be used to design and analyse educational computer games. However, the model works only as a link between educational theory and game design and does not provide the means to a whole game design project.	Education Game Design video games Flow
17	Games, motivation, and learning: A research and practice model	Garris, Ahlers & Driskell	In this article, the authors present an input-process output model of instructional games and learning that elaborates (a) the key features of games that are of interest from an instructional perspective; (b) the game cycle of user judgments, behavior, and feedback that is a hallmark of engagement in game play; and (c) the types of learning outcomes that can be achieved. The authors discuss the implications of this approach for the design and implementation of effective instructional games.	Education Training video games Motivation
18	Critical Play: Radical Game Design	Flanagan	The critical play method introduces several crucial elements into the interactive model. Human concerns, identifiable as principles, values, or concepts, become a fundamental part of the process. While moving through the stages of the Critical Play Method, the artist, activist, or designer can reflect upon the state of his project and see if the design continues to meet the base goals set initially for the research.	Game Development Game design Iterative Research

19	Designing educational games through a conceptual model based on rules and scenarios	Zarraonandia et al.	The design of a successful educational game (EG) is a challenging task that requires a lot of knowledge and a variety of skills. EG designers not only have to deal with the inherent technical complexity of game design, but also have to be able to interweave learning activities in a way that is enjoyable and educationally effective at the same time. In order to make available the benefits of game based learning to a wider audience, it is necessary to provide means to alleviate the cost of envisioning new EG by providing tools that might contribute to make the design process easier and quicker. As a first step towards this goal, in this paper we introduce a conceptual model that organizes in a modular way and in different design perspectives the game features. In order to help EG designers, the features that are most often regarded in the literature as significant in producing engaging, fun and educational game experiences, have been included in the model through a set of design entities.	Games Design Education Game Based Learning
20	How Game thinking can revolutionize your business	Werbach & Hunter	For the win reveals how a wide range of companies are successfully using game thinking. It also offers an explanation of when gamifying makes the most sense and a 6-step framework for using games for marketing, productivity enhancement, innovation, employee motivation, customer engagement and more.	Marketing Gamification Business
21	Design and Play: A Detailed Approach to Iterative Game Design	Macklin & Sharp	This book offers a play-focused, process-oriented approach for designing games people will love to play. Drawing on a combined 35 years of design and teaching experience, Colleen Macklin and John Sharp link the concepts and elements of play to the practical tasks of game design. Using full-colour examples, they reveal how real game designers think and work, and illuminate the amazing	Iterative Game Design Play

			expressive potential of great game design.	
22	MDA: A Formal Approach to Game Design and Game Research	Hunicke, LeBlanc & Zubek	In this paper we present the MDA framework (standing for Mechanics, Dynamics, and Aesthetics), developed and taught as part of the Game Design and Tuning Workshop at the Game Developers Conference, San Jose 2001-2004. MDA is a formal approach to understanding games – one which attempts to bridge the gap between game design and development, game criticism, and technical game research. We believe this methodology will clarify and strengthen the iterative processes of developers, scholars and researchers alike, making it easier for all parties to decompose, study and design a broad class of game designs and game artefacts.	Game Design Game development Research

13.3. APPENDIX 3 - IDENTIFIED PAPERS FOR VIDEO GAMES AND COGNITION

Authors	Title	Research/Games description	Category
Anguera & Gazzaley, 2015	Video games, cognitive exercises and the enhancement of cognitive abilities	Development of hybrid interventions, between video games (including serious games) and cognition.	-Cognitive Training and Assessment
Ball et al, 2002	Effects of cognitive training interventions with older adults	Cognitive function in older adults is related to independent living and need for care. Evaluate 3 cognitive training interventions	-Cognitive training and assessment
Baniqued et al, 2013b	Selling Points: What cognitive abilities are tapped by casual video games	Comparison of web based casual games against a cognitive battery of tests to analyse the potential of video games -Miniclip games	-Cognitive Training and Assessment -Commercial Video Game Dev
Basak, Boot, Voss & Kramer, 2008	Can training in a real-time strategy videogame attenuate cognitive decline in older adults	Using real time strategy games to attempt to train older adults in executive functions.	-Cognitive training and assessment -Commercial video game
Belleville, 2008	Cognitive training for persons with MCI	Proposes the need for a well-controlled randomized trial to observe cognitive training.	-Cognitive training and assessment -MCI and Healthcare
Bouchard et al, 2012	Developing serious games specifically adapted to people suffering from Alzheimer	Guidelines on designing serious games for elderly MCI people. -Prototype touch and click adventure (attempt to address the idea of transfer)	-Video Game based Research -MCI and healthcare

Chandra et al, 2016	Playing Action Video Games, a Key to Cognitive Enhancement	Analysing the impact of training on improvement in cognitive abilities and performance.	-Cognitive Training and Assessment
Coppola et al, 2013	Applying Mobile application development to help dementia and Alzheimer patients	The use of tablet based apps in the scope of helping improve quality of life of patients with AD or dementia.	-Cognitive training and assessment -Quality of life
Dobrowolski et al, 2015	Cognitive Enhancement in Video game players	The role of the video game genres in cognitive enhancement	-Cognitive Training and Assessment -Video Game based research
Fukui et al, 2015	Computerized Touch Panel Screening tests for detecting MCI and Alzheimer's Disease	A prototype screening test for MCI and early stage dementia.	-MCI and Healthcare -Cognitive training and assessment
Gamberini et al, 2006	Playing for a real bonus	Overview of recent game-based application for therapy and rehabilitation of elderly people. - Eldergames	-Potential of video games -Cognitive training and assessment
Garcia-Casal et el, 2016	Computer-based cognitive interventions for people living with dementia	Estimating the efficiency of computer-based cognitive interventions for improving cognition in people with dementia	-MCI and Healthcare -Cognitive training and assessment
Green & Bavelier, 2006	The Cognitive Neuroscience of Video Games	Explores the relation between video games and cognition, such as spatial skills, visual attention etc.	-Cognitive training and assessment -Potential of

			Video games -MCI and Healthcare -Video Game based research
Hackner & Lankes, 2016	Mindtraining: Playful interaction techniques for people with dementia	Gestures and interactions as a mechanic for tablet devices with people with dementia. -App developer Mindtraining	-Video Game Based Research -Exercise and physical interaction
Joddrell & Astell, 2016	Studies involving people with dementia and touchscreen technology: A literature review	The review presents an emerging body of evidence for tablet technology and people with dementia. Demand for independent activities on tablet technology for meaningful occupation, entertainment and fun.	-MCI and Healthcare -Cognitive training and assessment
Kramer & Erickson, 2007	Capitalizing on cortical plasticity	Review of papers on physical activity and exercise in relation to cognitive functions -References Nintendo's Brain training	-Exercise and physical interaction -MCI and healthcare
Lumsden et al, 2016	Gamification of Cognitive Assessment and Cognitive Training	Gamification as a solution to participant disengagement in cognitive tasks.	-Cognitive training and assessment
McCallum & Boletsis, 2013a,	A Taxonomy of Serious Games for dementia	Proposes serious games for dementia as a genre within games for health.	-MCI and healthcare - Video Game based research -Potential of Video Games
McCallum & Boletsis,	Dementia Games: A	A literature review of research and commercial based video games	-Video Game based research

2013b	literature review of dementia-related Serious Games	available for dementia patients	-MCI and healthcare
Mishra, Anguera & Gazzaley, 2016	Video Games for Neuro-cognitive Optimization	Sophisticated video games that integrate cognitive training with real-time bio-sensing and neuro-stimulation.	-Cognitive Training and Assessment -MCI and Healthcare
Nezerwa et al, 2014	Alive Inside: Developing Mobile apps for the cognitively impaired	Mobile app Alive inside, created to help improve quality of life for those with Alzheimer's disease.	-MCI and healthcare -Quality of life and wellness -Video game based research
Oei & Patterson, 2014	Playing a puzzle video game with changing requirements improves executive functions	Examining executive function before and after over 4 commercial video games.	-Cognitive Training and Assessment -Commercial Video Game Dev -Video Game based research
Stanmore et al, 2017	The effect of active video games on cognitive functioning in clinical and non-clinical populations	Observing the effects of exergames and cognitive impairment.	-MCI and Healthcare - Video Game based research -Exercise and physical interaction
Tarraga et al, 2006	A randomised pilot study to assess the efficacy of an interactive,	The usefulness of an interactive multimedia internet based system for cognitive stimulation of Alzheimer's disease.	-MCI and healthcare -Cognitive training and assessment

	multimedia tool of cognitive simulation in Alzheimer’s disease		
Van de Weijer, 2016	The Parkin’Play Study	Randomized trial to assess the effects of a health game on cognition in Parkinson’s patients.	-MCI and Healthcare - Video Game based research
Vasconcelos et al, 2012	Designing Tablet-Based Games for Seniors	Analysis and design of a tablet based gaming platform that promotes quality of life -Game-book & tablet based game Cogniplay	-Cognitive training and assessment -Quality of life and Wellness -Video Game based research

13.4. APPENDIX 4 – DESCRIPTIONS OF APPLICATION PROCESSES

Cognitive Training and Assessment

The most predominant theme that could be seen throughout the literature is the focus on cognitive training and assessment. The theme encompasses articles that targeted to ‘enhance’, ‘train’ or ‘assess’ cognition. A total of 18 articles out of the total 25 demonstrated an interest in assessing or observing cognition in video games.

Of these, some articles such as Tarraga et al (2006) and Belleville (2008) were interested in conducting randomized pilot studies to assess the effectiveness of video games for cognitive training. Belleville suggested the need for a uniform study, whereas Tarraga et al’s research suggested that the interactive multimedia tool provided an improvement above expectation. Along with the other literature inclusive of this theme, there is a dedicated support for video games being used as training or assessment, often for older people and particularly those with mild cognitive impairment. Ball et al study (2002) investigated three existing cognitive intervention training methods that support the effectiveness of cognitive interventions.

Most of these articles also suggested a follow up investigation was required to investigate the potential ‘transfer’ towards everyday life. ‘Transfer’ refers to the cognitive training being applied from an intervention towards daily activities. Bouchard et al (2012) proposed a method for developing serious games that can train cognitive abilities by keeping players within their ‘flow state’ (Csikszentmihalyi, 2002). Bouchard et al (2013) proposed guidelines and then developed a point and click adventure style game to simulate making breakfast. It is the only article in this review to suggest a step towards transfer.

Commercial Video Game Development

The following theme was selected to highlight and identify where a body of research had explored commercial video games and their possible use in games for cognition. This thesis is interested in observing how other researcher had selected commercial games and what cognitive processes had been associated with specific video game genres.

Only three articles were identified from the review that utilized commercial video games within the research. The most interesting article to the research was the Baniqued et al article (2013b) that enquired to what cognitive abilities are tapped by casual games. The research observes existing web based mini-games and their possibility as a training tool. The selected games and cognitive battery tasks were compared on a basis of their performance. Cognitive processes such as processing speed, memory, language and reasoning were observed in one session from cognitive task analysis. Games were then categorized using cognitive task analysis by cognitive psychologists. For example, *Memocubes* is a game of matching forms and colours of cubes and was grouped as a working memory task. While this study did not advocate to present evidence for cognitive training, the commercial game described provide some suggestions for how to design video games that are similar.

Basak et al (2008) utilized a commercial strategy game to observe the effect on working memory, perception and task switching. Their results discovered participants improved on cognitive tasks after playing the commercial strategy game.

MCI and Healthcare

This theme identified articles that were concerned with video games and cognition within a healthcare setting. These articles were focused on a mild cognitive impairment disease such as Alzheimer's or Parkinson's. This thesis is interested to see how the body of knowledge reflected the need of healthcare.

Of the total 25 articles, 14 demonstrated involvement within healthcare. The main body of these articles were concerned with delivering games and technology that could help with dementia. The majority were articles similarly referenced in the theme of cognitive assessment and training however there were a few exceptions that explored a different angle. Mishra, Anguera and Gazzaley (2016) explored video games for cognition in a different aspect, primarily looking at real-time bio sensing and the brain stimulation from games that incorporate cognition.

An interesting study to note is the Parkin' Play study by Van de Weijer et al (2016) which conducted a randomised controlled trial to assess the effects of a health game. The study used a developed game *Aquasnap* to monitor cognitive processes. The study evaluated a new possible non-pharmacological method for better understanding cognitive impairment in Parkinson's, opposed to trying to provide a method of assessment. The direction of the Parkin'Play study is similar to the objective of this research which is to better understand the use of video games within a healthcare setting.

Video Game Based Research

The following theme identifies studies and articles that were conducted to further understand video games and their relation to cognition. The theme is also inclusive of articles that further the understanding of game design principles in relation to cognitive psychology as well as the development of serious games.

A total of 11 articles were identified that contribute to video game based research. One of the papers, Bouchard et al (2012) as previously discussed for its attempt to address ‘transfer’ also demonstrates the methods of game design through the principles of flow (Csikszentmihalyi, 2002).

Dobrowolski et al (2015) interestingly looks into the role of the video game genre within cognitive psychology. As there have been studies into casual games, strategy games and action games, Dobrowolski et al research proposed to observe the difference in cognitive ability dependent on the video game genre. Dobrowolski et al also argue that the ‘action’ genre is too vague as it can encompass a few genres such as ‘clicker games’, ‘shoot-em-ups’, ‘adventure’ and many others. The study observed both first person shooters and real-time strategies on their cognitive abilities and found different video game genres attribute various levels of cognitive ability.

Hackner & Lankes (2016) argued a different approach to mechanics in video games, whereby they utilised video games and physical gestures as a method of input. Their app, *Mindtraining,* was an interactive application that required gestures to complete games/tasks for people with dementia. Their research discovered a lack of recommendations when it came to touch screen devices and new interaction techniques (Hackner & Lankes, 2016).

Exercise and Physical Interaction

Perhaps one of the smallest themes that arose, the prevalence of innovative technology has begun to give rise to ‘exergames’ or games that utilise a different physical interaction, as described before in Hackner and Lankes study before (Hackner & Lankes, 2016). Utilising a game mechanic of gestures provides both a different method of interaction, but also a form of exercise.

Other than Hackner & Lankes (2016) research, there is only two other papers that reference some association with exercise. The literature review by McCallum and Boletsis (2013b) discusses the use of existing games that can be used for dementia care, citing commercial video games such as the Wii Fit (Nintendo, 2017) that are used in some studies. Outside of the review, there is Stanmore et al research into exergames (Stanmore et al, 2017) and Kramer & Erickson review on articles that utilise physical activity to observe cognitive function (Kramer & Erickson, 2007).

Stanmore et al discovered that exergames improved executive functions, attentional processing and visuospatial skills (perception and attention processes) (Stanmore et al, 2017). The research found substantial evidence that exergames lead to an improvement to global cognition. Kramer and Erickson’s study argues that video games such as *Nintendo’s Brain Age (*Nintendo, 2017*)* may not deliver cognitive improvement due to most commercial games having a financial stake in their success (Kramer & Erickson, 2007). Kramer and

Erickson follow up their argument that exergames can also be expensive whereas exercise is nearly accessible to everyone. Their findings from their review suggest that physical exercise enhances cognitive function, suggesting a physical interaction could offset or protect against cognitive decline (Kramer & Erickson, 2007).

Quality of Life and Wellness

A rather important theme was to identify which articles considered the wellness of the intended audience, whether for children, those with learning difficulties or those with MCI. This thesis wishes to observe how many articles considered the quality of life of the intended audience.

Only 3 of the 25 articles highlighted an interest in observing or investigating the quality of life regarding video games and cognition. Vasconcelos et al study was focused on the development of a physical game book and then the development of a prototype, *Cogniplay* (Vasconcelos et al, 2012). Vasconcelos et al wanted to observe the cognitive enhancement of their prototype, but were more concerned with the quality of life a serious game could offer. Their study showed that senior users of *Cogniplay* could easily use the tablet device and video game and expressed an interest in the future use. Vasconcelos et al also argue ten rules of thumb that could be applied to other studies which argue the use for tablet devices, the need for a senior adapted interface, customization in games, social interaction, engaging goals, instant feedback and immediate rewards (Vasconcelos et al, 2012). The latter of these goals are often covered by basic game design frameworks, discussed previously in this chapter.

Another supporting article for quality of life is the *Alive Inside* project by Nezerwa et al (2014). The study is a student led development of a mobile app, Alive Inside, which utilises music in the app to promote reminiscence for people with Alzheimer's disease (Nezerwa et al, 2014).

Potential of Video Games

This theme considers the exploratory fields of video games and cognitive psychology, where articles have shown an experimental venture towards the body of research outside of the themes already listed above. This theme wishes to know where else video games for cognition are used outside of training and assessment.

Of the identified articles, only 3 indicated a possible different direction for video games and cognition.

Starting with the most renowned and cited study by Green and Bavelier (2006), who have conducted multiple studies into video games and cognition, specifically around action games and the comparison to cognitive tests. Their study identified in this research investigates the cognitive neuroscience of video games (Green and Bavelier, 2006). The article puts forward examples of video games that demonstrate cognitive ability. Their article also discusses and argues that video game play greatly enhances visuo-motor skills, such as improving reaction speed and hand-eye coordination (Green and Bavelier, 2006).

Green and Bavelier also argue that although the benefits are evident, there are many questions that need to be addressed, particularly which characteristics of a video game train a function. They also argue the need to ensure that cognitive training through games does not impact the social or emotional level of an individual in a negative aspect, such as someone becoming stressed or addicted to a gaming platform (Green and Bavelier, 2006).

McCallum and Boletsis present a taxonomy of serious games and describe the various avenues that video games for cognition have been applied for in addition to their other paper on a literature review of dementia games (McCallum and Boletsis, 2013a). They present serious games for dementia as a standalone genre and describe four game types that can classify a game for cognition: preventative, rehabilitation, educative and assessment.

Surprisingly, McCallum and Boletsis discovered a lack of games specifically developed to assess cognition. This is probably as most instances of assessing cognition are often done by comparing their cognitive ability rather than a game that directly assesses cognition (McCallum and Boletsis, 2013a). Boletsis and McCallum also argue that there is a lack of video games for educating individuals to cognition, except in the instance of some dementia awareness games.

Finally, the study by Gamberini et al discusses the current technologies available to elderly people specifically. They also present a project, *Eldergames*, which attempts to bridge the gap between cognitive training and sociability in elderly users (Gamberini et al, 2006). They argue the advantage of video games allows users to overcome physical impairments that limit participation in real social life; this argument contradicts the arguments put forward by exercise and physical interaction studies.

13.5. APPENDIX 5 – EXISTING GAMES ASSOCIATED WITH COGNITIVE PROCESSES

Cognitive Process	Existing games/research examples	Suggested game mechanics/game genre	Overall
Working Memory	SmartBrain (Educamigos, 2017 cited by McCallum & Boletsis, 2013b) - pairing flags, finding odd object, path finding, counting moving objects, rejecting shapes	Memory Mah-jong style game Matching puzzle game Spot the difference	Mainly a focus on the puzzle genre. Association of matching and comparing objects or entities. Most require some part of remembering a pattern or position.
	AquaSnap (Van de Weijer et al 2016)	Remember the position of the last object and tracking positions	
	Memotri (Platina Games cited by Baniqued et al 2013b)	Uncover three cards, remember the specific items associated with each. Attempt to identify all three in a single trial.	
	Simon Says (Neave.com cited by Baniqued et al 2013b)	Replicate light and sound conjunction patterns played in each level	
	Memocubes (Platina Games cited by Baniqued et al 2013b)	Nine cubes with different forms. Match forms of the same colour and shape.	
	Round Table (Platina Games cited by Baniqued et al 2013b)	A table hides a covered grid. Reveals marbles and the challenge is to remember the position of the marbles with each rotation.	
	Oddball (Armor Games cited by Baniqued et al 2013b)	Identify each object before the time runs out from the reference image given.	
	The Ryokansan (Ohtsu Computer cited by Fukui et al 2015b)	Flipping cards game, memorise positions.	

	Cogniplay (Vasconcelos et al 2012)	Mimic game, matching photos of known people to identical photos or even significant others.	
Long Term Memory	AquaSnap (Van de Weijer et al 2016)	Remembering objects and instances over the whole game play session	Using common knowledge as a challenge to the player or a given set of time to assess a player's long-term memory
	The Ryokansan (Ohtsu Computer cited by Fukui et al 2015)	Recite an old childhood story by touching panels in order of the narrative.	
Perception	Digital Switch (Miniclip cited by Baniqued et al 2013b)	Change colour of robots to catch specific falling colours to score	Acts of searching and a lot of association with processing. Identifying an objective or threat and acting on it.
	Crashdown (Miniclip cited by Baniqued et al 2013b) (also associated with processing speed)	Players prevent the wall from reaching the top of the display by selecting bricks that share the same colour (Tetris meets brick break)	
	25 Boxes (Platina Games cited by Baniqued et al 2013b) (also associated with processing speed)	Two set of matrices presented. Player searches for a character found in the first and the second	
	Phage Wars (Armor Games cited by Baniqued et al 2013b) (also associated with processing speed)	Spread parasites and overtake other parasites to become dominant	
	Alpha-attack (Miniclip cited by Baniqued et al 2013b) (also associated with processing speed)	Players prevent bombs falling on the character by reading the character and pressing the corresponding key	
	Jungle App (Coppola et al, 2013)	Select the reference animal hidden in the display	

Attention	SmartBrain (Educamigos, 2017) - pairing flags, finding odd object, path finding, counting moving objects, rejecting shapes, look for the ball, finding the odd drawing	Mah-jong style game Matching puzzle game Spot the difference Pattern recognition Finding differences	Multitasking and distraction are apparent in the examples for games associated with attention. Usually involving an objective and some object to mislead or distract the player.
	Wii Sports (McCallum & Boletsis, 2013 citing Weybright, Dattilo, Rusch, 2010) – Motion sensor sport games	Motion controlled tennis, bowling, baseball	
	AquaSnap (Van de Weijer et al 2016)	Capturing a group on objects and avoiding the incorrect answer	
	Filler (Knogregate.com cited by Baniqued et al 2013b)	Player has to fill 2/3 of the screen by creating new balls while avoiding bouncing balls	
	Enigmata (maxgames.com cited by Baniqued et al 2013)	Navigate a ship through space. Collect power ups and destroy opponents	
	Dodge (Armor Games cited by Baniqued et al 2013b)	Dodge missiles chasing the player's ship. Make missiles collide with each other.	
	Cathode (Armor Games cited by Baniqued et al 2013b)	Navigate a space while tracing a shape and avoiding enemies	
	Music Catch 2 (reflexive.com cited by Baniqued et al 2013b)	Aim is to catch certain shapes appearing on the screen while avoiding certain notes and shapes	
	Tom Clancy's Rainbow Six: Vegas 2 (Ubisoft cited by Chandra et al 2016)	First person shooter. Objectives and fast pace combat.	

	The Ryokansan (Ohtsu Computer cited by Fukui et al 2015)	Find mistakes (spot the difference images)	
	The Ryokansan (Ohtsu Computer cited by Fukui et al 2015)	Beating Devils, tap the devils when they appear, avoid the people.	
Processing Speed	AquaSnap (Van de Weijer et al 2016)	Task of capturing an image of multiple objects	Reference within perception and attention. Often featured as a time restriction or the speed an individual takes to complete a task
Thinking and Reasoning	AquaSnap (Van de Weijer et al 2016)	Quick shot while avoiding the incorrect answer	Given a problem and a limited control on how to deal with the problem. Learning the method and then providing a solution.
	Silversphere (Miniclip cited by Baniqued et al 2013b)	Maze puzzle and creating safe paths	
	Bloxorz (Miniclip cited by Baniqued et al 2013b)	Rotating a moving shape to fit the desired shape to complete the puzzle	
	Sushi-Go-Round (Miniclip cited by Baniqued et al 2013b)	Learn the recipes, complete orders and objectives to earn score.	
	Blobs (Miniclip cited by Baniqued et al 2013b)	Puzzle jumper. Only one blob an move at a time and in a specific direction. Micromanagement	
	TwoThree (Armor Games cited by Baniqued et al 2013b)	Shoot down rapidly presented numbers by subtracting them exactly down to zero.	
Language	SmartBrain (Educamigos, 2017) –	Puzzle Scrabble type puzzle	Trivia and puzzle genre

	ordering words, arranging letters, word bingo, writing words, naming tasks	Writing task	again with a focus on the written word. Whether searching for the word or writing the given answer.
	Mindtraining (Hackner and Lankes 2016) – Wordplay quiz	Quiz Word search	
	Cogniplay – Word Play (Vasconcelos et al 2012)	Matching words, spelling words and word association games.	

13.6. APPENDIX 6 – UX TEST CASE AND OBSERVATION LOG

The researcher created a UX test case to utilize the personal quality assurance experience in creating a functional video game. The test case also included an observation log to note any specific observation with participants. The example below detailed an early test of Match-Ups bugs before the user studies.

	Known bugs		
	Date:	Number of current bugs	
		2	
	Test Case	**Number of Occurences (number)**	**Notes**
	Bug		
1	A bug occured that briefly interrupted gameplay	0	
2	A bug occured that caused the user to comment on	0	
3	A bug occured that caused the game to be restarted	1	Match Up - Tiles are tapped that do not flip - Update, also happens when a match is made quickly
4	A bug occured that caused the whole application to be restarted	0	
5	A bug occured that affected the final score in the game	0	
6	A bug occured that affected the final time in the game	1	Match Up - Samsung Tablet Device loading time for game overlaps into game timer. The result is the player loses 7-10 seconds and not able to play the game.
7	A bug occured that caused confusion in the gameplay	0	
8	A bug occured that caused the device to freeze	0	
9	A bug occured that affected the players input (control) of the game	0	
	Controls		
10	The user was unsure with how to progress in the game	0	
11	The user was unsure with how to utilize the controls	0	
12	User comments on not knowing what to do	0	
13	User comments on the controls not working	0	
14	User comments on the controls being too difficult	0	
15	The user becomes fustrated with the controls of the device	0	
	User		
17	The user looked to the researcher for help		
18	The user needed the researchers help to progress		
19	The user talked about the game with the researcher		
20	The user questioned the researcher about the game (positively)		
21	The user questioned the researcher about the game (negatively)		
	Immersion		
22	The user appeared immersed in the game for a couple of minutes		
23	The user appeared immersed in the game for an estimaed 5 minutes		
24	The user appeared immersed in the game for longer than 5 minutes		
25	The user was immersed between progressing through a game to the next		
26	The user appeared to be fully concentrating on the game		
27	The user did not appear immersed (The user appears bored at the device)		
28	The user ignores the game		
29	The user refuses to use the game		
30	The user has no interest in playing the game		
31	An error occured with the device that broke the users immersion		
	The device locked and caused the player to become 'ejected' from the experience.		
	Other		
33	The user could no longer play the game (forfeit)		
34	Outwith circumstances ended the gameplay		
35	The user complained about the game and did not wish to continue		
36	The user felt ill playing the game		
37	The user complained at the surveys		
38	The user found the experience too challenging or fustrating		
	Use the space below to add other observations		
39			

13.7. APPENDIX 7 – BRAINPLAY SOURCE FILES AND LINKS

Brainplay Source Files : https://mikethingsbetter.itch.io/brainplay (These files allow Brainplay to be downloaded and run in Unity 5.

Brainplay Web Browser Version: https://mikethingsbetter.itch.io/brainplay

Brainplay Gameplay Trailer: https://youtu.be/LWNESlYqjWE

13.8. APPENDIX 8 – HMSAM QUESTIONS [STUDY 1]

Digital Link: https://strathsci.qualtrics.com/jfe/form/SV_6sVDx57YsULhwUt

HMSAM - Brainplay

User Experience Questionnaire

The following survey was created from the Hedonic motivation system acceptance model (HMSAM) developed by Lowly et al (2012). The HMSAM was a developed framework of the Technology Acceptance Model TAM that aimed to gather a person experience of a product/service.

Participant Number:

I found playing the game/intervention to be enjoyable

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

I had fun using the intervention

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

Using the intervention was boring

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

The experience really annoyed me

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

The experience was pleasurable

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

The experience left me unsatisfied

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

I had a lot of control

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

I could choose freely what I wanted to see or do

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

I had little control over what I could do

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

I was in control

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

I had no control over my interaction

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

I was allowed to control my interaction

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

I was able to block out most other distractions

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

I was absorbed in what I was doing

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

I was immersed in the game

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

I was distracted by other things very easily

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

My attention was not diverted very easily

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

Time appeared to go by very quickly using the game/intervention

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

I lost track of time when I was playing the game/intervention

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

Time "flew" when I played the game/intervention

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

This experience excited my curiosity

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

This experience made me curious

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

This experience aroused my curiosity

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

My interaction with the experience was clear and understandable.

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

Interacting with the experience did not require a lot of mental effort.

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

I found the experience to be trouble free.

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

found it easy to get the game/intervention to do what I want it to do.

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

Learning to operate the game/intervention was easy for me.

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

It was simple to do what I wanted with the game/intervention.

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

It was easy for me to become skilful at using the game/intervention.

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

I found the game/intervention easy to use.

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

The experience decreased my stress

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

The experience helped me better pass the time

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

The experience provided a useful escape

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

The experience helped me think more clearly

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

The experience helped me feel rejuvenated.

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

I would plan on using the game/intervention in the future.

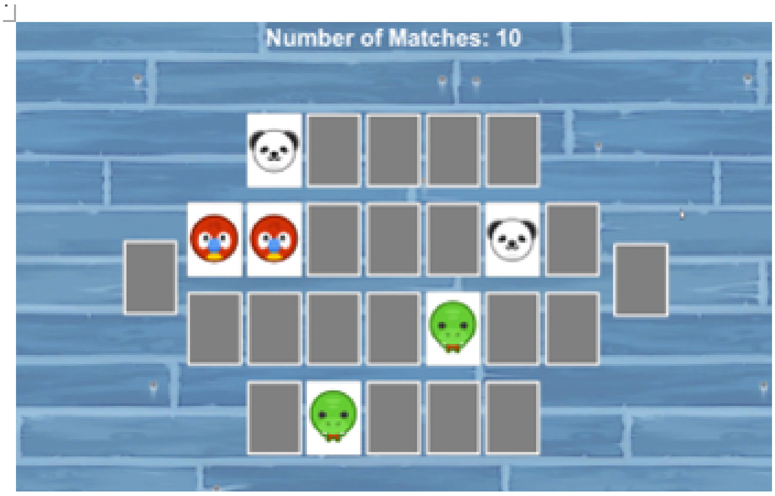
	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

I would intend to continue using the game/intervention in the future.

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍

I expect my use of it to continue in the future.

	Likert Scale						
	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Neither Agree or Disagree (4)	Somewhat Agree (5)	Agree (6)	Strongly Agree (7)
Odd Ones (1)	❍	❍	❍	❍	❍	❍	❍
Match Up (2)	❍	❍	❍	❍	❍	❍	❍
Which Word? (3)	❍	❍	❍	❍	❍	❍	❍



USER EXPERIENCE FOR VIDEO GAMES

Call for participants.

Looking for Volunteers to participate in a study of user experience in an experimental prototype.

30 - 40 minutes of your time required.

Volunteers required over age 18.

Sessions are accompanied by user experience questionnaire of 42 items. Recorded data is anonymous.

Participants receive a £10 Love-to-Shop voucher for their time and taking part.

Tablet based video game

User Experience Evaluation

All tools and tech supplied

Researcher
Michael Saiger
Room 12.13, 16 Richmond St, Glasgow, G1 1CQ

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Supervisors
Dr Marilyn Lennon
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13.10. APPENDIX 10 – DEMOGRAPHIC QUESTIONNAIRE [STUDY 1]

See link for digital survey: https://strathsci.qualtrics.com/jfe/form/SV_3O9MiYUBIODcKiN

Demographic Questions

Thank you for participating in this survey. Before you begin, make sure you have read and signed the consent form(s) before proceeding. The following survey contains non-compulsory questions. Questions you are not comfortable with can be skipped

Participant Number:

Select your gender

- ❍ Male (1)
- ❍ Female (2)
- ❍ Undisclosed (3)
- ❍ Other (4)

What is your age?

Select which statement is true for you regarding familiarity with technology

- ❍ I am highly proficient in the use of mobiles, tablet devices and computers (1)
- ❍ I am a frequent user of mobiles, tablet devices and computers (2)
- ❍ I am still learning to use mobiles, tablet devices and computer (3)
- ❍ I rarely use mobiles, tablet devices or computers (4)
- ❍ I avoid technology such as mobiles, tablet devices and computers as much as I can (5)

What technology do you own, or have access to, in your home? (Select multiple answers if applicable)

- ❑ Desktop Computer (1)
- ❑ Games Console (Xbox, PlayStation, Nintendo) (2)
- ❑ Handheld Console (Nintendo DS, PlayStation Portable) (3)
- ❑ Laptop (4)
- ❑ Smartphone (Mobile) (5)
- ❑ SmartTV (6)
- ❑ Sound System (7)
- ❑ Tablet device (e.g. iPad) (8)
- ❑ Other (9) ____________________

Have you used a tablet device before?

- ❍ Definitely yes (1)
- ❍ Probably yes (2)
- ❍ Might or might not (3)
- ❍ Probably not (4)
- ❍ Definitely not (5)

In the past 30 days, have you used your tablet device to do any of the following activities? (Please select all that apply.)

- ❑ Send or receive email (1)
- ❑ As a modem or internet hub for other devices (2)
- ❑ Connect to another device using Bluetooth (3)
- ❑ Manage social media accounts (e.g. Facebook, Twitter, LinkedIn) (4)
- ❑ Stream audio content (e.g. music, news, podcasts) (5)
- ❑ Stream video content (e.g. movies, television, news) (6)
- ❑ Purchase a product or service online (7)
- ❑ Download an application (8)
- ❑ Participate in a video call or chat (9)
- ❑ Read news stories (10)
- ❑ Use navigation or location-based information (Google maps) (11)
- ❑ Search for a product or service (12)
- ❑ Control a household device (e.g. thermostat, television, house alarm, etc.) (13)
- ❑ Record video or sound (14)
- ❑ Take a picture (15)
- ❑ Play a Video Game (16)
- ❑ I do not do any of the above activities and/or do not own a mobile device (17)
- ❑ Other (18) ____________________

What is highest level of education you have completed?

Have you ever played any video games on any device or platform? (Mobile, games console, PC etc.)

- ❍ Definitely yes (1)
- ❍ Probably yes (2)
- ❍ Might or might not (3)
- ❍ Probably not (4)
- ❍ Definitely not (5)

If you can recall any video games you have played, could you recall the names or genre of games you played and why you played them?

In the past 7 days, roughly how many hours have you spent playing video games (e.g. gaming consoles, mobile phones, computers, etc.)?

- ❍ None (1)
- ❍ 1 to 3 hours (2)
- ❍ 4 to 6 hours (3)
- ❍ 7 to 9 hours (4)
- ❍ 10 hours or more (5)

13.11. APPENDIX 11 – PARTICIPATION AND CONSENT FORM FOR GAME-PLAY EVALUATION [STUDY 1]

Participant Information Sheet for Game-Play Evaluation study

Name of department: Computer and Information Sciences- University of Strathclyde

Title of the study: Brainplay: An Investigation of Serious Games that Tap into Cognitive Processes

Introduction

The researcher, Michael John Saiger, is a postgraduate student undergoing a MPhil in Digital Health and Wellness within the department of Computer and Information Sciences, University of Strathclyde.

Participants can contact the researcher via email, Michael.saiger@strath.ac.uk.

What is the purpose of this investigation?

The primary aim of the study is to explore the feasibility of video games, designed from the mechanics dynamics aesthetics framework (MDA) as a potential for cognitive application. This phase of the research/ study will ask participants to fill out a demographic survey. They will then participate in playing the video game prototype ‘Brainplay’, designed from the MDA framework. After completing both the video game-play, participants will be asked to complete a hedonic motivation system acceptance model (HMSAM) to measure their user experience.

Do you have to take part?

The expectation is that if the participant agrees to complete the questionnaires, demographic and user experience (HMSAM) as well as play the developed prototype, Brainplay. Participants will try to answer all questions and give full detailed responses where they can. Participants can choose to not answer questions on both the demographic and HMSAM questionnaire if they are not comfortable answering the question.

What will you do in the project?

The demographic data will provide a background on the participant's information which will be useful in identifying anomalies or themes in the results. The HMSAM data will provide discussion into the response of Brainplay, and whether it is still enjoyed as a video game.

Location of the study will be conducted within the University of Strathclyde Livingston Tower building, or at a prior agreed location.

The demographic questionnaire is comprised of 10 questions which should take no longer than 5 minutes to complete. There is an allocated time of 15-20 minutes to play through the prototype mini- games and complete the user experience questionnaire for each mini-game. Participants will complete each game three times to ensure the participant establishes an understanding and opinion of the video games.

The user experience questionnaire is a series of 42 multiple choice statements for each of the games, with a 7-point Likert scale ranging from 'strongly agree' to 'strongly disagree'. In total, there are 126 multiple choice questions.

Why have you been invited to take part?

The main aim is to assess whether games, designed from the MDA framework, intended to be used in cognitive applications are still perceived as a 'game'. It is hoped that Brainplay retains the definition of a game, that it is a voluntary experience to overcome unnecessary obstacles.

What are the potential risks to you in taking part?

There is minimal risk to a participant in this study. The demographic questionnaire does not enforce participants to answer, however participants are encouraged to answer all questions. Missing data in the demographic survey does not impact the analysis of the main aim.

The risk associated with the video game is like the risk with any video game platform. In recruitment, a participant should be notified that individuals with a history of photosensitive epilepsy should not take part in the study.

Participants who cannot provide informed consent, not signing the accompanying consent form, then they will not be included in the study.

What happens to the information in the project?

All details regarding the participants' demographic data, game-play scores and user experience data will be kept confidential and anonymous.

Codes will be used to help the research team identify each participant.

Data will be stored on the secure cloud storage system StrathCloud (Sharefile). Any physical notes will be scanned into digital storage and then stored. The data will be stored for 10 years to allow follow up research.

The University of Strathclyde is registered with the Information Commissioner's Office who implements the Data Protection Act 1998. All personal data on participants will be processed in accordance with the provisions of the Data Protection Act 1998.

Thank you for reading this information – please ask any questions if you are unsure about what is written here.

Researcher contact details:

E: michael.saiger@strath.ac.uk

University of Strathclyde, School of Computer Science

Room 12.13, 16 Richmond St, Glasgow G1 1XQ

Chief Investigator details:

Marilyn Lennon

Marliyn.Lennon@strath.ac.uk

Senior Lecturer, Computer and Information Sciences

University of Strathclyde

Room 1311a Livingstone Tower

Tel 0141 548 3098

Martin Halvey

Martin.Halvey@strath.ac.uk

Lecturer (Assistant Professor)

Course Director MSc/PgDip Information Management

Department of Computer and Information Science

University of Strathclyde, UK

This investigation was granted ethical approval by the University of Strathclyde Ethics Committee.

If you have any questions/concerns, during or after the investigation, or wish to contact an independent person to whom any questions may be directed or further information may be sought from, please contact:

Secretary to the University Ethics Committee
Research & Knowledge Exchange Services
University of Strathclyde
Graham Hills Building
50 George Street
Glasgow
G1 1QE

Telephone: 0141 548 3707
Email: ethics@strath.ac.uk

Consent Form for Study Intervention

Name of department: Computer and Information Sciences

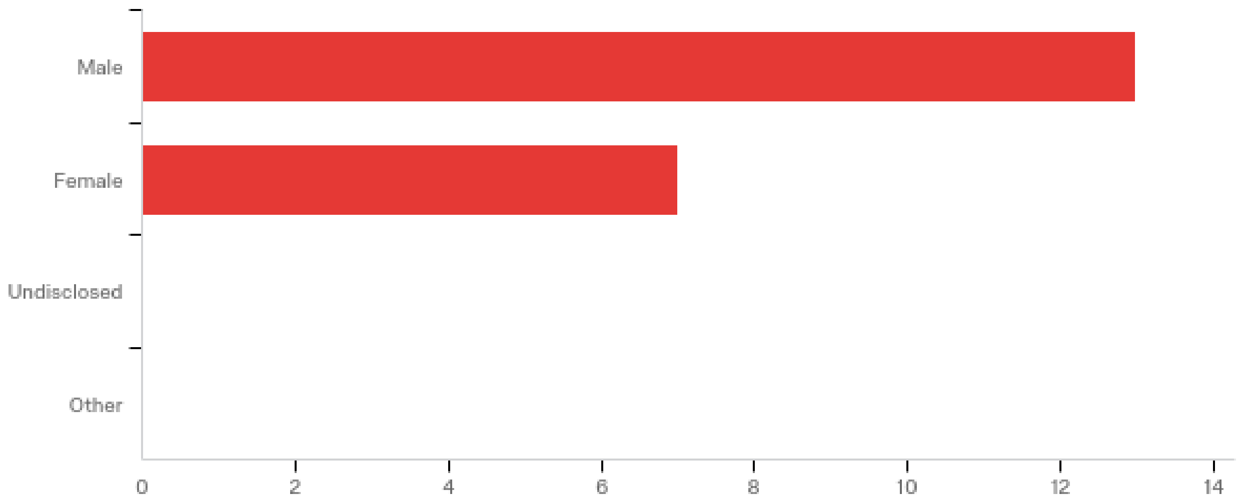
Title of the study: Brainplay: An Investigation of Serious Games that Tap into Cognitive Processes

- I confirm that I have read and understood the information sheet for the above project and the researcher has answered any queries to my satisfaction.
- I understand that my participation is voluntary and that I am free to withdraw from the project at any time, up to the point of completion, without having to give a reason and without any consequences.
- I understand that anonymised data (i.e. .data which do not identify me personally) cannot be withdrawn once they have been included in the study.
- I understand that any information recorded in the investigation will remain confidential and no information that identifies me will be made publicly available.
- I consent to being a participant in the project

(PRINT NAME)	
Signature of Participant:	Date:

13.12. APPENDIX 12 – DEMOGRAPHIC RESULTS

Q1 - Select your gender

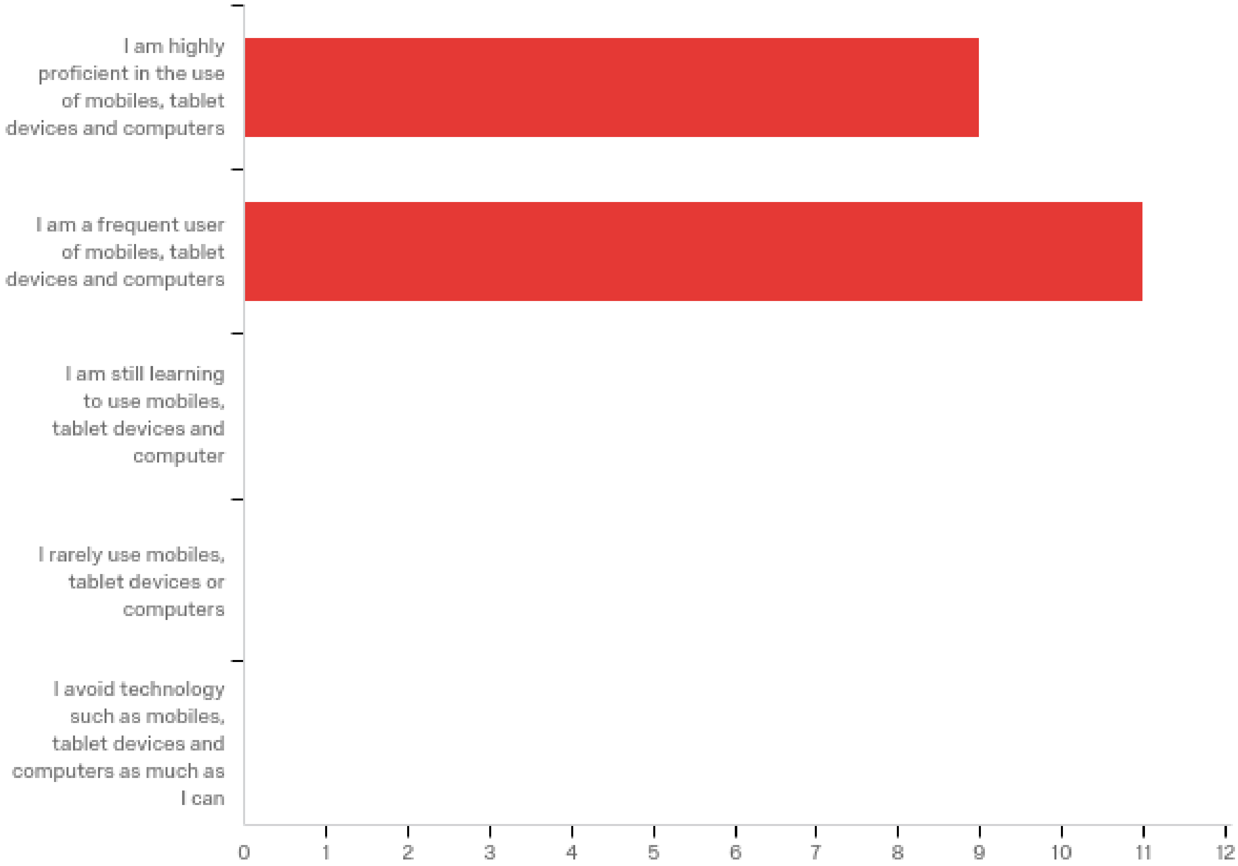


#	Answer	%	Count
1	Male	65.00%	13
2	Female	35.00%	7
3	Undisclosed	0.00%	0
4	Other	0.00%	0
	Total	100%	20

Q2 - What is your age?

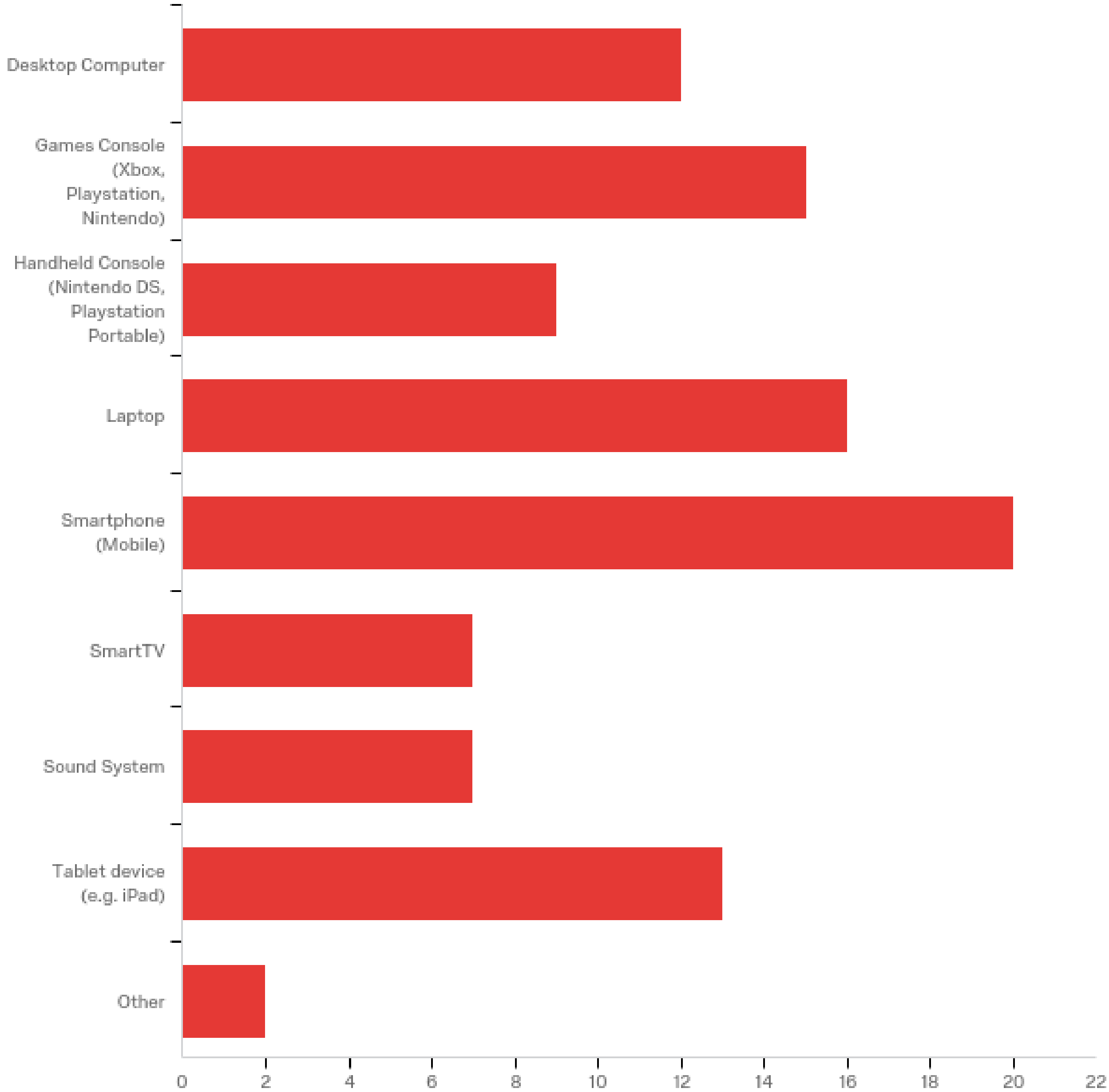
What is your age?
24
20
34
31
22
22
26
22
24
27
22
28
19
21
23
20
20
18
23
22

Q3 - Select which statement is true for you regarding familiarity with technology



#	Answer	%	Count
1	I am highly proficient in the use of mobiles, tablet devices and computers	45.00%	9
2	I am a frequent user of mobiles, tablet devices and computers	55.00%	11
3	I am still learning to use mobiles, tablet devices and computer	0.00%	0
4	I rarely use mobiles, tablet devices or computers	0.00%	0
5	I avoid technology such as mobiles, tablet devices and computers as much as I can	0.00%	0
	Total	100%	20

Q4 - What technology do you own, or have access to, in your home? (Select multiple answers if applicable)



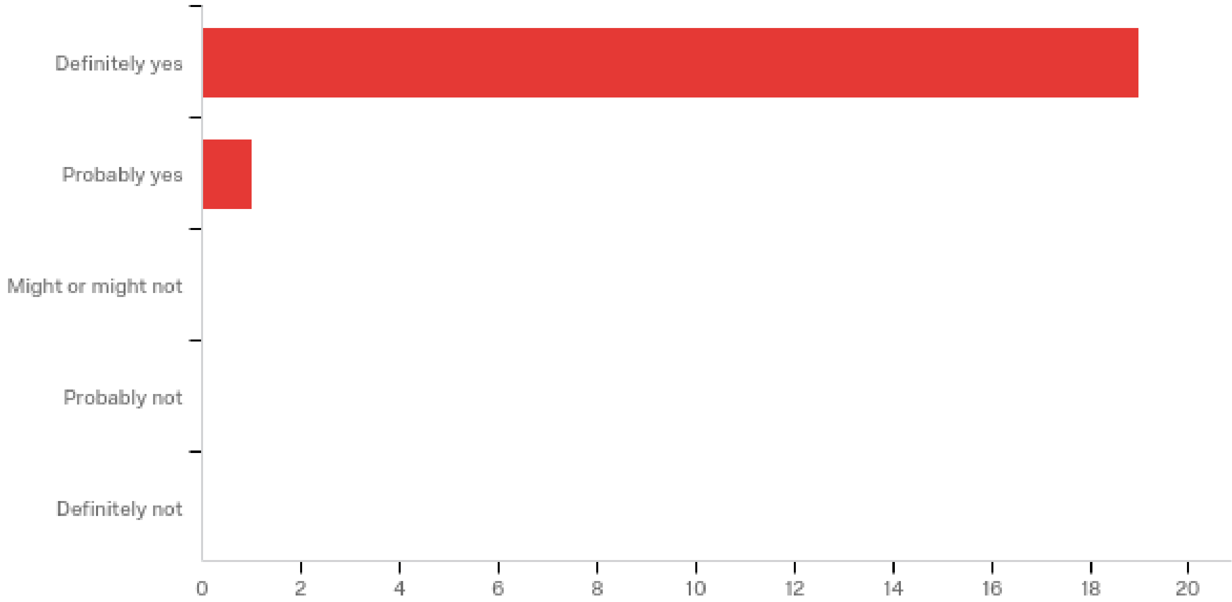
#	Answer	%	Count
1	Desktop Computer	11.88%	12
2	Games Console (Xbox, Playstation, Nintendo)	14.85%	15
3	Handheld Console (Nintendo DS, Playstation Portable)	8.91%	9
4	Laptop	15.84%	16
5	Smartphone (Mobile)	19.80%	20

6	SmartTV	6.93%	7
7	Sound System	6.93%	7
8	Tablet device (e.g. iPad)	12.87%	13
9	Other	1.98%	2
	Total	100%	101

Other

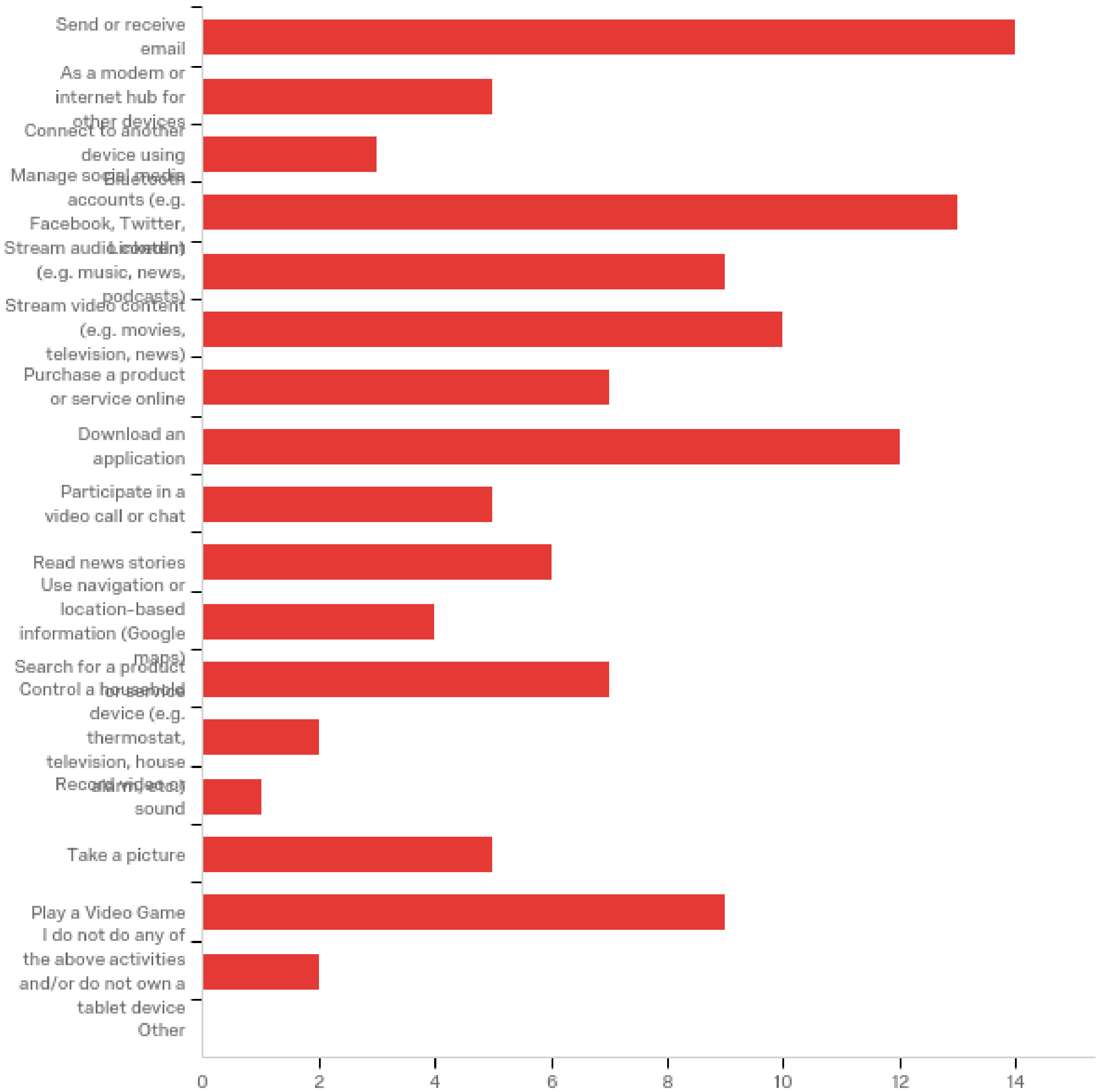
Other - Text
kindle
smart watch

Q5 - Have you used a tablet device before?



#	Answer	%	Count
1	Definitely yes	95.00%	19
2	Probably yes	5.00%	1
3	Might or might not	0.00%	0
4	Probably not	0.00%	0
5	Definitely not	0.00%	0
	Total	100%	20

Q6 - In the past 30 days, have you used your tablet device to do any of the following activities? (Please select all that apply.)



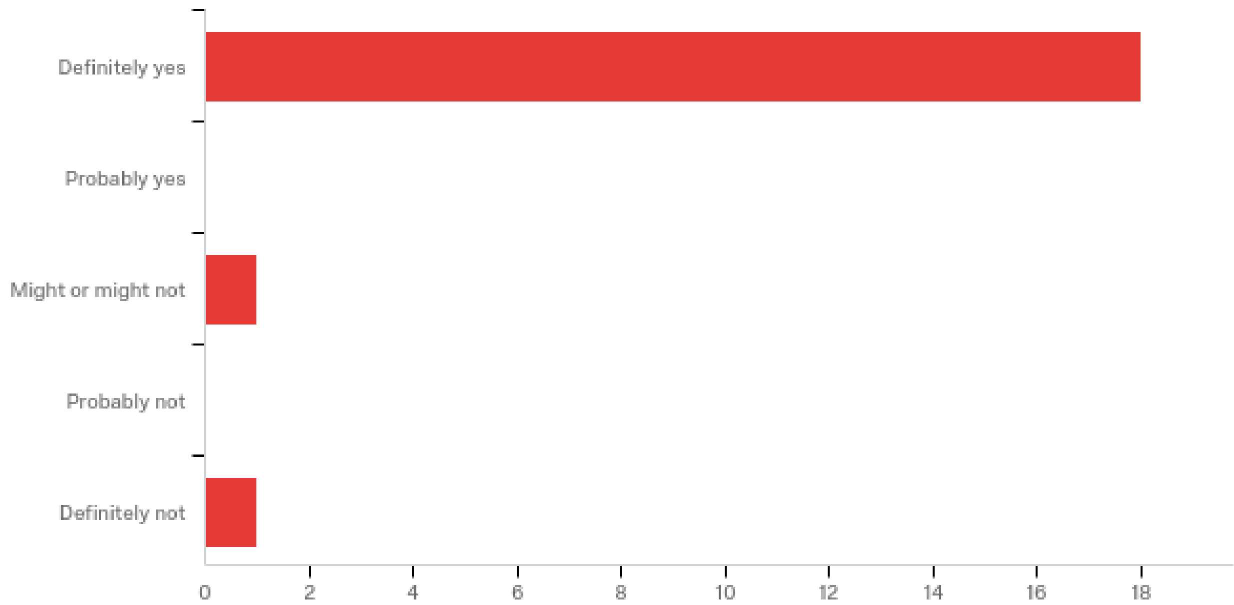
#	Answer	%	Count
1	Send or receive email	12.28%	14
2	As a modem or internet hub for other devices	4.39%	5
3	Connect to another device using Bluetooth	2.63%	3
4	Manage social media accounts (e.g. Facebook, Twitter, LinkedIn)	11.40%	13
5	Stream audio content (e.g. music, news, podcasts)	7.89%	9

6	Stream video content (e.g. movies, television, news)	8.77%	10
7	Purchase a product or service online	6.14%	7
8	Download an application	10.53%	12
9	Participate in a video call or chat	4.39%	5
10	Read news stories	5.26%	6
11	Use navigation or location-based information (Google maps)	3.51%	4
12	Search for a product or service	6.14%	7
13	Control a household device (e.g. thermostat, television, house alarm, etc.)	1.75%	2
14	Record video or sound	0.88%	1
15	Take a picture	4.39%	5
16	Play a Video Game	7.89%	9
17	I do not do any of the above activities and/or do not own a tablet device	1.75%	2
18	Other	0.00%	0
	Total	100%	114

Q7 - What is highest level of education you have completed?

What is highest level of education you have completed?
Degree
A-Levels
Master
Master
Sixth Form, A-Levels
sixthform
Bachelor of science degree
BA Honours
A Level
College BTEC
GCSE
pending BSc Degree
Pending bachelors degree
University Degree
BA in English Literature and History
HIGHER
HNC
University
Apprenticeship

Q8 - Have you ever played any video games on any device or platform? (mobile, games console, PC e.t.c)

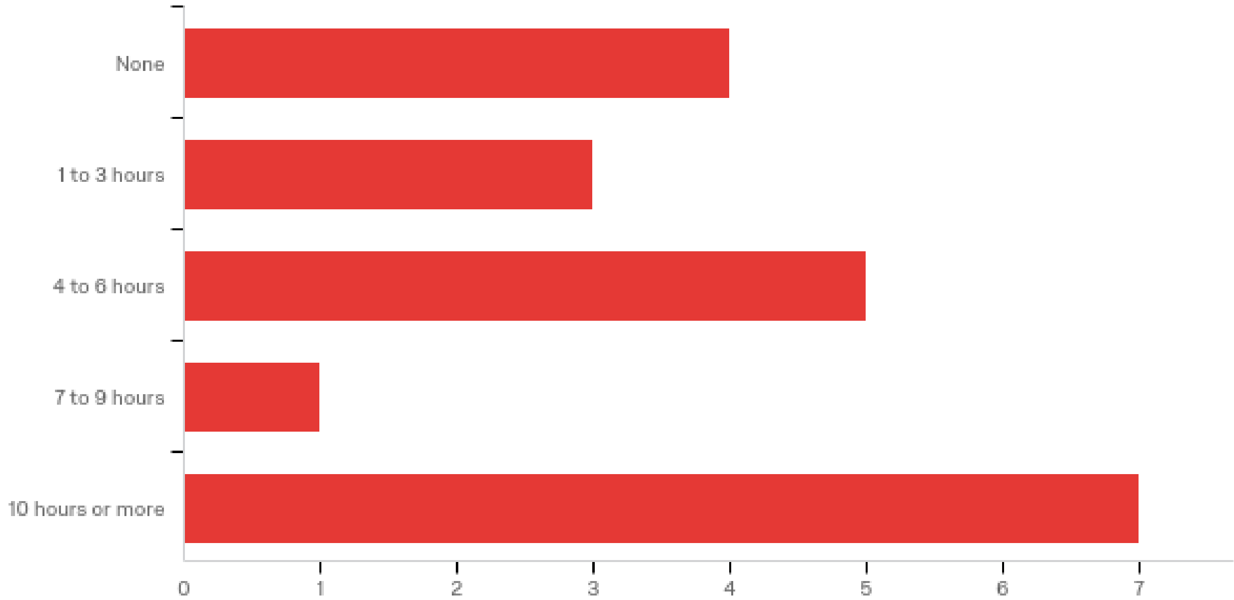


#	Answer	%	Count
1	Definitely yes	90.00%	18
2	Probably yes	0.00%	0
3	Might or might not	5.00%	1
4	Probably not	0.00%	0
5	Definitely not	5.00%	1
	Total	100%	20

Q9 - If you can recall any video games you have played, could you recall the names or genre of games you played and why you played them?

If you can recall any video games you have played, could you recall the names or genre of games you played and why you played them?
Sports, FPS games - I enjoy the competitive nature of these games!
Fallout 4, Call of Duty, Fifa Playing with friends/relaxation
Feetball Games, Interest
Destiny - FPS/RPG - Heavily invested from Alpha, love shooter games and the Halo universe so this was appealing from this basis Rocket League - Sports Game - Recommended by friends, love cars and football so this seemed like a good idea Paragon - MOBA - I have played LoL and DOTA 2 prior to this and have faith in EpicGames based on their work with Gears of War, so this was easy to pick up as it was free on PS4 Pokemon Go - Augmented Reality - I love the Pokemon franchise and the easy to pick up nature of this mobile game was appealing. As I travel for work it gave me something to do while on trains!
Ever oasis-fantasy open world played for the explorer aspect, Yonder - fantasy open world played for the exploration aspect, story of seasons - farming sim played for the achievement of putting in time and effoert and building your own farm, MineCraft - played for the multiplayer aspect.
battlefield one, fifa 17, elder scrolls online, I play them as something to do when bored or playing them with friends online
Stardew Valley, Simons Cat, Oblivion Elder Scrolls and Grand Theft Auto
Savarium (FPS) Overwatch (FPS) Redemer (Top Down twin-stick) Skyrim (RPG) Kingdoms and Castles (City Builder) - For me, immersion is a huge part of gaming and all these titles offer that.
Mass Effect Andromeda - For the adventure in a strange new galaxy. Monster Hunter - To fight incredible monsters with friends Stardew Valley - to enjoy creating things, in a slower pace of game.
Yes. Halo 5 the First Person Shooter on Xbox. Played the game because I love the series and am a big fan of first person shooters.
mostly survival games Ark Minecraft 7 days to die dont starve. peggle bouncy i play on the xbox one and on my phone to pass the time
Sims 4, NHL 17, Fallout 4 was bored and had spare time to spend playing games
Action/Adventure, first person shooters, mobile games on my smart phone.
Ludo star, Candy crush, Temple run, 8 ball pool - All for entertainment and being bored
Games: Call of Duty: Modern Warfare;Crash Bandicoot; Rayman; Assassin's Creed Reason: Mostly with friends/ leisure
FIFA 17
MarioKart, Candy Crush, Crash Bandicoot, Zuma, Puzzle games. i am a logical thinker and i like challenging myself.
Shooter and Simulation. I enjoy the online multiplayer of the shooting games and the free roaming of large maps the simulation games.

Q10 - In the past 7 days, roughly how many hours have you spent playing video games (e.g. gaming consoles, mobile phones, computers, etc.)?



#	Answer	%	Count
1	None	20.00%	4
2	1 to 3 hours	15.00%	3
3	4 to 6 hours	25.00%	5
4	7 to 9 hours	5.00%	1
5	10 hours or more	35.00%	7
	Total	100%	20

13.13. APPENDIX 13 – STUDY 1 PROCEDURE

Procedure	Tools and Materials Required	Steps Involved	Duration
Phase 1			
Explanation of the study and introduction to the prototype	-Flier. -Tablet (Samsung Galaxy Tab 10.1)	1. Researcher will welcome the participant and introduce themselves 2. Researcher will briefly explain the study and what is required of the participant 3. Researcher will enquire if the participant has any questions.	5 minutes
Phase 2			
Demographic Questionnaire	-Tablet (Samsung Galaxy Tab 10.1) -Digital copy of demographic questionnaire -Physical copy of demographic questionnaire -Pen	1. Researcher will open a demographic questionnaire on the tablet 2. If the participant struggles with the digital questionnaire, a physical one can be supplied	5 -10 minutes
Phase 3			
Brainplay Gameplay	-Tablet (Samsung Galaxy Tab 10.1) -Screen recording software -Brainplay app installed on device	1. Participants will be directed by the researcher to play each game two times 2. Two play-through's of each game allows each participant to establish an opinion of the games and understand the controls of the games	10-15 minutes
Phase 4			
HMSAM	-Tablet (Samsung Galaxy Tab 10.1) -Paper HMSAM test	1. Researcher will open the HMSAM questionnaire on the tablet 2. If the participant struggles with the digital questionnaire, a	5 -10 minutes

	Digital HMSAM test	physical one can be supplied	
Conclusion of study	-Love-to-shop vouchers -signature sheet for accepting vouchers -Pen	1. Researcher thanks participant and present the participant with £10 love-to-shop voucher for their time. (2 minutes)	2-3 minutes
Study end. Total Study length: 25 – 40 minutes			

13.14. APPENDIX 14 – NORMALITY TESTS

Tests of Normality

	Game	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Joy	Odd Ones	.196	20	.043	.872	20	.013
	Match Up	.153	20	.200*	.868	20	.011
	Which Word	.215	20	.016	.791	20	.001
Control	Odd Ones	.203	20	.030	.756	20	.000
	Match Up	.244	20	.003	.849	20	.005
	Which Word	.189	20	.059	.869	20	.011
Immersion	Odd Ones	.209	20	.022	.876	20	.015
	Match Up	.123	20	.200*	.939	20	.232
	Which Word	.138	20	.200*	.944	20	.281
Temporal_Dissociation	Odd Ones	.149	20	.200*	.913	20	.071
	Match Up	.151	20	.200*	.903	20	.048
	Which Word	.185	20	.072	.879	20	.017
Curiosity	Odd Ones	.200	20	.035	.931	20	.160
	Match Up	.149	20	.200*	.927	20	.138
	Which Word	.168	20	.141	.946	20	.306
Perceived_Ease_Of_Use	Odd Ones	.205	20	.028	.914	20	.076
	Match Up	.190	20	.055	.894	20	.032
	Which Word	.258	20	.001	.866	20	.010
Perceived_Usefulness	Odd Ones	.158	20	.200*	.959	20	.524
	Match Up	.158	20	.200*	.951	20	.389
	Which Word	.143	20	.200*	.975	20	.856
Behavioural_Intention_to_Use	Odd Ones	.284	20	.000	.875	20	.014
	Match Up	.261	20	.001	.855	20	.006
	Which Word	.187	20	.066	.947	20	.318

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

13.15. APPENDIX 15 – FRIEDMAN TEST RESULTS

Ranks

	Mean Rank
Joy_OddOnes	2.45
Joy_MatchUp	1.90
Joy_WhichWord	1.65

Test Statistics[a]

N	20
Chi-Square	8.246
df	2
Asymp. Sig.	.016

a. Friedman Test

Ranks

	Mean Rank
Control_OddOnes	2.13
Control_MatchUp	1.88
Control_WhichWord	2.00

Test Statistics[a]

N	20
Chi-Square	1.042
df	2
Asymp. Sig.	.594

a. Friedman Test

Ranks

	Mean Rank
Immersion_OddOnes	2.18
Immersion_MatchUp	1.90
Immersion_WhichWord	1.93

Test Statistics[a]

N	20
Chi-Square	1.947
df	2
Asymp. Sig.	.378

a. Friedman Test

Ranks

	Mean Rank
TemporalDissociation_OddOnes	2.23
TemporalDissociation_MatchUp	1.85
TemporalDissociation_WhichWord	1.93

Test Statistics[a]

N	20
Chi-Square	4.846
df	2
Asymp. Sig.	.089

a. Friedman Test

Ranks

	Mean Rank
Curiosity_OddOnes	2.30
Curiosity_MatchUp	1.85
Curiosity_WhichWord	1.85

Test Statistics[a]

N	20
Chi-Square	6.353
df	2
Asymp. Sig.	.042

a. Friedman Test

Ranks

	Mean Rank
PerceivedEaseOfUse_OddOnes	2.35
PerceivedEaseOfUse_MatchUp	1.63
PerceivedEaseOfUse_WhichWord	2.03

Test Statistics[a]

N	20
Chi-Square	12.412
df	2
Asymp. Sig.	.002

a. Friedman Test

Ranks

	Mean Rank
PerceivedUsefulness_OddOnes	2.30
PerceivedUsefulness_MatchUp	1.75
PerceivedUsefulness_WhichWord	1.95

Test Statistics[a]

N	20
Chi-Square	6.200
df	2
Asymp. Sig.	.045

a. Friedman Test

Ranks

	Mean Rank
BehaviouralIntentionToUse_OddOnes	2.28
BehaviouralIntentionToUse_MatchUp	1.98
BehaviouralIntentionToUse_WhichWord	1.75

Test Statistics[a]

N	20
Chi-Square	4.189
df	2
Asymp. Sig.	.123

a. Friedman Test

13.16. APPENDIX 16 – WILCOXON SIGNED-RANK TESTS

	Joy_MatchUp - Joy_OddOnes	Joy_WhichWord - Joy_MatchUp	Joy_WhichWord - Joy_OddOnes	Control_MatchUp - Control_OddOnes	Control_WhichWord - Control_MatchUp	Control_WhichWord - Control_OddOnes
Z	-1.706[b]	.000[c]	-3.219[b]	-1.288[b]	-1.355[d]	-.455[d]
Asymp. Sig. (2-tailed)	.088	1.000	.001	.198	.176	.649

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

c. The sum of negative ranks equals the sum of positive ranks.

d. Based on negative ranks.

Immersion_MatchUp - Immersion_OddOnes	Immersion_WhichWord - Immersion_MatchUp	Immersion_WhichWord - Immersion_OddOnes	TemporalDissociation_MatchUp - TemporalDissociation_OddOnes	TemporalDissociation_WhichWord - TemporalDissociation_MatchUp	TemporalDissociation_WhichWord - TemporalDissociation_OddOnes
-2.103[b]	-.794[d]	-1.630[b]	-2.023[b]	.000[c]	-1.892[b]
.035	.427	.103	.043	1.000	.058

Curiosity_MatchUp - Curiosity_OddOnes	Curiosity_WhichWord - Curiosity_MatchUp	Curiosity_WhichWord - Curiosity_OddOnes	PerceivedEaseOfUse_MatchUp - PerceivedEaseOfUse_OddOnes	PerceivedEaseOfUse_WhichWord - PerceivedEaseOfUse_MatchUp	PerceivedEaseOfUse_WhichWord - PerceivedEaseOfUse_OddOnes
-2.383[b]	-1.122[d]	-1.409[b]	-2.666[b]	-2.240[d]	-2.120[b]
.017	.262	.159	.008	.025	.034

PerceivedUsefulness_MatchUp - PerceivedUsefulness_OddOnes	PerceivedUsefulness_WhichWord - PerceivedUsefulness_MatchUp	PerceivedUsefulness_WhichWord - PerceivedUsefulness_OddOnes	BehaviouralIntentionToUse_MatchUp - BehaviouralIntentionToUse_OddOnes	BehaviouralIntentionToUse_WhichWord - BehaviouralIntentionToUse_MatchUp	BehaviouralIntentionToUse_WhichWord - BehaviouralIntentionToUse_OddOnes
-2.252[b]	-1.642[d]	-2.066[b]	-1.857[b]	-.261[d]	-1.367[b]
.024	.101	.039	.063	.794	.172

13.17. APPENDIX 17 – DESCRIPTIVE STATISTICS OF HMSAM ELEMENTS

Descriptive Statistics

	Game			Statistic	Std. Error
Joy	Odd Ones	Mean		6.4590	.12600
		95% Confidence Interval for Mean	Lower Bound	6.1953	
			Upper Bound	6.7227	
		5% Trimmed Mean		6.5006	
		Median		6.6700	
		Variance		.318	
		Std. Deviation		.56350	
		Minimum		5.17	
		Maximum		7.00	
		Range		1.83	
		Interquartile Range		.83	
		Skewness		-.901	.512
		Kurtosis		-.151	.992
	Match Up	Mean		6.0000	.21865
		95% Confidence Interval for Mean	Lower Bound	5.5424	
			Upper Bound	6.4576	
		5% Trimmed Mean		6.0928	
		Median		6.1700	
		Variance		.956	
		Std. Deviation		.97783	
		Minimum		3.33	
		Maximum		7.00	
		Range		3.67	

		Interquartile Range		1.33	
		Skewness		-1.302	.512
		Kurtosis		1.782	.992
	Which Word	Mean		6.0320	.20979
		95% Confidence Interval for Mean	Lower Bound	5.5929	
			Upper Bound	6.4711	
		5% Trimmed Mean		6.1561	
		Median		6.2500	
		Variance		.880	
		Std. Deviation		.93820	
		Minimum		2.83	
		Maximum		7.00	
		Range		4.17	
		Interquartile Range		.80	
		Skewness		-2.238	.512
		Kurtosis		6.747	.992
Control	Odd Ones	Mean		6.0170	.26459
		95% Confidence Interval for Mean	Lower Bound	5.4632	
			Upper Bound	6.5708	
		5% Trimmed Mean		6.1856	
		Median		6.2500	
		Variance		1.400	
		Std. Deviation		1.18329	
		Minimum		2.00	
		Maximum		7.00	
		Range		5.00	
		Interquartile Range		1.63	
		Skewness		-2.118	.512
		Kurtosis		6.351	.992
	Match Up	Mean		5.6740	.28688

		95% Confidence Interval for Mean	Lower Bound	5.0736	
			Upper Bound	6.2744	
		5% Trimmed Mean		5.7583	
		Median		5.8350	
		Variance		1.646	
		Std. Deviation		1.28295	
		Minimum		2.83	
		Maximum		7.00	
		Range		4.17	
		Interquartile Range		1.46	
		Skewness		-1.103	.512
		Kurtosis		.587	.992
	Which Word	Mean		6.2250	.17486
		95% Confidence Interval for Mean	Lower Bound	5.8590	
			Upper Bound	6.5910	
		5% Trimmed Mean		6.2683	
		Median		6.4150	
		Variance		.612	
		Std. Deviation		.78199	
		Minimum		4.67	
		Maximum		7.00	
		Range		2.33	
		Interquartile Range		1.46	
		Skewness		-.512	.512
		Kurtosis		-1.113	.992
Immersion	Odd Ones	Mean		6.1100	.19920
		95% Confidence Interval for Mean	Lower Bound	5.6931	
			Upper Bound	6.5269	
		5% Trimmed Mean		6.1667	

		Median		6.3000	
		Variance		.794	
		Std. Deviation		.89083	
		Minimum		4.20	
		Maximum		7.00	
		Range		2.80	
		Interquartile Range		1.50	
		Skewness		-.712	.512
		Kurtosis		-.674	.992
	Match Up	Mean		5.8000	.19304
		95% Confidence Interval for Mean	Lower Bound	5.3960	
			Upper Bound	6.2040	
		5% Trimmed Mean		5.8111	
		Median		5.9000	
		Variance		.745	
		Std. Deviation		.86329	
		Minimum		4.40	
		Maximum		7.00	
		Range		2.60	
		Interquartile Range		1.55	
		Skewness		-.140	.512
		Kurtosis		-1.153	.992
	Which Word	Mean		5.9200	.17254
		95% Confidence Interval for Mean	Lower Bound	5.5589	
			Upper Bound	6.2811	
		5% Trimmed Mean		5.9444	
		Median		6.0000	
		Variance		.595	
		Std. Deviation		.77160	
		Minimum		4.40	
		Maximum		7.00	

		Range		2.60	
		Interquartile Range		1.50	
		Skewness		-.266	.512
		Kurtosis		-.803	.992
Temporal_Dissociation	Odd Ones	Mean		5.8825	.21413
		95% Confidence Interval for Mean	Lower Bound	5.4343	
			Upper Bound	6.3307	
		5% Trimmed Mean		5.9250	
		Median		6.0000	
		Variance		.917	
		Std. Deviation		.95763	
		Minimum		4.00	
		Maximum		7.00	
		Range		3.00	
		Interquartile Range		1.59	
		Skewness		-.513	.512
		Kurtosis		-.676	.992
	Match Up	Mean		5.4995	.28770
		95% Confidence Interval for Mean	Lower Bound	4.8973	
			Upper Bound	6.1017	
		5% Trimmed Mean		5.6106	
		Median		5.6650	
		Variance		1.655	
		Std. Deviation		1.28662	
		Minimum		2.00	
		Maximum		7.00	
		Range		5.00	
		Interquartile Range		1.50	
		Skewness		-1.056	.512
		Kurtosis		1.488	.992
	Which Word	Mean		5.5825	.27133

		95% Confidence Interval for Mean	Lower Bound	5.0146	
			Upper Bound	6.1504	
		5% Trimmed Mean		5.7028	
		Median		6.0000	
		Variance		1.472	
		Std. Deviation		1.21344	
		Minimum		2.00	
		Maximum		7.00	
		Range		5.00	
		Interquartile Range		1.17	
		Skewness		-1.332	.512
		Kurtosis		2.822	.992
Curiosity	Odd Ones	Mean		5.8170	.16126
		95% Confidence Interval for Mean	Lower Bound	5.4795	
			Upper Bound	6.1545	
		5% Trimmed Mean		5.8150	
		Median		6.0000	
		Variance		.520	
		Std. Deviation		.72116	
		Minimum		4.67	
		Maximum		7.00	
		Range		2.33	
		Interquartile Range		1.17	
		Skewness		-.025	.512
		Kurtosis		-.878	.992
	Match Up	Mean		5.3505	.22468
		95% Confidence Interval for Mean	Lower Bound	4.8802	
			Upper Bound	5.8208	
		5% Trimmed Mean		5.4078	

		Median		5.1650	
		Variance		1.010	
		Std. Deviation		1.00481	
		Minimum		2.67	
		Maximum		7.00	
		Range		4.33	
		Interquartile Range		1.33	
		Skewness		-.602	.512
		Kurtosis		1.440	.992
	Which Word	Mean		5.6175	.19691
		95% Confidence Interval for Mean	Lower Bound	5.2054	
			Upper Bound	6.0296	
		5% Trimmed Mean		5.6306	
		Median		5.8350	
		Variance		.775	
		Std. Deviation		.88061	
		Minimum		4.00	
		Maximum		7.00	
		Range		3.00	
		Interquartile Range		1.25	
		Skewness		-.125	.512
		Kurtosis		-.873	.992
Perceived_Ease_Of_Use	Odd Ones	Mean		6.3025	.12598
		95% Confidence Interval for Mean	Lower Bound	6.0388	
			Upper Bound	6.5662	
		5% Trimmed Mean		6.3428	
		Median		6.3800	
		Variance		.317	
		Std. Deviation		.56342	
		Minimum		4.88	
		Maximum		7.00	

		Range		2.12	
		Interquartile Range		.84	
		Skewness		-1.048	.512
		Kurtosis		.911	.992
	Match Up	Mean		5.7775	.22561
		95% Confidence Interval for Mean	Lower Bound	5.3053	
			Upper Bound	6.2497	
		5% Trimmed Mean		5.8500	
		Median		6.0050	
		Variance		1.018	
		Std. Deviation		1.00894	
		Minimum		3.25	
		Maximum		7.00	
		Range		3.75	
		Interquartile Range		1.07	
		Skewness		-1.158	.512
		Kurtosis		.913	.992
	Which Word	Mean		6.1895	.15542
		95% Confidence Interval for Mean	Lower Bound	5.8642	
			Upper Bound	6.5148	
		5% Trimmed Mean		6.2383	
		Median		6.4400	
		Variance		.483	
		Std. Deviation		.69508	
		Minimum		4.50	
		Maximum		7.00	
		Range		2.50	
		Interquartile Range		.72	
		Skewness		-1.216	.512
		Kurtosis		.968	.992
Perceived_Usefulness	Odd Ones	Mean		5.7000	.15458

		95% Confidence Interval for Mean	Lower Bound	5.3765	
			Upper Bound	6.0235	
		5% Trimmed Mean		5.7222	
		Median		5.8000	
		Variance		.478	
		Std. Deviation		.69130	
		Minimum		4.00	
		Maximum		7.00	
		Range		3.00	
		Interquartile Range		.75	
		Skewness		-.591	.512
		Kurtosis		.836	.992
	Match Up	Mean		5.2500	.19242
		95% Confidence Interval for Mean	Lower Bound	4.8473	
			Upper Bound	5.6527	
		5% Trimmed Mean		5.2889	
		Median		5.5000	
		Variance		.741	
		Std. Deviation		.86054	
		Minimum		3.20	
		Maximum		6.60	
		Range		3.40	
		Interquartile Range		1.30	
		Skewness		-.701	.512
		Kurtosis		.083	.992
	Which Word	Mean		5.5300	.16497
		95% Confidence Interval for Mean	Lower Bound	5.1847	
			Upper Bound	5.8753	
		5% Trimmed Mean		5.5333	

		Median		5.7000	
		Variance		.544	
		Std. Deviation		.73778	
		Minimum		4.00	
		Maximum		7.00	
		Range		3.00	
		Interquartile Range		1.10	
		Skewness		-.131	.512
		Kurtosis		-.132	.992
Behavioural_Intention_to_Use	Odd Ones	Mean		5.9340	.17538
		95% Confidence Interval for Mean	Lower Bound	5.5669	
			Upper Bound	6.3011	
		5% Trimmed Mean		5.9822	
		Median		6.0000	
		Variance		.615	
		Std. Deviation		.78434	
		Minimum		4.00	
		Maximum		7.00	
		Range		3.00	
		Interquartile Range		.75	
		Skewness		-.784	.512
		Kurtosis		.762	.992
	Match Up	Mean		5.3670	.34020
		95% Confidence Interval for Mean	Lower Bound	4.6550	
			Upper Bound	6.0790	
		5% Trimmed Mean		5.4817	
		Median		6.0000	
		Variance		2.315	
		Std. Deviation		1.52142	
		Minimum		1.67	

	Maximum		7.00	
	Range		5.33	
	Interquartile Range		2.09	
	Skewness		-1.240	.512
	Kurtosis		1.175	.992
Which Word	Mean		5.4995	.23017
	95% Confidence Interval for Mean	Lower Bound	5.0177	
		Upper Bound	5.9813	
	5% Trimmed Mean		5.5367	
	Median		5.8350	
	Variance		1.060	
	Std. Deviation		1.02937	
	Minimum		3.33	
	Maximum		7.00	
	Range		3.67	
	Interquartile Range		1.25	
	Skewness		-.478	.512
	Kurtosis		-.472	.992

13.18. APPENDIX 18 – RECRUITMENT EMAIL FOR MDA EVALUATION INTERVIEW

Dear Sir or Madam,

I am writing to enquire about conducting research with you as part of a study into “Exploring the feasibility of serious video games designed from the MDA framework and their potential for assessment, diagnosis or treatment of cognitive impairment”. I am looking for experienced game developers to interview and discuss the framework/design choices used to create the research prototype ‘Brainplay’.

The interview will take between 20 – 30 minutes. There is a total of 5 questions, some with follow up questions. The location of the study will be at Livingston tower within the University of Strathclyde or at an agreed location that is convenient to you. The interview can also be conducted online via skype.

In short, the interview will involve a brief discussion of your role within game development, a video of Brainplay and then the five questions and discussion of the framework used to develop Brainplay. Interviews will be recorded so I may transcribe the interview for data analysis.

If there are any questions then please do not hesitate to get in touch. Thank you for your time and please reply to this email (_) if you wish to participate in this study.

Yours Sincerely

13.19. APPENDIX 19 – PARTICIPATION AND CONSENT FORM FOR MDA EVALUATION [STUDY 2]

Participant Information Sheet for MDA Evaluation study

Name of department: Computer and Information Sciences- University of Strathclyde

Title of the study: Brainplay: An Investigation of Serious Games that Tap into Cognitive Processes

Introduction

The researcher, Michael John Saiger, is a postgraduate student undergoing a MPhil in Digital Health and Wellness within the department of Computer and Information Sciences, University of Strathclyde.

Participants can contact the researcher via email, Michael.saiger@strath.ac.uk.

This study concerns the evaluation of the MDA design framework used by the researcher to develop 'Brainplay'. The study will gather qualitative data from game development professionals on the design process for 'Brainplay'.

What is the purpose of this investigation?

The primary aim of the study is to explore the feasibility of video games, designed from the mechanics dynamics aesthetics framework (MDA) as a potential within healthcare and cognition. This phase of the research/ study will contact game development professionals for an in-depth interview on the design of 'Brainplay'.

The purpose of the in-depth interview is to evaluate the design choices made and use of the MDA framework. The data collected from the study will provide a discussion on whether, or whether not, the MDA framework was a feasible method to design video games for cognition.

Do you have to take part?

The expectation is that if the participant agrees to be recorded in a one-to-one interview. The data gathered from the interview will be used in the discussion of the MDA framework and its use in the experiment. Participants will try to answer all questions honestly and give full detailed responses where they can.

What will you do in the project?

The answers given in this interview will form a body of data that will be transcribed and then analysed using interpretive phenomenological analysis (IPA), to observe the themes and recurring statements or answers from each participant. The data will provide a discussion towards the design choices that were made to develop ‘Brainplay’.

Location of the study will be conducted within the University of Strathclyde Livingston Tower building, or at a prior agreed location.

Interviews can be conducted online at the convenience of the participant.

The researcher has prepared 5 questions for the interviewee, some of which contain follow up questions. There is an allocated time of 20-30 minutes for the interview.

Why have you been invited to take part?

Participants who have been asked to take part are chosen because of their professional game development background.

Participants will be invited to provide their honest opinion and reaction to Brainplay, a game developed to assist with cognitive tasks.

What are the potential risks to you in taking part?

There is minimal risk to a participant in this study.

The risk associated with the video game is like the risk with any video game platform. In recruitment, a participant should be notified that individuals with a history of photosensitive epilepsy should not take part in the study.

Participants who cannot provide informed consent, not signing the accompanying consent form, then they will not be included in the study.

What happens to the information in the project?

All recordings and transcripts will be stored safely and anonymously for data protection. The data will then be processed for analysis at a future date

Codes will be used to help the research team identify each participant.

Data will be stored on the secure cloud storage system StrathCloud (Sharefile). Any physical notes will be scanned into digital storage and then stored. The data will be stored for 10 years to allow follow up research.

The University of Strathclyde is registered with the Information Commissioner's Office who implements the Data Protection Act 1998. All personal data on participants will be processed in accordance with the provisions of the Data Protection Act 1998.

Thank you for reading this information – please ask any questions if you are unsure about what is written here.

Researcher contact details:
E: michael.saiger@strath.ac.uk

University of Strathclyde, School of Computer Science

Room 12.13, 16 Richmond St, Glasgow G1 1XQ

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Martin Halvey

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Lecturer (Assistant Professor)

Course Director MSc/PgDip Information Management

Department of Computer and Information Science

University of Strathclyde, UK

This investigation was granted ethical approval by Departmental Ethics Committee and anyone with concerns should approach the Departmental Ethics Committee using enquiries@cis.strath.ac.uk as the contact email.

If you have any questions/concerns, during or after the investigation, or wish to contact an independent person to whom any questions may be directed or further information may be sought from, please contact:

Computer & Information Sciences
Livingstone Tower
26 Richmond Street
Glasgow, G1 1XH

- enquiries@cis.strath.ac.uk
- +44 (0) 141 548 3189

Consent Form for Study Intervention

Name of department: Computer and Information Sciences

Title of the study: Brainplay: An Investigation of Serious Games that Tap into Cognitive Processes

- I confirm that I have read and understood the information sheet for the above project and the researcher has answered any queries to my satisfaction.
- I understand that my participation is voluntary and that I am free to withdraw from the project at any time, up to the point of completion, without having to give a reason and without any consequences.
- I understand that anonymised data (i.e. .data which do not identify me personally) cannot be withdrawn once they have been included in the study.
- I understand that any information recorded in the investigation will remain confidential and no information that identifies me will be made publicly available.
- I consent to being a participant in the project

  I consent to being audio and/or video recorded as part of the project

(PRINT NAME)	
Signature of Participant:	Date:

13.20. APPENDIX 20 – INTERVIEW QUESTIONS FOR MDA EVALUATION

The questions below were a guide for the interviewer to help direct the conversation

1. Have you heard of the MDA framework?

> ***In case you haven't. Here is an explanation taken from Hunicke, LeBlanc and Zubec's paper proposing the MDA Framework***
> *Explanation "In game design the* ***Mechanics-Dynamics-Aesthetics*** *(MDA) framework is a tool used to analyse games. It formalizes the consumption of games by breaking them down into three components - Mechanics, Dynamics and Aesthetics. These three words have been used informally for many years to describe various aspects of games, but the MDA framework provides precise definitions for these terms and seeks to explain how they relate to each other and influence the player's experience.*
> *Mechanics are the base components of the game - its rules, every basic action the player can take in the game, the algorithms and data structures in the game engine etc.*
> *Dynamics are the run-time behavior of the mechanics acting on player input and "cooperating" with other mechanics.*
> *Aesthetics are the emotional responses evoked in the player."*

   a. Have you used the framework before?

2. Have you used any other games design framework/model/methods in the development of video games?

   a. Which ones?

   b. For what purpose?

3. To design Brainplay, the researcher started with a cognitive process and first developed mechanics, then the dynamics of the game, and then the aesthetics. Below is a summary on the method of design used to develop Brainplay and a reference image of each game. What are your thoughts on Brainplay's development in this way? How would you develop games for the cognitive processes? What would you do differently?

4. How would have you approached the design of video games for cognitive assessment?

5. From the table given below, could you follow application of the MDA framework to the table to create new games for cognitive impairment, cognitive training, cognitive therapy etc.?

13.21. APPENDIX 21 - PARTICIPANT A'S CODING OF TRANSCRIPT (STUDY 2)

Participant	**Initial Coding**	**Interview Data**
A	Confirmation that they have heard of the MDA	*Interviewer: First off, have you heard of the MDA?* Participant: Yes *Interviewer: (MDA explanation) And have you ever used the framework before?* Participant: I have used it a couple of times when analysing games as part of previous work but have not used it in nearly a year.
	Used the MDA previously	
	MDA used as a method of analysis	
	Use of another methodology (fail faster)	*Interviewer: Have you used any other game design framework/model/methods in the development of video games?* Participant: Yes, the fail faster methodology. *Interviewer: What purpose did you use that?* Participant: When designing and developing the game it was important to test new ideas quickly and to get feedback on them as soon as possible due to the time constraints on the project. Fail Faster is a methodology that was ideally suited for the project and we ended up picking it up fairly quickly. A lot of the ideas we tried out were shot down quickly but the rapid fire of different ideas for mechanics led to some interesting mechanics the we normally may have not been able to try or implement.
	Test new ideas quickly	
	Brainstorming methodology	
	Gain feedback quick	
	Methodology Worked well for time constraints	
	Easy to learn methodology (fail faster)	
	Development of interesting mechanics.	
	Supports the design process	*Interviewer: (summary of how Brainplay was developed) What are your thoughts to this design process? What would you do differently?* Participant: Seems pretty good to me. I can't say I'd really do anything all that differently apart from maybe having an extra step after choosing the art theme to see if there was anything either mechanically or dynamic that could be added or changed to tie in with the art theme though this seems unlikely with this type of game.
	Unsure what they would differently	
	Investigate what mechanics or dynamics could be further added in association with the art style	
	Background research into processes	*Interviewer: How would you have approached the design of video games for cognitive assessment?* Participant: Firstly, I would do research into exactly how cognitive process and processes are defined and measured. From this I would note any metrics or measurements that could be used as a score in the game.
	Using metrics for cognitive processes as a score	

	Designing process would look at other games	Next I would look at other games for cognitive assessment and examine what methods they use to measure these metrics or if they use different metrics and if so what they are. From this I would decide on the basic idea of the mechanics and art theme that would be used and would move to create a prototype for testing. From the prototyping I would tweak the mechanics based on feedback as well as either change or improve the art style depending on feedback. After a few rounds of prototyping I would like to get an expert in cognitive assessment involved to take a look at the game and see if they feel it is either doing something wrong or is missing something . After this I would enter the main stage of development creating the full fleshed out product.
	Observe their methods	
	Prototype and test	
	Early feedback to tweak mechanics	
	Gather external expertise	
	Critique game for something wrong or missing.	
	Able to replicate the process of creating games for cognitive processes	*Interviewer: I sent you a table that are the result of deconstructing existing games for cognitive processes and what features are seen in specific cognitive process games.* *Could you follow application of the MDA framework to the table to create new games for cognitive impairment, cognitive training, cognitive therapy..?* Participant: I’d say so. The tables seem detailed and it would be fairly easy to pick mechanics from it to create new games. Only issue might be how the different mechanics would interact in the overall experience but that would be noticed and resolved in testing.
	Ability to pick mechanics	
	How to get different mechanics work well together	

13.22. APPENDIX 22 - PARTICIPANT B'S CODING TRANSCRIPT (STUDY 2)

Participant	Initial Coding	Interview Data
B	Knowledge of MDA	*Interviewer: I suppose my first question is, have you heard of the MDA framework?* Participant: Oh yeah. *Interviewer: Have you used the framework in any game development?* Participant: I have used it as a light basis for the design. The project I worked on *Independent title* that was, I actually created a framework from the MDA framework to help streamline the process of *Independent title*. I think, the MDA framework works well, it helps to add focus. I think that, Especially with games like *independent Title* , the style of play is much more themed of the game, rather than the mechanics dynamics…it's good to focus development.
	MDA to help in design	
	Streamline design process	
	Used framework in independent development	
	MDA works specifically well for a certain theme of playstyle?	
	MDA helpful to focus development	
	Not used framework in commercial development	*Interviewer: Have you used any other game design framework, methods or models for other titles you have worked on?* Participant: I'd say that many of the things I have worked on I have not really used a framework, it's been a lot more freeform. So it was looking at how the game functioned, there was no set framework. Very much an iterative process.
	Freeform approach to design	
	Iterative processes normally, focused on functionality.	
	Who needs games like Brainplay	*Interviewer: Summary of how games were developed for Brainplay.* *How would you develop video games for a cognitive process such as perception, working memory or language? What would you do differently?* Participant: That's quite a question. I think what I would do, I don't know how much individual research you did, but asking individuals who need to use these games, how they feel about games for cognition, seeing what these people (healthcare staff and patients) want to see. The market if you will. I can't really think of any other stage I would do? There are a lot issues out there, disability or learning difficulty, so there are various aspects to observe, whether or not there is a physical
	Gather thoughts and opinions on games for cognition	
	Market research as a stage of development	
	Suggests a worry of wide audience, each with specific needs	
	Considering individual needs for different patients	

	How would certain disabilities affect the game development	impairment or not. Looking into, research into the issues that can arise and how that would affect approaching game development.
	Feedback from Brainplay would be improved. Both visual and auditory.	*Interviewer: What are your opinions on the games of Brainplay, what would you add or change about them? Or what would you do differently?* Participant: I think the key factor would be the feedback, both audio and visual. I think that would be one area, I think in terms of its goal, what it's trying to achieve, it's perfectly acceptable. I think that there are areas, say if you had to test with people with autism, you would need to tailor the game for that audience. But they seem to be doing what they are aiming to do.
	'Goal' is met	
	Targeting the specific audience	
	design for the end 'goal' or 'aim'	
	Positive response to replicating the development of video games for cognition.	*Interviewer: With the information provided, could you follow the application of the MDA framework to develop your own games for cognition?* Participant: Yeah I'd say so.

13.23. APPENDIX 23 - PARTICIPANT C'S CODING TRANSCRIPT (STUDY 2)

Participant	Initial Coding	Interview Data
C	No knowledge of game design frameworks	*Interviewer: Have you heard of the MDA Framework?* Participant: No.
	Lack of clarity of game design frameworks	*Interviewer: Have you used any other game design frameworks, models or methods in the development of video games?* Participant: It depends somewhat what you mean, if you count narrative framework such as the concept of the hero's journey or Dan Harmons story circle then perhaps you can make an argument that those are "frameworks" intended to design narratives, which I've applied to games before. But the best answer I suppose, is no.
	Shows that there is no universal understanding for a game design framework	
	Other suggested framework used for narrative	
	Intended suggests the participant does not have a lot of faith in frameworks.	
	Vague agreement with interviewer's development of Brainplay	*Interviewer: (Summary of how games were developed for Brainplay.) How would have you developed games for cognitive processes? Would you do anything differently?* Participant: Seems a fair approach. If memory/matching games are shown to be suitable for the purpose, it's a good idea to take the example I suppose. I might question the level of adherence to previous titles on a mechanical level. I don't know, maybe it's just the developer in me speaking, but it sort of seems that no matter the problem process or the proposed used of the application, a game needs to be engaging to be effective. Too strong a commitment to themes, genres and mechanics of previously proven titles might limit the process too much.
	Question the level of adherence, how accurate had the development followed similar development.	
	Regardless of use or process, it still needs to remain a game.	
	Games need to be engaging to be effective.	
	Using previous titles may limit the process (creativity)	
	May limit the potential of Brainplay.	
	Approach an expert	*Interviewer How would you approached the design of video games for cognitive assessment?* Participant: Difficult to say. Not being experienced in cognition. Likely I would approach an expert and seek guidance. All I can say really. Playtesting would be important, along with iterative experiments in gameplay and form to compare results to established methods.
	Guidance on cognition.	
	Playtesting would be important	
	Iterative development	
	Possibly comparing iterative models and comparing results	
	Does not think they could replicate the study	*Interviewer: With the information provided in the table I sent you, could you follow the application*

	Due to no exposure of the MDA	*of the MDA framework to develop your own games for cognition?* Participant: I don’t think so to be honest. Having no exposure to the mechanics of MDA I would find it difficult.
	Supports the need of universal game development processes to help design games	

13.24. APPENDIX 24 – INVITATION FOR THE POTENTIAL COGNITIVE USE INTERVIEW

Dear Sir or Madam,

I am writing to enquire about conducting research with you as part of a study into "Exploring the feasibility of serious video games designed from the MDA framework and their potential for assessment, diagnosis or treatment of cognitive impairment". I am looking for health and care professionals to interview and discuss the potential of a video game, Brainplay, within a health or care setting.

Brainplay, is an experimental prototype that has been developed from a game design framework (MDA) and cognitive processes, to explore how video games can be applied within a healthcare setting.

The interview will take between 20 and 30 minutes. There is a total of 5 questions, some with follow up questions. The interview can be conducted online via skype.

In short, the interview will involve a brief discussion of your role within health or care, a video of Brainplay and then the five questions and discussion towards the potential application of Brainplay. Interviews will be recorded so I may transcribe the interview for data analysis.

If there are any questions then please do not hesitate to get in touch. Thank you for your time and please reply to this email (Michael.saiger@strath.ac.uk) if you wish to participate in this study.

Yours Sincerely

13.25. APPENDIX 25 – PARTICIPATION AND CONSENT FORM FOR POTENTIAL USE OF BRAINPLAY IN HEALTHCARE [STUDY 3]

Participant Information Sheet for Potential Cognitive Care study

Name of department: Computer and Information Sciences- University of Strathclyde

Title of the study: Brainplay: An Investigation of Serious Games that Tap into Cognitive Processes

Introduction

The researcher, Michael John Saiger, is a postgraduate student undergoing a MPhil in Digital Health and Wellness at the School of Computer and Information Sciences, University of Strathclyde.

Participants can contact the researcher via email, Michael.saiger@strath.ac.uk.

This study investigates the potential utility for 'Brainplay'. The study will gather qualitative data from healthcare professionals on the perceived utility or usefulness of 'Brainplay' in a health care setting. It also serves to learn whether the cognitive processes, that Brainplay was designed from, are recognised by the healthcare professionals within the games.

What is the purpose of this investigation?

The primary aim of the study is to explore the feasibility of video games, designed from the mechanics dynamics aesthetics framework (MDA) as a potential aide or tool for cognitive care (assessment or diagnosis for example). This phase of the research/ study will contact healthcare professionals for an in-depth interview on the potential use within healthcare for 'Brainplay'.

Do you have to take part?

The expectation is that if the participant agrees to be recorded in a one-to-one interview and that the information they give as part of the interview will be used in a discussion of the potential application of Brainplay for use in a healthcare setting. Participants will try to answer all questions honestly and give full detailed responses where they can.

What will you do in the project?

The answers given in this interview will form a body of data that will be transcribed and then analysed to observe the themes and recurring statements or answers from each participant.

Location of these interviews will vary. Interviews will be arranged at the convenience of the participant so long as the area is not too loud for recording devices.

Interviews can be conducted online at the convenience of the participant.

The researcher has prepared 5 questions for the interviewee, some of which contain follow up questions. There is an allocated time of 25-35 minutes for the interview.

Why have you been invited to take part?

Participants who have been asked to take part are chosen because of their professional health or care background, in the hope that you will provide an in-depth discussion on the potential use of 'Brainplay' in assessment, diagnosis or treatment of people with cognitive impairment (such as dementia).

Participants will be invited to provide their honest opinion and reaction to Brainplay.

What are the potential risks to you in taking part?

There is minimal risk to a participant in this study.

The risk associated with the video game is the similar risk with any video game platform. In recruitment, a participant should be notified that individuals with a history of photosensitive epilepsy should not take part in the study.

Participants who cannot provide informed consent, not signing the accompanying consent form, then they will not be included in the study.

What happens to the information in the project?

All recordings and transcripts will be stored safely and anonymously for data protection. The data will then be processed for analysis at a future date

Codes will be used to help the research team identify each participant.

Data will be stored on the secure cloud storage system StrathCloud (Sharefile). Any physical notes will be scanned into digital storage and then stored. The data will be stored for 10 years to allow follow up research.

The University of Strathclyde is registered with the Information Commissioner's Office who implements the Data Protection Act 1998. All personal data on participants will be processed in accordance with the provisions of the Data Protection Act 1998.

Thank you for reading this information – please ask any questions if you are unsure about what is written here.

Researcher contact details:
E: michael.saiger@strath.ac.uk

University of Strathclyde, School of Computer Science

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Department of Computer and Information Science

University of Strathclyde, UK

This investigation was granted ethical approval by Departmental Ethics Committee and anyone with concerns should approach the Departmental Ethics Committee using enquiries@cis.strath.ac.uk as the contact email.

If you have any questions/concerns, during or after the investigation, or wish to contact an independent person to whom any questions may be directed or further information may be sought from, please contact:

Computer & Information Sciences
Livingstone Tower
26 Richmond Street
Glasgow, G1 1XH

- enquiries@cis.strath.ac.uk
- +44 (0) 141 548 3189

Consent Form for Study Intervention

Name of department: Computer and Information Sciences

Title of the study: Brainplay: An Investigation of Serious Games that Tap into Cognitive Processes

- I confirm that I have read and understood the information sheet for the above project and the researcher has answered any queries to my satisfaction.
- I understand that anonymised data (i.e. .data which do not identify me personally) cannot be withdrawn once they have been included in the study.
- I understand that any information recorded in the investigation will remain confidential and no information that identifies me will be made publicly available.
- I consent to being a participant in the project
- I consent to being audio and/or video recorded as part of the project

(PRINT NAME)	
Signature of Participant:	Date:

13.26. APPENDIX 26 – INTERVIEW QUESTIONS FOR POTENTIAL USE OF BRAINPLAY IN HEALTHCARE [STUDY 3]

1. Do you utilise any interactive technologies (such as video games or apps) in your area of healthcare?

   If yes, what do you use these ‘interactive technologies for’? Who are the main users? Is it for staff or patients?

   If no, have you ever expressed an interest in involving interactive technologies in your job?

2. After playing Brainplay, do you think that Brainplay could be used in a healthcare setting?

   a. Follow up questions: What setting? What area of healthcare? E.g., diagnosis, assessment, etc.

   b. Are there any reasons to why you would not use Brainplay within a healthcare setting?

3. Each of the games in Brainplay were designed from a specific cognitive process.

What do you think Match Up assesses, in terms of cognition, in your opinion?

What do you think Which Word assesses, in terms of cognition, in your opinion?

What do you think Odd Ones assesses, in terms of cognition, in your opinion?

4. Do you think there is demand for video games, such as Brainplay, within your department/organisation/work?

   follow up with, what do you need the video games for?

5. Who do you think the ideal target audience is for Brainplay?

13.27. APPENDIX 27 - PARTICIPANT D'S CODING OF TRANSCRIPT (STUDY 3)

Participant	Initial Coding	Interview Data
D	No knowledge of healthcare staff using video games Application used by nurses Help with daily tasks of a nurse Application used by patients Assistive technology Wide user base The need for smartphone access (save time)	*Interviewer: Do you utilise any interactive technologies (such as video games or apps) in your area of healthcare?* Participant: I have not seen any healthcare professionals use interactive technologies such as video games. In regard to apps some nurses may use the NHS BMI tracker app for clinics, appointments or on a ward. These are also an app called my local NHS. This app allows patients or service users to keep track of appointments or locate various services such as A&E or pharmacies and allows you to store notes ready for when you visit your GP or attend a hospital appointment. *Interviewer: Who are the main users of technology then? Staff or patients?* Participant: The main users of technologies would be staff such as GPs, nurses et and patients _ service who have access to smartphone technology
	Strong opinion Brainplay should be used in healthcare Relieve anxiousness of patients Brainplay as a distraction tool. Active, wanting to interact Focus on the elderly as an audience Brainplay to help alleviate boredom or loneliness	*Interviewer: After watching Brainplay, do you think that Brainplay could be used in a healthcare setting?* Participant: I think that Brainplay would ultimately be used in a healthcare setting. This would be use in waiting rooms to relieve feelings on anxiousness or to take their (patients) mind off the environment that they are in. This app could also be good for occupational therapy intervention *Interviewer: Could you explain how Brainplay could be used as an occupational therapy intervention?* Participant: – activities done with the elderly for example in a ward or care home where they may feel bored and lonely

	Which word assessing dyslexia Personal experience with dyslexia and dyspraxia Similar test done, spoken instead of interactive. Match up assessing Memory Opinion on the potential of Brainplay Odd Ones to assess colour blindness Uncertainty with the potential of Odd Ones, suggesting face recognition as well	*Interviewer: Could you tell me in your opinion, what do you think the Which Word game assesses, in terms of cognitive process?* Participant: Which word would assess dyslexia, from my own personal experience I undertook a dyslexia and dyspraxia test with an educational psychologist and a test like this was done, only is was spoken and not done interactively. *Interviewer: Same question as before, what do you Match Up assesses with regard to a cognitive process?* Participant: Match Up could assess memory or photographic memory. Could be used in memory tests alongside the MMSE in my opinion. *Interviewer: And Odd Ones?* Participant: Odd Ones could be used to assess colour blindness, maybe even face recognition through the ability to recognise familiar animals and when they have been altered.
	Uncertain on the demand for video games in health. Personal opinion of finding them useful	*Interviewer: Do you think there is demand for video games, such as Brainplay, within your area of work?* Participant: I'm unsure if there is a demand, although I can see how they could be useful
	Target audience of young children	*Interviewer: Finally, who do you think is the target audience for Brainplay in your opinion?* Participant: Young children age 7-10 perhaps?

Participant *D* displayed knowledge of applications used by nurses in their field as well as a personal connection to dyslexia and dyspraxia which was identified as a form of assessment in Which Word. Participant *D* suggested the audience for Brainplay to be young children and the possible use as a distraction tool. The participant also suggested that Brainplay could assist with boredom or loneliness, which suggests a potential for Brainplay to be used for quality of life purposes.

13.28. APPENDIX 28 - PARTICIPANT E'S CODING OF TRANSCRIPT (STUDY 3)

Participant	Initial Coding	Interview Data
E	Existing application use Technologies underused in healthcare Enthusiasm for interactive technologies Positive use for Brainplay. patient care?	*Interviewer: Do you utilise any interactive technologies in your line of work?* Participant: We use Online access app for patients to access their medical records and to order prescriptions. We also use the app to book appointments. *Interviewer: Have you ever expressed an interest in involving interactive technologies in your job?* Participant: I think interactive technologies are underutilised in healthcare and there is so much potential. *Interviewer: Where would this potential be?* Participant: I'd say it is around patient care. Interactive technologies would be a great way to gather information about a patient.
	Used with an existing clinical system Use of a tablet. Opposed to computer Uncertainty to sector of health care Dependent on finished product. Concern for ease of use and cost Assertive in area of healthcare potential. Focus on younger patients Concern on cost (Financial)	*Interviewer: After watching Brainplay, do you think that Brainplay could be used in a healthcare setting?* Participant: Yes- if it were connected to the clinical system and data inputted using a tablet. Not sure if better suited to secondary or primary care though. It would depend on the finished product, ease of use and cost etc. *Interviewer: What setting would you see for Brainplay? Like diagnosis or assessment?* Participant: Diagnosis. Using it to determine any mental or physical capabilities, especially with younger patients. *Interviewer: Are there any reasons to why you would not use Brainplay within a healthcare setting?* Participant: If the cost were prohibitive. *Interviewer: So it needs to be affordable for the practice?* Participant: Yes, the cost of buying an app and distributing would be a fundamental factor to use within the practice.
	Which Words assessment of knowledge Comprehension focus Opinion focus on challenging image and identity Assurance in Odd Ones potential	*Interviewer: Each of the games for Brainplay were designed for a specific cognitive process. In your opinion, what do you think Which word assess?* Participant: I would say that which word assesses Knowledge, gathering a person's basic mental capacity. *Interviewer: What do you think Match Up assesses, in terms of cognition or executive function, in your opinion?* Participant: Match Up looks to assess Comprehension from a person. It looks to

		demonstrate a person's understanding of image and identity. *Interviewer: What do you think Odd Ones assesses?* Participant: Analysis tasks, definitely. Analysing the images and choosing the correct answer.
	Technology use in healthcare rising.	*Interviewer: Do you think there is demand for video games, such as Brainplay, within your practice?* Participant: The use of technology is increasing in the healthcare sector and this type of videogame is an excellent alternative to traditional ways of assessing cognitive function. I wouldn't say there is particular demand from practices at present but CCG's (Clinical Commissioning Groups) and NHS England are increasingly looking at ways to better utilise technology and this is then rolled out across practices. Some practices are resistant to begin with (online consultations is the current initiative meeting resistance from many practices!) but usually there will be some that are interested and lead the way in terms of piloting such projects and often they do end up saving time for practices in the long term. *Interviewer: What would you like to use video games for?* Participant: I would like to see other practices and CCG adopt video games, to better to see what video games can do for the NHS.
	Alternative and not addition	
	Assessment focus of cognition	
	There isn't a demand from practices.	
	Potential markets	
	Desire to use technology within health	
	Sceptic surrounding video games in health	
	Online consultations are not being easily adopted by practices	
	Save time, and not money	
	Desire to see video games in other places first.	
	Require evidence	
	Uncertainty on target audience	*Interviewer: Who do you think the ideal target audience is for Brainplay?* Participant: Unsure of this at present.

13.29. APPENDIX 29- PARTICIPANT F’S CODING TRANSCRIPT (STUDY 3)

Participant	Initial Coding	Interview Data
F	Application use (health practice apps) App for health and wellbeing App for patient care App for patients to use Apps are for patients, less for staff Prescribing information.	*Interviewer: Do you utilise any interactive technologies, like apps or video games in your line of work?* Participant: I use as part of my mental health practice apps such as mood diary we also use apps for wellbeing and health such as dailylio which tracks your daily activity. I also use silvercloud for patients and the RCPsych Mental Health app. For my acute patients I recommend Five Ways to Wellbeing as an app for them to use *Interviewer: Are these apps for staff or patients? Who are the main consumers?* Participant: All of the app are for patients’, however because they provided information as to the patient’s health and situation, we can as practitioners learn from this and prescribe according to the information they provide.
	Opinion on Brainplay Recognition and repetition Reaction time Brainplay could carry relevance in physical and mental health Some suggestion to value of Brainplay Still some ambiguity surrounding defining cognitive impairment Brainplay as a diagnosis tool Used in either primary or secondary care Market for the elderly Brainplay to help with dyslexia or dyspraxia	*Interviewer: You have watch the gameplay trailer for Brainplay; in your opinion do you think Brainplay could be used in a Healthcare setting?* Participant: I think the use of Brainplay is interesting as it’s about reaction, cognitive recognition and repetition. All of these aspects are relevant in both physical and mental health. *Interviewer: Could you be more specific? like which area of healthcare like diagnosis or assessment for example* Participant: I think there is real worth in using something such as this in areas where we are trying to define and diagnose cognitive impairment, acute confusional states and behavioural aspects of health – it could be used either in front line services such as primary care or in a secondary setting such as mental health or care of the elderly. Or the diagnosis of dyslexia, dyspraxia.. *Interviewer: Are there any reasons to why you would not use Brainplay in your line of work?* Participant: Yes where patient have capacity concerns- we would need consent and if a patient does not have capacity then this would not be ethical to use
	Belief that Which Word challenges multiple components Which word targets multiple processes opposed to one it was	*Interviewer: Each of the games for Brainplay were designed for a specific cognitive process. In your opinion, what do you think Which word assesses?* Participant: Various cognitive components are tested in this task which I believe comprise of

	designed for. Visual and colour test in match up Visual perception and motor skills in match up Testing brain function Assessment of processing speed in Odd Ones Short term memory in Odd Ones Suggested attention present in Odd Ones Important for healthcare professional to distinguish between auditory and visual memory.	scanning, matching, switching, and writing operations that are reflective of several higher cognitive functions like perception, encoding and retrieval processes, transformation of information stored in active memory and decision making *Interviewer: What do you Match Up assesses?* Participant: Visual and colour representations alongside image and due to compromise to almost any brain system this includes aspects like visual-visual attention, language, praxis, motor, to see if other brain systems are basically intact *Interviewer: And finally, what do you think Odd Ones assesses?* Participants: It appears to measure processing speed deficits. It's about short-term auditory memory; also, attention and concentration. Weak attention capacity can have an effect on language, memory, listening and recall abilities. For me it is important to differentiate between memory for meaningful and non-meaningful abilities as well as the difference between auditory and visual memory. This helps me to understand strengths and weaknesses.
	Positive response to the demand. Patients as the target market	*Interviewer: Do you think there is demand for interactive application such as Brainplay within your area of healthcare?* Participant: Absolutely *Interviewer: Just to spin off that last question, where or who would you like to see video games designed for?* Participant: Patients who need support and something that is provided in a 'fun form'
	Wide audience for Brainplay Young person target audience Combat depression Encourage engagement	*Interviewer: Who do you think the ideal target audience is for Brainplay?* Participant: All ages depending upon the needs and the area of healthcare. There would be real value in something such as this for young person's in relation to depression and engagement.