Exploring Collaborative Agreement in Interactions

by

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Abstract

The benefits of play and collaboration in children's learning and development cannot be overemphasized. Through play, children learn many social skills and how to be creative but children's play is not always harmonious as it relies on power relations between groups. As children grow, they build peer groups where they prefer to play with same-sex peers and may display gender-typed behaviours, which grows stronger as they grow into adolescence. On the other hand, working in small groups enhances children's problem solving skills and motivation, encourages development of skills of critical thinking and communication and allows longer retention of concepts. To reap the benefits associated with collaboration, there is need for children to develop and practice skills for effective collaboration. Collaborative games provide platforms for children to practice the skills required for effective collaboration however, in some collaborative games where players are expected to collaborate and learn the skills associated with collaboration, competition still occurs. This can be detrimental especially in the classroom settings as it can increase hostility between students and weaken the intrinsic motivation to learn due to focus on winning. In this research, the concept of Enforced Collaborative Agreement (ECA) is introduced and explored. ECA is a type of interaction whereby collaborative agreement is required in order to play a digital game. It is believed that ECA games would make co-located children play together in an equitable and inclusive way thus allowing them to contribute and participate equally when working together. The aim of the research is to understand the behaviours participants aged between 11-16 years old grouped in pairs and within co-located spaces exhibit to reach agreement while playing an ECA enabled game using a range of interaction methods. While several research works have been undertaken to explore collaboration in enforced situations none has explored collaboration in the way described in this thesis (using a range of data gathering approaches and focusing on how participants reach agreement). Additionally, this research explores the effects of ECA on the participants' enjoyment, one of the dimensions of gameplay experience and highlights the importance of ECA in enabling collaborative interactions. A mixed methods and user-centred approach was taken where established methods such as observation of the participants' behaviours during interaction, survey (fun Toolkit and questionnaire), logging participants' actions and unstructured interview were used. The key contribution of this research is the

understanding of ECA as a concept and methods to study it. Additional contributions are the understanding of how participants collaborate to reach agreement within one part of the larger space where ECA can be applied and associated design guidelines for designers wishing to design games/applications that support ECA.

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1 CHAPTER ONE: INTRODUCTION

This chapter provides an overview of the research conducted in this thesis. Section 1.1 provides the motivation of this research, section 1.2 contextualizes the research, section 1.3 states the research aim, objectives and the questions the research seeks to answer, section1.4 states the contributions of the research with section 1.4.1 and section 1.4.2 as its major and minor contributions respectively, section 1.5 describes the methodology of the thesis followed by the ethical issues related to the research. Finally, section 1.6 outlines the summary of the content of each chapter and section1.7 concludes this chapter.

1.1 Research Motivation

Collaboration with others forms a large and important part of our lives from childhood games, through education, to workplaces and beyond. Research in psychology and education has consistently shown that working in small groups can have advantageous effects on children's learning and development. For example, it enhances problem solving skills and motivation in children (Wilson, Hoskin, & Nosek, 1993), encourages development of skills of critical thinking, communication, coordination and conscious knowledge construction mechanisms (Dillenbourg, 1999), allows a longer retention of concepts and promotes positive attitudes towards the learning materials (Kreijns, Kirschner, & Jochems, 2003). To reap the benefits associated with collaboration, children need to develop and practice the skills for effective collaboration (Hayes, 2006).

On the other hand, play is vital in the cognitive, social and physical development of children. Through play, children learn how to be creative by creating and adapting game rules and characters (Verenikina, Harris, & Lysaght, 2003). Many basic social skills are also learnt and developed during play for instance, the ability to make inferences about themselves and others, peer inclusion and participation in social groups, how to interact with other children and how to make friends (Poppe, van Delden, Moreno, & Reidsma, 2014). The bodily actions in play help children to develop and maintain muscular fitness and flexibility and use of objects during play aids in the development of hand-eye coordination for young children (Poppe et al., 2014). Parten classified children's play into various stages (Parten, 1933):

- **Unoccupied play:** where a child is relatively stationary and appears to be performing random movements with no apparent purpose.
- **Solitary play:** where a child plays alone with toys regardless of their proximity to other children. This type of play is mostly prevalent in children aged 2 years-old.
- **Onlooker play:** where a child observes play of other without joining in.
- **Parallel play:** where a child plays along with other children but with little interaction among them.
- **Associative play:** where a child begins to show more interest in the toys other children are playing with.
- **Cooperative play:** where children are more organized and are able to play together and have conversations with a common goal.

Parten noted that while children shift between the types of play, as they grow older, they participate less in the first four types of play and more in the last two which involves greater organization and interaction (Parten, 1933).

Children's play however is not always harmonious as it relies on power relations between the groups. There would typically be a leader and follower, establishment of rules and bondaries (e.g. who sets or breaks the rules) and decision to play (e.g. a game might be picked but not everyone will want to play the game all the time). There is also developmental changes that occur for example, young children are very egocentric and are quite happy to play together with no distinction between the sexes (boys and girls). But as they get older, they notice this difference between the sexes and then start to build peer groups where they prefer to play with same-sex peers and may display gender-typed behaviours where for instance, boys who are active may seek out other children who are active, presumably boys or girls who are gentle and cooperative may show enhanced preference for same-sex play relative to other girls (Martin & Fabes, 2001). This division even gets stronger as they grow into adolescence.

In the world of digital gaming, most co-located multiplayer games (for example, chess, space invaders etc) are usually competitive as players compete against each other. But with the likes of Minecraft, a massively multiplayer online game, where ideally players are expected to collaborate, competition still occurs where someone sets a partner's house on fire or kill others' virtual characters and destroy their creations (Ames & Burrell, 2013). This suggests that children still attempted to compete even when they are expected to play collaboratively. As opposed to collaboration, competition can be detrimental especially within the classroom context as it can increase hostility between students, lead to lower self-esteem and weaken the intrinsic motivation to learn because of the focus on winning (Huizenga, 2011).

In order to make co-located children play together in an equitable and inclusive way, the concept of Enforced Collaborative Agreement (ECA) is introduced and explored. ECA is a type of interaction where synchronous agreement between players is required in order to interact with a digital game. For example, within an ECA game all players must agree to press 'left' button at the same time in order to move the game character left. While several research works have been undertaken to explore collaboration in enforced situations (Kerawalla, Pearce, Yuill, Luckin, & Harris, 2008; Light, Foot, Colbourn, & Clelland, 1987; Pianesi, Zancanaro, Venuti, Gal, & Weiss, 2009; Piper, O'Brien, Morris, & Winograd, 2006; http://www.bbc.co.uk/news/technology-26417482), the current research described in this thesis differs from these previous works in that it explored the concept of ECA where players have to synchronously generate the same control inputs in order to interact with a game within co-located settings where face-to-face negotiation, outside of the game environment, is required to reach agreement. ECA has the potential to foster new kinds of face-to-face collaboration around interactive applications, encourage equitable participation and eliminate social loafing practices such as '*free riding*' thereby allowing participants to contribute and participate equally when working in groups. Additionally, ECA has the potential to make solitary single-player electronic games collaborative and social thereby offering a rich way for children to develop and practice the skills (e.g. language and communication skills) they need for effective collaboration in other contexts. It could also potentially provide game designers with alternative ways of designing collaborative applications for children. These benefits may be particularly valuable in the context of educational environments and serious games.

In the past, the design and evaluation of children's interactive products involved adult users (e.g. parents and teachers) who served as proxies through which the views and opinions of children were sought. However, with the inception of Child-Computer Interaction (CCI) and

Interaction Design and Children (IDC) communities, it is now believed that children are a good source of data about their experiences because of the widely held belief that children have the right to give their opinions about products designed for them (J.C. Read, 2007) and the view that adults and children are two separate humans in two separate worlds with different likes, dislikes, curiosities, physical, emotional and cognitive needs (Bruckman, Bandlow & Forte, 2002; Druin, 2002a). Consequently, specific understandings and methods to work with child users have been developed. Within this context however, the age group of child users is predominantly between 3-12 years (Fitton, Read, & Horton, 2013); working with older participants i.e. children between 13 and 19 years old (also known as teenagers) have received comparatively less attention despite the fact they represent nearly one-fifth of the world's population (Poole & Peyton, 2013). The research reported in this thesis involved a range of older children and early teenagers (11- 16 years old) as participants in the evaluation studies because they can combine the creativity of younger children with the articulation of adults therefore serving as a good representation in the design of adults as well as children technologies (Fitton & Bell, 2014). Also, they have the capacity to work collaboratively on a given task with no mediation (Lai, 2011). Furthermore, participants aged between 17 and 19 years old were not considered as the research work done within ChiCI research group focuses on school aged children aged 16 and under.

1.2 ECA Model

The vision for ECA is that there are different contexts where it can be applied depending on the type of game involved. This is because ECA depends greatly on making decisions in order to interact in games and in different games there are different ways of interacting in making decisions. As shown in Figure1-2, the ECA model describes the perceived effect of interaction and urgency within the context of gaming. Effect is described in this work as the degree to which an interaction influences the gameplay. On the other hand, urgency refers to how quickly players are required to interact within the game environment. Explicitly, urgency describes the rapid interaction occurring in gameplay as a result of players being required to quickly perform an action otherwise something either bad or good happens. Various possibilities for ECA as shown in the model include: High-Urgency-Low-effect, High-Urgency-High-Effect, Low-Urgency-Low-Effect and Low-Urgency-High-Effect. These spaces alter the way collaborative agreement is reached in different types of games. For example, space invader game is in the High-Urgency/Low-effect space because players need to interact quite rapidly otherwise they get killed by the bomb, but the degree to which players interaction influences the game play is small (e.g. moving one pixel left). In the game, if every player is frantically pressing all the buttons, at some point players might probably reach agreement indicating that there is a degree of chance in the way they reach decision. However, in a roleplaying game such as 'Junior Vets' where players answer questions, there might not be a time limit on how long they get to answer the questions and the effect of their interaction on game play is bigger. In this case, there is no degree of chance as every player has to agree in order to give their answer. This type of role playing game falls within the Low-Urgency/High-Effect space. The Low- Urgency/High-Effect space is also occupied by the Separate Control of Shared Spaces (SCOSS) framework to encourage collaborative learning. In SCOSS framework, pairs of collocated children are provided with separate control of an identical version of a word categorization task for each child within their own private screen space that is visible to both children. Similar to the junior vets game scenario, there is no time limit on how long it takes to categorize the words, but the effect of their interaction is big (i.e. either they get the categorization right or wrong). The SCOSS framework share some similarities with ECA and include: control of the interface using separate input methods, participants are collocated and grouped in pairs and both participants need to agree in order to proceed. However, agreement in the SCOSS framework is more explicit requiring children to click their individual 'we agree' button to proceed. Also, agreement and disagreement are more visually explicit providing a good resource for discussions during interactions. Furthermore, ECA uses contemporary input methods and though participants have separate controllers, they can only move left, right or fire if they agree in their controller input while in SCOSS each child can control only their own task elements with their own mouse.

In the Low-Urgency-Low-Effect quadrant of the model, much slower pace is required during interaction and the effect of interaction on gameplay is very low. Jigsaw puzzles are typical examples of games that fall within this space. During gameplay, players might take their time to decide where to place the game pieces and any incorrect move has little effect on gameplay since the goal of the game is to assemble the numerous game pieces to form a complete picture. Also in this case, there is no degree of chance as every player has to agree in order to move a game piece to a new location. In the High-Urgency-High-Effect space, players are required to interact quickly and the outcome of their interaction is important for example, in 'Whack a mole' game, to successfully hit the moles and force them back into their holes the players have to interact quite rapidly. The effect of the players' interaction on game play is quite high as players can only gain scores if they successfully hit a mole or lose scores if they fail to hit the mole thus risk having low scores after the stipulated game time expires.

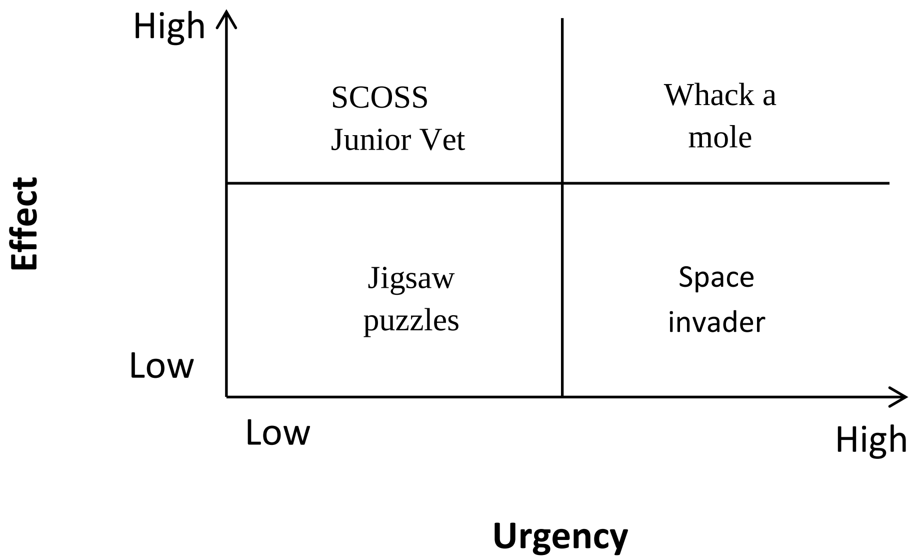

Figure 1-1: ECA Model

1.3 Research Context

The research reported in this thesis follows the User Centered Design approach and has its wider context in Human Computer Interaction (HCI) although it is majorly situated within the context of Child-Computer Interaction (CCI) and more specifically, Teen Computer Interaction (TeenCI). The research also cuts across other disciplines such as educational psychology, educational technology and sociology.

HCI is multidisciplinary deriving its context from both natural sciences and design discipline (Mackay & Fayard, 1997). Historically, HCI has its roots in ergonomics, human factors and socio technical research with its attention on ways to enhance performance of machines maneuvered by humans (Mazzone, 2012; Read & Bekker, 2011). Initially, its interest focused on highly powered machineries such as airplanes, military and war machines but later spread into a wider area to include systems used in working contexts, deriving ways to minimize mistakes in systems when people use them (Mazzone, 2012). The advent of a new era in the use of computers from work based fixed systems to personally owned systems brought about a shift in focus of HCI research which now looks at how humans interact with the computers and consequently, devising methods to improve user experiences.

CCI is a relatively new research area within HCI which began with interests in the use of technologies within education and schools (Read & Bekker, 2011). CCI encompasses traditional HCI but also specifically reaches out into areas of child psychology, learning and play (Read et al., 2008). It involves the design and evaluation of technologies where the humans are children and is focused on developing innovative work through investigating the different context of children and technology use (Read & Bekker, 2011). The limited consideration of teens as participants and end users in CCI and mainstream HCI has led to the need for the development of a new field 'TeenCI' which though overlapping sits between CCI and HCI as shown in Figure 1-2(Fitton et al., 2013). While TeenCI is not yet a full blown research area or identifiable community within the HCI space, it has begun the process of maturing into its own discipline with its own associated methods and solutions. Efforts are being made to gather together researchers, interaction designers, academics and UX practitioners (through the organization of workshops) to share experiences, insights and methodos for teen research with the aim to understanding this unique population against the backdrop of HCI and technology development (Lang, Atkinson, & Fitton, 2014). The research reported in this thesis contributes to the development of TeenCI by adapting child-centered methods which have not been extensively used in studies with teens to evaluate teen UX.

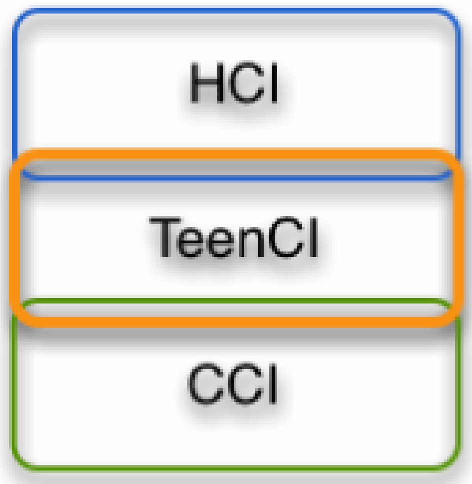

Figure1-2: The place of TeenCI (Fitton et al., 2013).

1.4 Research Aim and Objectives

The overall aim of the research reported in this thesis was to explore the collaborative behaviours participants aged 11-16 years old grouped in pairs within co-located spaces exhibit to reach agreement while interacting with ECA games and to specifically determine whether the behaviours was influenced by the use of different input methods (gamepad, dancemat and tangible controller). In this research, small group collaboration was considered appropriate because it is easier for participants to identify and easily and quickly correct any misconception that may occur during game play. Besides, small groups are considered as more suitable than large groups for group discussions and equal contributions of group members (Finegold & Cooke, 2006). Also, studying collaboration in co-located spaces allows more direct interaction among collaborators enabling visibility of their body expressions and gestures that contribute to more effective communication (Bricker & Tanimoto, 1995). The three controllers represent different interaction possibilities: traditional, tangible and embodied and were chosen in this research because the researcher was keen to explore a range of interaction possibilities in order to understand whether the type of interaction method influenced the collaboration. Furthermore, the chosen controllers support away from the desktop interaction, relatively cheap to obtain, easy to integrate into game and have the ability to influence collaboration in diferent ways. An additional aim was to study the effect of ECA on participants' enjoyment, one of the dimensions of game play experience and highlight the benefits of ECA in enabling collaborative interactions. In order to achieve this aim, the work poses the following research questions:

RQ1: What collaborative behaviours do participants' exhibit to reach agreement while playing games that support ECA?

RQ2: What factors influenced participants' interactions during gameplay?

RQ3: Are the behaviours identified in **RQ1** influenced by different input methods?

RQ4: What effect does ECA have on participants' gameplay experience?

To respond to these questions, the following interlinked objectives are addressed in the work:

1. To investigate collaborative behaviours exhibited by participants to reach agreement within the context of ECA games and their implications to game design processes (**OBJ1**). This objective is addressed through evaluation studies involving observations of participants during gameplay (video recording and researcher observation) and logging of the participants' interaction. These approaches helped in providing the answers to **RQ1**.
2. To identify the factors that influenced participants' interactions whilst playing an ECA enabled game (**OBJ2**). These factors emerged from questionnaire responses and interview sessions with the participants complemented with analysis of log file data obtained throughout the studies and were beneficial towards achieving **RQ2.**
3. To investigate if the participants' behaviours identified in **RQ1** are influenced by different input methods (**OBJ3)**. This objective was also addressed using similar approaches as in **OBJ1.**
4. To investigate the effect of ECA on participants' gameplay experience (**OBJ3**). This objective is achieved through series of evaluation studies carried out in the research work involving user centred approaches and provides the answer to **RQ3**

1.5 Research Contributions

The following contributions to knowledge are envisaged:

1.5.1 Major Contributions

MA1: To explore the concept of ECA using a range of existing methods for evaluating collaboration and produce an Effect/Urgency model (ECA model) which describes the different contexts where ECA can be applied. This model would be used to inform game designers on how ECA fits into different game genres

MA2: To understand the behaviours exhibited by participants to reach agreement during interaction with ECA games and their associated design guidelines for incorporating ECA in games. These could also be adapted for other applications that support ECA.

1.5.2 Minor Contributions

MI1: To provide an understanding of user experience within the context of ECA

M12: To provide an understanding of a range of interaction methods and how they influence ECA.

1.6 Methodology

This research followed a mixed method and a user-centred approach in order to achieve the outlined objectives and provide the answers to the research questions. Two versions of the prototype used in the research were created: single-player version and collaborative versions. The requirements for the creation of the prototype were initially gathered by the researcher and then iteratively refined following user testing studies conducted with child users and an informal testing by members of the ChiCI group. Both qualitative and quantitative data collection and analysis methods were adopted in all evaluation studies conducted in this research, however, the methods evolved during the studies to effectively capture variables of interest.

In the first pilot study, both pre-test and post-test questionnaires were respectively used to obtain participants' demographic information and gather their opinions on the technology, Fun Toolkit (smileyometer, Again-Again table and Funsorter) was used to measure participants' enjoyment of the game (this helped in providing answer to **RQ4**), observation method, where the researcher observed the participants and took notes, was used to explore the strategies that participants adopted to reach decisions and control during game play (this helped in providing answer to **RQ1 and RQ3**) and lastly an attempt was made to log participants' interactions during gameplay to obtain quantitative data for analysing ECA. These initial set of methods were altered in the second pilot study for example video recording of participants interactions during gameplay as opposed to researcher observing the participants was adopted and participants interactions were logged differently as the log files from first pilot study were not designed in a way to provide useful data from participants key presses (or actions). In addition new methods were adopted e.g. Children IMI interest/enjoyment scale was used to compare the participants' enjoyment of the single and collaborative versions of the game (this helped in providing answer to **RQ4**) and unstructured interview using graphs of the participants' actions during gameplay as prompts to help the participants discuss as a group what went on during gameplay and to provide more thoughtful and detailed explanations to what influenced their interactions (this helped in providing answer to **RQ2**). In the main study, some methods were dropped for example Children IMI interest/enjoyment scale and Funsorter while improvements were made to some of the methods for example, the participants' interactions (key presses) were again logged differently to enable more effective analysis of ECA and extra questions were included in the questionnaires.

During analysis, the participants' responses to questions (questionnaire, Fun Toolkit and Children IMI interest/enjoyment scale) were coded and analysed using both descriptive and inferential statistics like counts, percentages, mean and median scores, range t-test and correlation. Also, in some cases graphs were used to illustrate findings and show relationships. The recording from unstructured interview sessions were transcribed verbatim and analysed using thematic analysis method. Also, the notes taken during observation by the researcher were analysed using thematic analysis method. The video data was transcribed using ELAN and coded, an in-depth narrative description of participants' behaviours was provided and collaborative networks were used to show patterns of behaviours occurring within the video data. The logfile data were extracted and counted as well as represented graphically using GNU Plot.

To ensure the reliability and validity of this research, an extensive literature review was carried before selecting the methods adopted to ensure that the methods chosen were appropriate, well understood and applied correctly. In a case where adaptations were made to existing methods, it was ensured appropriate reasons and justifications were provided (e.g. in the use of prompts during interview sessions). Also, it was ensured that the analysis of data obtained in the research was performed with appropriate method(s). In order to reduce bias, the observational notes taken by the researcher as well as the interview data were analysed with another researcher experienced in coding qualitative data and then sent to a senior researcher for validation. Furthermore, it was ensured that the questions asked were appropriate in answering the research questions

During the evaluation studies conducted in this thesis, participants played the single-player version of the game first before playing the collaborative version. The evaluation studies took place in two different settings: University labs where participants recruited from two schools in the UK visited the labs and Youth centres were participants performed leisure activities.

These methods, analysis approaches and study settings will be explained in more details in the relevant chapters of this thesis.

1.7 Outline of the Thesis

This section presents an overview of the contents of each of the eight chapters of this thesis. Following the introductory chapter is chapter 2 which presents literature on developmental psychology, collaboration, input technologies and evaluation which are relevant to the research.

Chapter 3 presents the design decisions and justifactions taken during the creation of the game as well as the controllers used in this research. It also reported the design of the logging used to record participants' interactions with the game and how it evolved. Furthermore, it presents the user testing studies which served as means to identify and correct technical errors and wrong design decisions.

Chapter 4 presents the first pilot study which was an initial attempt to explore the collaborative behaviours participants adopted to reach agreement while interacting with an ECA enabled game. The study was carried out to test the appropriateness of the data collection methods and readiness of test materials for the research as well as monitor the operation of the study design. It also served as a preliminary step to see if the technologies chosen for the research were appropriate.

Chapter 5 presents the second pilot study which sets out to address the shortcomings of the data colletion methods used in the first pilot study as well as served as pilot for the video analysis.

Chapter 6 reports the main study of this research carried out with a larger user population to explore the aims of the research and anwer the research questions.

Chapter 7 discusses the findings from the three studies reported in this thesis with more focus on the main study results and provides design guidelines for researchers who wish to design aplications that support ECA.

Chapter 8 concludes the thesis by summarizing the research and providing answers to the research questions. It also discussed the limitations of the work, contributions of the research to the HCI community and makes suggestions for possible directions for future research.

1.8 Conclusion

This chapter presented an introduction of this research highlighting the research motivation, the context in which the research is situated, the aim and objectives, the research questions and an overview of the methods used in the research. The next chapter will discuss in detail literature that are relevant to this research.

2 CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

An extensive literature review conducted to evaluate research within child development, collaboration, input technologies and user experience is reported in this chapter. Most of the papers reviewed in this chapter were gathered from top journals and conference proceeding papers in HCI including Interaction Design and Children (IDC), Child-Computer Interaction (CHI) and NordiCHi. These sources have also been complemented with articles found through keyword search from other scientific databases such as Science direct and ACM as well as child psychology databases (e.g. psychNet), papers and books. This chapter is divided into four key sections:

Section 2.1 provides the definition of the child and overview of adolescents with the aim of understanding the needs, nature, abilities and interest of the target user group of this research. Section 2.2 takes a look at understanding the concept of collaboration by exploring the various definitions of the term by researchers from diverse disciplines and highlighting the qualities that characterize true collaborative interactions. The section also reviewed previous research works which explored collaboration and children in collocated spaces as well as existing approaches and methods for measuring collaboration. Section 2.3 explores various input technologies and how these technologies impact collaboration. Section 2.4 reviews the concept of UX, its nature and dimensions. As one of the objectives of this thesis is to explore the effects of ECA on participants' experience within the context of gaming and with focus on enjoyment, section 2.4 also presents a review of the tools for evaluating children's enjoyment of interactive products.

2.2 Definition of the Child

There are several definitions of what a child is. The most commonly used definition comes from the United Nations Convention on the Rights of a Child (UNCRC) which has to do with legal requirements. In the definition a child is *"every human being below the age of eighteen years old unless under the law applicable to the child, majority is attained earlier"* (UN Assembly, 1989). This definition was ratified by 191 countries including the UK in 1989, however there are several other laws across the UK that specify age limits in different circumstances such as age of consent, child protection and age of criminal responsibility. From a biological point of view, children are considered as humans in the development phase of childhood which is a period between infancy and the onset of puberty which cuts it off at 12 or 13 years (Keenan & Evans, 2010). This definition suggests that one can be legally considered a child but not in childhood. There is also a global complexity of what a child is, for example, children in the third world countries take on responsibilities such as going to wok at a very early age (11-12years). Though they are still officially children, their childhood has actually come to an end because they behave like adults. Therefore, age alone is a very blunt metric for discussing children because it assumes that at one specific point in time, one leaves childhood and enters adulthood (Panos Markopoulos, Read, MacFarlane, & Hoysniemi, 2008). Consideration needs to be given to the differences in cultures and societies when discussing children. Children have been involved in research across various disciplines such as sociology and psychology, computing, education, medical etc. but the majority of the research undertaken with this unique user group focuses on children aged sixteen and under (Horton, 2013). Older children are considered to be more like adults as their ideas and opinions often conforms to adult user groups.

As children grow up, they move through different stages of development; the rates at which they develop also vary from one child to another and even from one group to another. Additionally, children have their own likes, dislikes and needs which vary between different age groups and even from those of adults (Druin, 1996). In the instance, where children will perform evaluation of technologies, it is vital to understand that children are not a homogenous group for which a single theory and practice should be recommended rather they vary in diverse ways (cognitively, physically, emotionally and socially) at different stages of their development (Markopoulos & Bekker, 2003).

As stated earlier in chapter one, participants aged between 11-16 years old (also known as adolescents) were involved in the evaluation studies reported in this thesis. This unique group of individuals reside in a fascinating and dynamic space between childhood and adulthood (Fitton & Bell, 2014). Therefore when working with such user group as participants, it is important to understand the characteristics, needs and skills that differentiate them from other user groups which might help in understanding their world.

2.2.1 Adolescence and their development

Adolescence is the period of developmental transition between childhood and adulthood which is characterized by dramatic biological, cognitive, psychological and social changes (Blakemore & Mills, 2014). Initially, the period of adolescence was regarded as a single period in the life span but studies of adolescents showed that there is a marked difference in the behavioural patterns of young and older adolescents (Hurlock, 1967). Consequently, adolescence have been classified in several ways sparking a debate in literature surrounding the age boundaries of adolescence (Dashiff, 2001; Poole & Peyton, 2013). This could be attributed to the fact the physical changes characterizing the start of adolescence may begin as early as the age of 6 and or as late as 15 (Dorn, Dahl, Woodward, & Biro, 2006) or in the case of brain development may extend into a person's 20's (Dahl, 2014). Also, there is no generally accepted age when adolescence ends; while Peterson and Leffert suggests 20 (Peterson & Leffert, 1995), popular imagination sees adolescence as ending when a person completes compulsory education, moves away from parents or leaves their 'teen' years, precisely at either 18 or 19 (Poole & Peyton, 2013). In this research, adolescence is considered as being three distinct phases (Smetana, Campione-Barr, & Metzger, 2006): early adolescence (10-13 years), mid adolescence (14-17 years) and late adolescence (18 until early twenties). While it is true that each adolescent is an individual with a unique personality, likes, dislikes and special interests, there are numerous developmental issues that all adolescents face during the early, middle and late adolescent years. As the research reported in this thesis involved 11-16 year olds, the discussion hereafter will focus on the changes that occur during early and middle adolescence.

Regardless of any culture, there are three types of fundamental changes that occur universally during the period of adolescence. These include biological, cognitive and social changes (Kendall, 2006) and can be influenced by individual and cultural differences in terms of the age at which they occur. The beginning of biological growth (which starts during early adolescence) is characterized by the onset of puberty in which a child is transformed to an adult and associated with a myriad of biological changes including sexual maturation, changes in body composition and increases in height and weight to mention but a few. During the early adolescence, girls and boys become more aware of their gender than they were when they were younger children, and they make adjustment to behaviour or appearance in order to fit with the perceived norm. The second fundamental change is cognitive change wherein a diverse range of cognitive developments (e.g. an increase in memory function, increased speed of processing and acquisition of abstract thought capabilities) occurs as the adolescent brain approaches physical maturation (Steinberg, 2005). With advancements in developmental neuroscience, researchers have shown how developing adolescent brains actually processes information differently to children and adults (Steinberg, 2005), in particular social information (Blakemore & Mills, 2014). Within this period of brain development, adolescents display an increased willingness to take risks and a heightened sensitivity to immediate rewards as opposed to long-term rewards (Steinberg, 2004). Social change occurs when adolescents are increasingly no longer viewed as children and as a result given the privileges and responsibilities of adults (Fitton & Bell, 2014). In developed countries, these social changes may include age related milestones such as driving, voting, alcohol consumption or military service. 'Context' refers to the social environment such as family, schools, peer groups and work/leisure environments where teenagers spend most of their time (Smetana et al., 2006), which influences the way they experience the fundamental changes associated with adolescence and shapes the course of their development. In the modern world, technology and media feature heavily in all the four social environments (family, peer groups, schools and work /leisure places) and plays a crucial role in shaping the nature of the developmental contexts. For instance, the technological advancement in communication (including access to the internet, social networking sites, instant messaging and text messaging) have changed the nature of teen peer groups by increasing the number of peers with whom they can regularly communicate, the style of their social interactions and the medium through which they communicate. During the psychosocial stage of adolescent development (i.e. changes that are both psychological and social in nature), they face several challenges such as identity, intimacy, sexuality, autonomy and achievement (Steinberg, 2008). While these challenges are not unique to just adolescents and may be experienced by individual at any stage of life where change is occurring, the way they are experienced is considered to be unique to the adolescent population. For instance, most adolescents develop a sense of self (identity negotiation as individuals and as part of the broader social world) for the first time during the period of adolescence (Erikson, 1968; Lloyd, 2001). However, this sense of self or identity is not fully developed within this period but is continuously shaped throughout a person's life and greatly influenced by the person's experiences. Also, the sense of self that occurs in the period of adolescence could be considered as unique since they cannot be experienced prior to the period of adolescence due to the immature cognitive processing of a pre-adolescent brain (Fitton & Bell, 2014).

2.2.2 Challenges involving adolescents as participants in research studies

Adolescents are a very diverse and highly contextualized group of individuals who are influenced by a range of factors (biological, cognitive, social and psychological), thus posing several challenges when involved in research. These challenges have been highlighted in literature (Dashiff, 2001; Fitton & Bell, 2014; Fitton et al., 2013) and includes issues related to use of methods, cultural understanding, context in which to engage teenagers and ethical considerations.

In terms of methodological challenges, special consideration is required as methods developed for child or adult users may not be appropriate or entirely successful with teen users. Several researchers have provided some useful guidelines on collecting reliable data when teenagers are involved in research studies; some of which were considered in the current research (Dashiff, 2001; Mack, Giarelli, & Bernhardt, 2009; Poole & Peyton, 2013). For example, use of prompts during interviews especially when open-ended questions are used (Mack et al., 2009). Furthermore, the increase in cognitive development in the area of abstract reasoning during adolescence (Piaget, 1972) allows adolescents to move beyond the concrete to use of verbal hypothesis and logical deduction. However, younger adolescents are more likely to be concrete in their reasoning and less likely to think about future consequences of their decisions compared to older adolescents (Dashiff, 2001). Also, decision making and reasoning ability are likely to affect responses to questions before age 14 but after 14, adolescents reasoning and decision making ability becomes as mature as in adulthood as long as the situation is one where the adolescent has experience in (Khun, Amsel, & O'Loughlin, 1988). Due to these cognitive differences, questioning approaches which require more abstract reflection or formal logic may not be well suited for younger adolescents. Therefore, it has been suggested to use more concreate rather than abstract questions during interviews with younger adolescents as they are more likely to be concrete in their thinking than abstract (Dashiff, 2001).

Several different settings exist for working with adolescents e.g. classrooms, homes, youth centres and research labs however the choice of where to conduct research studies is likely to impact their behaviours and the power relations between adolescents and the researcher (Fitton et al., 2013). For example, while a school setting (or classroom) presents easy access to large number of adolescent, high level of supervision, familiar and organized environment to observe and obtain feedback, their behaviours towards the researcher will be representative of their experiences with their teachers and if the research work involves group working, their behaviour is likely to be influenced by the presence of peers e.g. possible tension between mixed sex groups (Fitton et al., 2013). Furthermore, working with adolescents in their homes may be problematic especially when scheduling appointments for studies as they are more independent and may have separate schedules (Dashiff, 2001). Conflicts with parents can also impact studies conducted at the homes of the adolescent participants.

Ethical considerations may include informing adolescents about the context of the research and the potential impact of their participation in the study to allow for appropriate consenting and participation as well as how their contributions will be disseminated e.g. in research papers. The Child-Computer Interaction (ChiCI) group at the University of Central Lancashire (UCLAN) has made a commendable effort in designing tools (CHECk1 and CHECk2) to assist researchers in communicating the purpose and practicalities of their research works (Read et al., 2013). These tools were used during the research studies reported in this thesis.

2.3 Understanding Collaboration

Collaboration is a ubiquitous term that can be used to describe a wide range of behaviours and generally refers to any activity performed together by a pair or a group of individuals. Within social sciences, collaboration is "*a process in which autonomous actors interact through formal and informal negotiation, jointly creating rules and structures governing their relationships and ways to act or decide on the issues that brought them together; it is a process involving shared norms and mutually beneficial interaction*"(Thomson & Perry, 2006). Within learning sciences, Lipponen provided two approaches adopted by researchers towards the definition of collaboration: collaboration as a process of participation in collective activities and collaboration as a special form of interaction (Lipponen, 2002). The former approach offers a broader definition of collaboration than the latter and is mainly concerned with the process of participating in knowledge communities (Lipponen, 2002). Rochelle and Teasley considered collaboration as a special kind of interaction and wrote that collaboration is "… *a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem*" (Teasley & Jeremy, 1998). Their definition stresses the role of shared understanding of a problem amongst the collaborators. They defined the 'Joint Problem Space' (JPS) as the shared knowledge structure that supports problem-solving by integrating goals, descriptions of the current problem state, and awareness of available problem solving actions, as well as associations that relates goals, features of current problem solving state and available actions. According to Roschelle and Teasley, collaboration takes place within this joint problem space, which provides the structure needed to allow meaningful conversations about the problem (Teasley & Jeremy, 1998). To construct a joint problem space, partners must have ways to introduce and accept knowledge, monitor exchanges for evidence of divergent meanings, and repair any divergences identified.

Several qualities that characterize truly collaborative interactions have been identified by Dillenbourg (1999). Firstly, collaboration is characterized by a relatively symmetrical structure and various forms of symmetry are differentiated. In situations with symmetry of action, each participant has access to the same range of actions. This contrasts with the typical division of labour in cooperative learning structures; partners split up the work, solve sub-tasks individually, and then put their respective contributions together. Symmetry of knowledge occurs when all participants have roughly the same level of knowledge, although they may have different perspectives. Symmetry of status involves collaboration among peers rather than interactions involving supervisor/subordinate relationships. Finally, symmetry of goals involves common group goals rather than individual goals that may conflict (Dillenbourg, 1999). The quality of interactions, especially the degree of interactivity and negotiability is another marker of true collaboration (Dillenbourg, 1999). Interactivity does not refer to the frequency of interactions but to the extent to which interactions influence participants' thinking (cognitive processes). Negotiability refers to the extent to which no single group member can impose his view unilaterally on all others, but rather will argue for his standpoint, justify, negotiate, attempt to convince other group members. Dillenbourg (1999) points out that negotiation can only occur if there is space for negotiation - obvious, trivial and unambiguous tasks provide few opportunities to observe negotiation because there is nothing about which to disagree. Besides, misunderstandings may actually be important from a learning standpoint; they force participants to construct explanations, give reasons, and justify their positions (Lai, 2011). Other features include positive interdependence where the success of an individual is dependent on the success of the group (Laal, 2013; Lew, Mesch, Johnson & Johnson, 1986), mutual support, intimacy among participants, the quality of interpersonal relations of those interacting already in place at the time collaborative encounter is initiated and a rich supply of external resources which facilitate mutual understanding and shared goals e.g. computers (Crook, 1998).

Roschelle and Teasley differentiated collaboration from cooperation (a form of working together) stressing that cooperation requires division of labour where each person is responsible for a portion of a problem while collaboration emphasizes on a mutual engagement of participants in a coordinated effort to solve a problem together (Roschelle & Teasley, 1995). Thus participants work together on the same task rather than in parallel on separate portions of the task. Kerawalla *et al.* further highlighted that when a task is collaborative participants make joint decisions (Kerawalla et al., 2008) but in cooperative task situations, participants divide the task into parts taking responsibility for their own part and may come together to fit the parts together. Dillenbourg however noted that division of labour may occur spontaneously during collaboration hence the distinction between cooperation and collaboration is not certainly clear-cut (Dillenbourg, 1999). Additionally, the level of social interaction is necessarily high when participants collaborate and share in the decision making process whereas it may not be the case for cooperative workers (Underwood, Underwood & Turner, 1993).

In the context of gaming, Zagal et al. (2006) provided three distinct categories of games namely competitive, cooperative and collaborative. In competitive games, players form strategies that directly oppose those of the other players in the game which results to either a win or lose (e.g. chess, basketball and soccer). Cooperative games model situations where two or more individuals have interests that are "*neither completely opposed nor completely coincident*" (Zagal et al., 2006) and provide opportunities for players to achieve a win-win condition by working together (although it not assured that the cooperating players will benefit equally or even benefit at all). Additionally, cooperative games include enforceable rules for negotiation allowing players to identify desirable outcomes for the parties involved. In collaborative games, all players work together and wins/loses as a team (an example is the ECA enabled space invaders game described in this thesis). Consequently, success can only be achieved when all members of the group reach their goal which also assures joint rewards. Collaboration in gaming demands that players work together as a team having one goal and sharing the rewards or penalties of their actions whereas when individuals cooperate among themselves during gameplay, they may have different goals and payoffs (Zagal et al., 2006).

In this thesis, collaboration is viewed as a special kind of interaction stressing the idea of mutual engagement of the parties involved. Particularly, the work focuses on enforced collaborative situations in a gaming context and co-located settings where face-to-face interactions is required to reach agreement in player controller inputs.

2.3.1 Mechanics of collaboration

This refers to the small-scale actions and interactions that group members must do in order to collaboratively carry out a task on shared workspaces (Gutwin & Greenberg, 2000; Pinelle, Gutwin, & Greenberg, 2003). The 'mechanics of collaboration' was first presented by Gutwin and Greenberg (2000) but later revised to include a more extensive list which provide a well-defined way of conceptualizing and describing teamwork in groups (Pinelle, Gutwin, & Greenberg, 2003). The mechanics of collaboration is comprised of four categories: explicit communication, information gathering, management of shared access and transfer.

- ***Explicit Communication***: This refers to communication that is not intentional or planned and is the most fundamental element of collaboration. It includes:
  - Spoken communication: This is the most common type of explicit communication and includes 'ordinary conversation' where people engage in a dialogue while working together on a task, and 'verbal shadowing' a running commentary that people usually produce alongside their actions which is not directed to anyone in particular but intended to help others to be aware of what a person is doing and why.
  - Written communication: This refers to conversations that can be carried out through writing to relay a message to someone. The mechanics of collaboration framework primarily focuses on short-term written communication used to convey ideas or provide details for a particular item rather than the lengthy reports or long-term documents that are commonly used to send messages to someone is not currently present . An example is the text chat tool in groupware systems used to send and receive messages from group members collaborating on a given task(s).
  - Gestural communication: Gestures are frequently used in face-to-face work situations to communicate messages to others for example pointing to indicate objects, area and directions or instances where a gesture stands for a particular word or phrase e.g. thumps-up representing 'OK'. However, for gestural communication to be meaningful the sender must have a medium that is rich enough to convey the gesture and the receiver must be able to see the gesture with enough fidelity to interpret it.

- Deictic Reference: This is the combination of both verbal and gestural communication for instance, in a group work someone might instruct a group member on what direction to go by saying “go there” as well as pointing to the direction he/she wants the partner to go. However, interpreting combined communication depends on the knowledge about what objects are being discussed and what the sender is doing.
- Manifest Action: These are actions that entirely replace verbal communication during collaborative work. For example, when someone uncaps a marker in front of a collaborative whiteboard during a brainstorming task, it tells other group members that the person is about to write down an idea without having to verbalize it.

- **Information gathering:** This refers to the gathering of information from group members’ activities when collaborating on a task(s). Pinelle, Gutwin, and Greenberg (2003) identified different kinds of information that can be gathered:
  - Basic group Awareness i.e. information gathered in order to keep track of the basic organization of the collaborative session (e.g. who is in the workspace, where they are working and what they are working on) which helps collaborators communicate more efficiently and identify opportunities to assist or collaborate more closely with other people in the group.
  - Feedthrough i.e. information about people’s activities which are gathered by seeing or hearing the effects of manipulating objects in the workspace. For example, seeing changes to objects and inferring an activity has taken place.
  - Consequential communication i.e. information unintentionally given off by others as they go about their activities.
  - Visual evidence i.e. visual actions which provide evidence that the utterances of those collaborating on a task have been understood or misunderstood.
  - Information gathered by overhearing other people’s explicit conversations even if the parties only intend to communicate with one another. Overhearing serves two purposes: firstly, it conveys the message that other members are present and are interacting; and secondly, the content of the conversation may be valuable to the person that overheard the conversation.

- **Management of shared access:** This mechanic deals with coordination issues relating to how objects within the workspace are accessed and used. It is typically evident where there are limited shared resources such as artefacts, tools, the workspace itself or even time. Three coordination issues were identified in the framework:
    - Obtain a resource – as many shared resources can be used by one individual at a time, people act to obtain the resources for their own purposes by either taking the object or tool or occupying a part of the shared space with their bodies. This activity is coordinated in groups by one's ability to see which objects that are not close to other members of the group as well as the movement of their arms. In a situation where two people are in a resource conflict (for example grabbing the same object), the conflict is usually resolved by social protocols (i.e. one person releasing the object with the realization that there is a resource conflict).
    - Often times, people working in share spaces attempt to reserve resource for future use. For example, gathering up objects they will make use of later on or moving to a part of the workspace where they plan to work in next.
    - People tend to ensure that others in the group do not interfere with or destroy their completed work by explicitly communicating to others or monitoring others to make sure they do not make changes to their work.
- **Transfer:** This concerns the transfer of objects and tools from one person to another. Ability to transfer objects or tools to another person is crucial in switching roles and providing help to one another when required. There are two ways in which objects can be transferred in shared workspaces:
    - Handoff - This is a synchronous interaction where one person transfers an object to another either by physically handing the object to the receiver or through verbal communication where ownership or responsibility of an object is transferred, even if the item itself is not.
    - Deposit - This is an asynchronous type of transfer where one person leaves an object in a particular place for another person to retrieve later. Communicaton is usually required to identify the deposit location as well as to notify the recipient that the deposit has occurred.

Yuill and Rogers also presented three mechanisms for collaboration from a psychological perspective: control over the interface, awareness of other's actions and interactions and availability of background information (Yuill & Rogers, 2012). Control of action refers to the ways in which users can effect changes in actions within the system and hence decision within the group. One of the ways users can have control on multi-user workspaces is illustrated in the idea of 'multiple entry points' which gives users opportunities for control by different means, for example users could move items on a surface and place cards and use tangibles to design a garden (Rogers, 2009). While the idea of multiple entry points makes it more inviting and easier for users to interact whenever they want, it has been argued that there can be too many touches thus making it less obvious as to how a co-loctaed group should coordinate their interactions and collaborate (Yuill & Rogers, 2012). One of the ways to deal with the difficulties of all users acting at one time is to control closely how they have to act together to control a task. Benford et *al.* described a continuum of support to guide the design for collaboration (2000). At one end of the spectrum are approaches that give away control, where users can act independently and are free to coordinate their actions if they choose to (enabling collaboration). At the other end of the spectrum are approaches that strongly enforce strict rules during collaboration and are very rigid. A typical example is SIDES, a multitouch table application where teenagers with varying behavioural difficulties played a board game on a multitouch table that enforced turn-taking in that only a specified person can move objects at any one time (Piper et al., 2006) or by demanding that users have to synchronize their actions in order to succeed (as used in this thesis). Encouraging collaboration sits in the middle of the continuum and provides an added benefit for users if they work together as in the case of Kidpad (Benford et al., 2000). Awareness of actions refer to the degree to which individuals have ongoing awareness of actions, intentions, emotions and other mental states of others interacting on multi-user interfaces. Several ways in which people subtly show awareness while interacting on multiuser technologies have been identified in literature. For example, an empirical study which compared two kinds of input (multitouch and multi mice) showed that users displayed several different signs of awareness when designing a seating plan using the multitouch and these include making running commentary on their own actions, anticipating collisions by adjusting their position and even sometimes using their elbows to get others out of the way (Hornecker, Marshall, Dalton, & Rogers, 2008). While awareness of actions plays a crucial role in supporting collaboration on multi-user interfaces, there is also a risk of cognitive overloading as such interfaces have the capacity to present large amounts of information and a high degree of simultaneous actions by multiple users (Harris et al., 2009). Availability of information refers to the externalization of background information relevant to users' behaviours and the task at hand. It differs from awareness in that the information is explicitly available for all whereas awareness relates to ongoing moment-to-moment implicit cues that are used during interaction.

2.3.2 Children and Collaboration

There are opposing views in literature as to when children develop the capacity to collaborate on a given task. Piaget's cognitive development theory postulates that knowledge acquisition is a self-continuous process where knowledge is gathered and re-invented as children develop and interact with their surrounding world (Driscoll, 2005). Piaget believed that children think and reason differently at different stages of their lives which he grouped into four stages: sensorimotor, preoperational, concreate operational and formal operational. The different stages of development are briefly reviewed below:

- **Sensori-motor:** This stage lasts from birth to 2years old during which children go from being newborn babies who explore the real world through their senses and movements to toddlers with basic capacity for thinking (Smith, Cowie & Blades, 2011). Through this stage, children begin to notice the effect their behaviours have on objects around them e.g. shaking a rattle to make a noise. Children also begin to act in ways they know will yield certain results, learn to differentiate themselves from the environment and develop the capacity to from internal mental representations.
- **Pre-operational:** This stage lasts from 2years until 7 during which children begin to understand about the classification of objects through the symbolic use of language and intuitive problem-solving. Imagination and memory are developed in this stage, children lack ability to cope with more than one aspect of a task at a time and view the world from an egocentric perspective; that is they have difficulty taking viewpoints of others from their own perspective (Smith et al., 2011).
- **Concrete:** This stage lasts from 7years until 11 during which children become less egocentric and can more easily take the perspectives of others. They have a better understanding of mental operations and can think logically about objects and events.

However, children are still limited in their ability to think abstractly (Markopoulos et al., 2008)

- **Formal operational:** This stage begins at 11 years and marks the period when human cognitive development has reached its full potential. In this stage, children can think hypothetically as well as understand highly abstract concepts.

From the Piagetian perspective, children younger than 7 years old due to the fact that they have not reached the concrete operation stage may lack the skills to benefit from collaboration as they cannot reason logically, have difficulty recognizing the views of others and lack the ability to sustain discussion of alternative hypothesis. However, children tend to benefit from collaboration once they reach the concrete stage of development and are able to apply mental operations to concreate problems (Tudge, 1992). While Vygotsky did not identify particular stages at which children are able to collaborate, he emphasized the benefits of collaboration when children differ in their initial skill sets (Lai, 2011). Hence, collaboration occurs between a child and a more competent or knowledgeable pair (adult, peer, computers etc.). Vygotsky termed this conceptual space in which children learn and develop if they are adequately supported by an adult or a more capable pair the 'Zone of Proximal Development' (ZPD).

In contrast to the Piagetian perspective, it is suggested that young children especially those in their early childhood can acquire the skills necessary to collaboratively interact with their peers if they are taught. For example, a study that compared pre-school children who were taught how to resolve conflicts with other children who were not revealed that children who received the training correctly used the skills they acquired to resolve conflicts in a positive fashion (Stevahn, Johnson, Johnson, Oberle, & Wahl, 2000). Also, Gómez and his colleagues showed that pre-school children are capable of collaborating on a task with the mediation of their teacher who provided scaffolding (i.e. guidance and encouragement from a skilled or more knowledgeable person) that directed the children towards their ZPD, thus helping them to collaborate and eventually learn in the process (Gómez et al., 2013).

Researchers have highlighted collaboration as an important skill for children's learning and development (e.g. Daiute & Dalton, 1993; Rogoff, 1994) and as a result have invested time and effort in studying the concept. A large body of previous work has explored collaboration with children in co-located settings. Antle et *al.* developed Youtopia, a hybrid tangible and multi-touch land use planning activity for elementary school aged children, to investigate issues surrounding the design and evaluation of children's collaborative learning application using digital tabletops (2013). Africano and his colleagues presented a design concept for developing interactive play system and learning tool for children illustrated with ELY the explorer- a set of tangible tools and software application (Aficano et al., 2004). The majority of previous works focused on the use of technology to support children's collaborative interactions e.g. multi-touch table tops (Goh, Shou, Tan, & Lum, 2012; Jamil, O'Hara, Perry, Karnik, & Subramanian, 2011; Rick et al., 2009), separate control of shared spaces (Kerawalla et al., 2008), handheld devices (Fails, Druin, & Guha, 2011), single display groupware (Scott, Mandryk, & Inkpen, 2003) and multiple mice (Inkpen, Ho-Ching, Kuederle, Stacey, & Garth, 1999; D. Stanton & Neale, 2003). These studies identified different collaborative behaviours exhibited by children when they interact in varying collaborative settings. The most featured is the nature and content of discussions that went on between collaborators. For example, (Harris et al., 2009) observed a group of children whilst they designed a seating plan for their classroom using single touch and multi-touch tabletops. They identified task-focused and turn-taking discussions in the multi-touch and single touch conditions respectively. An explanation for this result is logical - the single touch condition allowed one child to interact at a given time, thus children resorted to turn-taking to ensure everyone in the group participated in the task. In the multi-touch condition, children could interact at the same time hence they devoted more of their time to discussion of the task. In the use of multiple mice, (Inkpen et al., 1999) explored the effects of multiple mice on children's collaborative interactions. They found that when provided with multiple mice children appeared to participate more actively and exhibited high levels of engagement. These results were similar to those of Scott *et al.* (Scott et al., 2003) and Pawar *et al.* (Pawar, Pal, & Toyama, 2006). However, providing children with multiple mice without enforcing collaboration does not guarantee highly collaborative behaviours or improve the likelihood of concurrent or equitable interactions between children. A typical example is a study which compared how the dual control of a Separate Control of Shared Space (SCOSS) and the dual control of a single user interface mediate the collaborative decision making process between pairs of 7-9 year old children carrying out word categorization tasks on a shared computer (Kerawalla et al., 2008). The SCOSS is an interface that provides an identical version of tasks where each child's space was visible to both participating children but accessible to only one child. Although children used multiple mice when interacting with both interfaces, it was observed that they exhibited behaviours that were not conducive to joint understanding (such as parallel working and more domineering behaviours with minimal discussions) in the single task. The reason is because it was possible for only one child to complete the task with their own mouse in the single user interface. The features of SCOSS interface enforced collaboration by permitting each child to contribute to the decision making process (a typical example is being able to express their agreement/disagreement by placing their words where they think they should go). The SCOSS framework is similar to the work described in this thesis as participants were co-located, played in pairs with dual control of the interface using separate input method and had to agree in some way but differs in that agreement was more explicit (as children were required to agree with each other by clicking their own 'we agree' button before they can proceed) and agreement/disagreement were more visual providing a good resource for discussions during interactions. Also, ECA is an evolution of the SCOSS framework which aims to understand collaboration and technology with children using contemporary controllers. Although the participants have separate controllers, they can only move left, right or fire if they agree in their controller input while in SCOSS each child can control their own task elements with their own mouse.

Within gaming contexts, collaborative mechanics have become prominent with the likes of massively multiplayer online games (MMOGs) such as World of Warcraft, Lord of the rings, Minecraft etc. However, most of these games encourage rather that enforce collaboration (Zagal, 2006). Pianesi *et al.* explored the design and evaluation of a collaborative Puzzle game to foster collaboration and social skills in children with ASD (Pianesi et al., 2009). Their work employed an enforced collaborative mechanism, and focused on children with Autism Spectrum Disorder (ASD). This is the closest work to that presented in this thesis but differs in so far as in this work we explored enforced collaboration using a range of data gathering approaches i.e. video analysis of gameplay, and use of graphs of gameplay data as prompts during unstructured interview sessions with participants, a range of interaction techniques, and a focus on agreement between pairs of participants with no diagnosed developmental difficulties collaborating during game play. Furthermore, a recent experiment, Twitch (Margel, 2014), where millions of players simultaneously controlled one character in an online game employed the concept of ECA. However, Twitch is distinct from the work explored in this thesis where participants were co-located and interacted with the game using game controllers and not issuing commands. In the Twitch experiment, there is no way of ascertaining the participants' characteristics (e.g. age group) and communication is not possible as the the chat room was used as input. While all papers previously cited have used a wide range of approaches and formed a valuable set of findings to inform this work, no study has yet systematically explored synchronous forced collaboration with participants in the way that is described in this thesis.

2.3.3 Measuring Collaboration

Several useful approaches have been adopted by researchers for analysing collaborative processes in technology-supported settings. These include quantitative, qualitative, theory-based and data-driven approaches. Quantitative approaches allow researchers to quantify the number and types of interactions that take place among collaborators as well as identify particular interaction patterns and roles during collaboration (Spada, Meier, Rummel, & Hauser, 2005; Wortham, 1999). Some examples include nodal networks analysis which is used to show the relations between members in a group where a node or point represents each member of the group and lines signify bi-directional connections between them (Wortham, 1999), interaction matrix analysis which is a matrix representation of nodal networks/diagrams (Wortham, 1999), analysis of computer generated log files and coding schemes which have been developed in order to quantitatively assess instances of certain types of behaviours or speech acts during collaborative process (Kneser & Ploetzner, 2001; Pilkington, 1999). Rather than analysing collaboration purely on the occurrence of behaviours or utterances, some researchers focused on the quality of the collaborative process and adopted various approaches. For example, Häkkinen *et al.* developed a theory-based analysis method for rating the level of perspective taking in text-based online discussions (Häkkinen, Järvelä, & Mäkitalo, 2003). The method involved an initial categorization of the online discussions into groups (question, suggestion, comment, experience, new point/theory), then graphs showing the progress of discussion, dynamics of different types of messages, mentor's role and cross referencing were drawn. These graphs aided the grouping of all the discussions into high-level, progressive and low-level discussions and finally, the specific analysis of a stage of perspective taking in discussions was conducted. Collazos and Guerrero adopted a different method where they observed groups of four individuals playing a TeanQuest game (each person had one computer physically distant from one another and communication was only possible through a chat system). Several data were collected during gameplay including messages sent by each member of the group, time when the messages were sent, the person who sent the message(s), the person who received the message(s), the mouse location when the message was sent and in-game play data (scores, start and finish time). These data were then used to develop a set of five indicators for analysing the quality of a collaborative process (Collazos & Guerrero, 2004):

- First indicator - Applying strategies: This indicator capture the ability of the group members to generate, communicate and consistently apply a strategy to jointly solve a problem
- Second indicator – Intra-group cooperation: This indicator relates to the employment of collaborative strategies previously defined during the group work process. An understanding of how each group member's task relates to the global team goal makes it easier for the group to coordinate.
- Third indicator – Reviewing of the success criteria: This indicator measures the degree of involvement of the group members in reviewing boundaries, guidelines and roles during the group activity.
- Fourth indicator – Monitoring the activity: This indicator is a regulatory activity which checks if the group maintains their chosen strategy to solve a problem.
- Fifth indicator – Group performance: This indicator refers to the quality of proposed solution to the problematic situation measured by three factors (1) errors made by the group, (2) achievement of the main goal and (3) efficiency of mouse movement.

Other approaches have been data-driven and qualitative in nature often following the ethnographic research tradition where emphasis is placed on identifying concepts and patterns as they emerge from the data. For example, Stanton and Neale adopted the 'collaborative networks' to examine the process of pairs of children's collaboration when using one or two mice at a desktop to recreate a poem (Stanton & Neale, 2003). The approach followed three steps:

- Verbal communication of the children as well as the computer-based activities were recorded
- Then a coding scheme was developed from the data

- Descriptive data (verbal communications/actions) and their accompanying codes were represented in the collaborative network to present a clear picture of how dialogue and computer-based actions influenced the process of collaboration.

The collaborative networks were useful in highlighting the collaborative patterns of behaviour in the one mouse and two mice conditions. Qualitative approaches give rich, holistic descriptions and emphasize the social settings in which phenomena of interest are embedded (Häkkinen et al., 2003).

Clearly, there is an incredible diversity in the approaches that researchers have adopted to measure collaboration however, the various methodological approaches differ intensely with regard to dimensions such as sources of data collection, the way the analyses are conducted (e.g. technology and tools used) and the level or unit of analysis (Rummel & Spada, 2004). The unit of analysis of collaborative activities could range from analysing turns of talks (verbal participation) and physical participation (Harris et al., 2009), speech acts or time units of various lengths to analysing bigger chunks of interactions like screens. Furthermore, analytic approaches may differ in aspects of the interaction such as verbal behaviour such as the nature of discussion (Harris et al., 2009) and non-verbal behaviours (e.g. gestures, facial expression, posture, voice modulation) that are included in the analysis.

According to Rummel and Spada (2004), no single method is sufficient to unravel all aspects of a collaborative process. The various methods and approaches need to complement one another to help reveal the richness of information contained in a collaborative interaction. Nevertheless, there is always the necessity to choose methodological approaches that allow one to gain data on aspects of the collaborative process that are of focal interest for a given research question. Consequently, in this thesis the researcher carefully selected methods deemed fit to provide answers to the research questions. The approaches consists of both qualitative i.e. use of 'collaborative networks' to identify participants' collaborative behaviours while playing an ECA enabled game and quantitative approaches i.e. analysis of log files and coding scheme.

2.4 Understanding Input Technologies

Communication with computers can be possible only through the use of input technologies which allow users to feed instructions to computers for processing, display, storage and transmission. Input technologies sense physical properties such as position, velocity, temperature, or pressure of people, places and things and their usage provide a multifaceted experience which encompass physical sensor, feedback to the user, interaction techniques and ergonomic and industrial design. In the past, communication with computers relied on traditional input technologies such as keyboards and mouse devices however with the advent of fields like ubiquitous computing, context-aware computing and pervasive computing, various novel approaches have come into existence. This section focuses on input technologies for gaming as the research reported in this thesis explored collaboration within gaming context.

Tangible interaction: According to Keay-Bright and Howarth, tangible interaction is *"an approach to computing where the digital world of cognitive information is closely coupled with physical user input, maximizing on people's innate familiarity with interacting in the physical world"*(Keay-Bright & Howarth, 2011). Their definition of the term is similar to Ulmer and Ishii's, one of the pioneers in the field of Tangible interaction, which is centred on controlling digital data with physical objects (Ullmer & Ishii, 2000). With advancement in the field and people from diverse areas of study getting involved, the concept has broadened. Hornecker argued that the concept of tangible interactions goes beyond giving physical form to digital information and consequently developed a framework (structured around four themes) which offers different perspectives on tangible interactions (Hornecker, 2004) as follows:

- **Tangible manipulation**: This *refers to the material representations with distinct tactile qualities, which are typically physically manipulated in tangible interaction*.
- **Space and spatiality**: This *refers to the fact that tangible interaction is embedded in real space and interaction therefore occurs by movement in space*
- **Embodied Facilitation**: This *highlights how the configuration of material objects and space affects and directs emerging group behaviour*
- **Expressive representation**: This *focuses on the material and digital representativeness employed by tangible interaction system, their expressiveness and legibility.*

Various application domains of tangible interaction have been identified in literature. Within the learning environment, tangible interactions have been used for problem solving, planning and simulation e.g. Tinkersheets (Zufferey & Jermann, 2009), tangible programming e.g. Tern which allows children to control educational robots by constructing computer programs out of a collection of wooden jigsaw-shaped blocks(Horn, Solovey, Crouser, & Jacob, 2009), curlybot a two-wheeled educational toy designed for children in their early stages of development to promote programming by example i.e. it records and plays back intricate gestures created by children accurately and repeatedly (Frei, Su, Mikhak, & Ishii, 2000). Tangible interactions have also been used in music education (e.g. CoolMag(Zhang, Shen, Wang, Tian, & Wang, n.d.) and MogClass (Zhou, Percival, Wang, Wang, & Zhao, 2011)), information visualization(e.g. GeoTUI (Couture, Rivière, Libération, & Reuter, 2008)), social communication (e.g. Lover's Cup (Chung, Lee, & Selker, 2006)) and entertainment/edutainment (e.g. Tangible Farm, (Marco, Baldassarri, Cerezo, Xu, & Read, n.d.), Rope Revolution (Yao, Dasgupta, & Cheng, 2011), tangible games created to stimulate learning in children for example Hunting the Snark (Price, Rogers, Scaife, Stanton, & Neale, 2003) and the Nintendo WiiRemote). The Nintendo WiiRemote is highly useful to multiplayer game interfaces and could serve as a good tangible input device for interacting on large projected screens with the help of its wireless physical interface.

Whole body Interaction: This describes an approach to interaction design that mainly deals with how the understanding and involvement of human relationship with the world, both physical and social, could be incorporated into the design and use of interactive systems (Antle, Corness, & Droumeva, 2009). It involves the use of human body movements to directly control computing systems, providing a more natural or intuitive form of interaction as compared to keyboards, mouse, and screen set up of desktop computers. Contrary to tangible interaction, the concept of whole body interaction stresses the combination of bodily and social skills in shaping contextual and situated experience with interactive systems (Marti, 2012). Consequently, it does not only imply physical embodiment of digital components but also encompasses other aspects of our everyday world such as participation in action, perception and social exchanges.

Whole body interaction has become a huge aspect of the gaming world with a lot of games requiring human physical movement as part of the interaction. Most games are designed not only to allow people mentally participate in the game but to physically participate as well. Examples include: dancing games such as Dance-Dance Revolution where players dance in time with a musical dance tune and moving graphical objects using dance mats as input, Wii Sport where players use the Wii remote to mimic actions performed in actual sports e.g. swinging the arm to roll a bowling ball, the Wii balance board makes use of the body weight to control game characters, the Kinect supported games where players control their avatars with their body movements and more recently exergames, which combine exercise with gaming to promote physical activity and health (Suhonen & Väätäjä, 2008).

Gestural Interaction: Gestures are body movements which are used to convey some kind of information from one person to another (Väänänen & Böhm, 1993) and usually evident when people communicate or interact with one another. Nansen and his colleagues categorized gestures into three (Nansen et al., 2014):

- Symbolic gestures include sign language and emblems such as gesture for 'OK', which have come to have a single meaning within a culture.
- Semantic gestures contain semantic content that conveys information in a referential or representational manner e.g. deictic (pointing), iconic and pantomimic gestures. Deictic gestures also known as pointing gestures direct listeners' attention to specific objects or events in an environment and tend to dominate gestural interaction research in HCI. Iconic gestures convey information about size orientation and shape of object of discourse while pantomimic gestures are used to mimic actions.
- Idiosyncratic gestures are gestures which do not communicate meaningful information e.g. beats and meaningless gesticulations used to reflect habitual movements or emphasize a point

The use of hand gestures for natural and intuitive human computer interaction have attracted great interest within HCI. In HCI, gestures are used to convey information from a user to a computer system. To exploit the use of gestures, it is important to provide a means by which such gestures can be interpreted by the computers. Consequently, gesture recognition systems which track movements of the hands, face and other parts of the body have been developed to allow users interact with and control computing devices and applications in intelligent environment. Hand gestures are mainly classified into two: device-based and vision-based techniques (Asadzadeh, Kulik, & Tanin, 2012). Device-based gestural interactions require the use of props such as glove-based equipment (e.g. data glove), accelerometer enabled devices (e.g. remote controllers) or body markers while the vision-based techniques do not require any aides but uses camera to capture hand or body related movements (Stenger, Woodley, Kim, & Cipolla, 2009). For example, wand devices such as Vision wand(Cao & Balakrishnan, 2003) and the Magic wand (Ciger, Gutierrez, Vexo, & Thalmann, 2003) use camera vision techniques to detect the position of the hand during interaction. Gestural technologies have been developed for use in a lot of domains including virtual reality, augmented reality, pervasive computing, mobile computing and more popularly within gaming/entertainment on platforms such as Sony eye toy and Microsoft Kinect. While the use of gestural interactions on one hand permits natural body movements, they can on the other hand be relatively intrusive to users as in the case of glove-based techniques and also can cause occlusion body movement as in the case of vision-based techniques. Additionally, it can be challenging in some cases to enter gestures accurately and effectively as well as remembering gestures for specific tasks (association errors).

2.4.1 Effects of input technologies on collaboration

Interaction with input devices has always been a vital part of computer graphics. Traditionally, computers were designed to allow an individual interact with computers using a single mouse and keyboard. Most often, the design of such input devices are influenced by performance metrics such as reliability, precision and accuracy as they are used by one single user at any one time. While this design legacy has carried through to nearly all modern computer systems, several research works have explored the role input devices play in group situations as people are often required to communicate and work collaboratively in social environments such as school or the workplace. This review focuses on input devices that support collaboration between people in co-located spaces i.e. individuals physically close to each other (Stewart, Bederson, & Druin, 1999).

Ha *et al.* examined how the choice of different input devices affects collaboration between group members collaborating around the tabletop display (Ha, Inkpen, Mandryk, & Whalen, 2006). They presented several benefits and drawbacks of using direct and indirect input devices to interact on the tabletop: direct input devices such as stylus and touch promote natural, intuitive and fluid interactions, support coordination by providing collaborators with greater awareness of their partner's intentions and actions and causes a greater degree of occlusion. On the other hand, indirect input device such as mouse are less tiring to use, require less physical effort to use and are more effective in reaching distant objects on the tabletop than the direct input device. Also, collaborators using the direct input device (stylus) were hesitant to interact with items that were close to their partner; they interacted with items in their personal space more frequently when using the indirect input device (mouse). A study which compared groups of three people using three mice against using a multi-touch table revealed that the affordances of touch input and body movements resulted in a better awareness about (but also more interference with) other group members and promoted fluid interactions as opposed to mouse based interaction (Hornecker et al., 2008). Summarily, from the review of literature above the factors to consider when selecting input devices for collaboration include workspace awareness, user comfort, naturalness and intuitiveness, personal space, physicality of inputs, spatial distribution of the set-up and visibility of actions. Of interest to this research is a range of input technologies which support away from the desktop interaction in addition to having a strong potential for enabling collaborative interactions with digital applications (e.g. games) for co-located users. Consequently, three input methods were selected for use: 1) game pad, a traditional and usual method of interaction which served as a control, 2) dance mat which represents embodied interactions providing a great freedom of body movement and have not been widely used in studies with children and 3) tangible controller which supports tilt interaction. The idea was to see if the three input technologies have any differences on ECA.

2.5 Understanding User Experience

The concept of User Experience (UX) formed around the turn of the millennium is an umbrella term for new ways of understanding and studying the quality-in-use of interactive products. As research in UX gains more and more attention within the HCI community, several attempts have been made to define the concept. This includes the formal definition by the International Standard Organization (ISO) as "*a person's perceptions and responses that result from the use or anticipated use of a product, system or service*"(Vermeeren, Law, & Roto, 2010). However, there is a debate that UX is still not clearly defined and understood (Bernhaupt, 2010; Bevan, 2009; Pirker & Bernhaupt, 2011). For example the ISO definition lacks the temporal aspect of UX i.e. how UX evolves from expectation through to actual interaction to the total experience that includes reflection on the experience (Bevan, 2009). According to law and his colleagues (2009), there are several reasons why researchers have found it challenging reaching a consensus towards a universal definition of UX. They argued that UX is associated with 'fuzzy and dynamic concepts' including hedonic, experiential, affective, aesthetic and emotional aspects of technology usage. Consequently, inclusion and exclusion of particular variables seem arbitrary depending on the author's background and interests. Additionally, the landscape of UX research is fragmented and complicated by diverse theoretical models with different foci such as emotion, pragmatism, pleasure, value, hedonic quality, experience etc. (Law et al., 2009).

Contrary to usability research, UX research represents ‘a turn to experience’ motivated by the search for novel approaches to the design of interactive products, which accommodate the experiential qualities of technology use rather than product quality (Hassenzahl, Diefenbach, & Göritz, 2010). Review of UX literature reveals the characteristics or nature of UX as highlighted below:

1. UX is centred on the positive aspects of users’ interaction with interactive products. Initial UX research moved away from a stated dissatisfaction with removing usability problems and improving task completion time to focus on positive aspects of interaction especially, on hedonic, non-instrumental aspects (Bargas-Avila & Hornbæk, 2011). Hedonic aspects refer to dimensions (such as visual aesthetic, beauty, joy of use, stimulation, personal growth or surprise) that have no obvious relation to the task the user wants to achieve with the system but fulfil general human needs(Hassenzahl, Platz, Burmester, & Lehner, 2000). These hedonic aspects create delight and have been found to increase customer loyalty more than satisfaction alone does (Chitturi, Raghunathan, & Mahajan, 2008)
2. UX emphasizes the dynamic and situational aspects of using interactive products (Hassenzahl & Tractinsky, 2006; Law et al., 2009) and the importance of context (Law et al., 2009). As the current internal state of a person, previous experiences as well as the current context affect UX, researchers advocate that UX should not only be seen as something evaluable after interacting with an artefact but also before, during (Law et al., 2009; Vermeeren et al., 2010) and even long after interaction (Kujala & Roto, 2011).
3. UX is viewed by some researchers as entirely subjective and focuses on ‘lived experiences’ (Kaye, 2007) i.e. how users experience interactive products from their perspective rather than assessing how useful or productive a system is from its own perspective (Rogers, Sharp, & Preece, 2012). This implies that the objective usability measures such as task completion times, number of clicks or error rates and performance are not valid measures of UX: what is required is an understanding of how a person/user feels about a system (Vermeeren et al., 2010). However, other conceptualization of UX exists: as an elaboration of the satisfaction component of Usability (Hedegaard & Simonsen, 2013) and as an umbrella term for all User’s perceptions and responses whether measured objectively or subjectively.

4. UX takes a holistic view of users' interaction with interactive products. Most definitions of UX emphasize that all aspects of product use (including anticipated use of products and experiences following the use situation) are in focus. Some authors put a particular emphasis on emotions for instance Forlizzi and Battarbee stressed that '*emotion is at the heart of any human experience and an essential component of user-product interactions and user experience'* and that '*emotion affects how we plan to interact with products, how we actually interact with products, and the perceptions and outcomes that surround those interactions*' (Forlizzi & Battarbee, 2004). For other authors, the holistic perspective takes into account user experience created in social contexts leading to a focus on co-experience i.e. the creation of meaning and emotion among users through product use (Battarbee, 2003; Forlizzi & Battarbee, 2004). The emphasis therefore is on people constructing and at the same time experiencing a situation together.

Playing digital games have the potential to evoke a wide range of experiences and these experiences otherwise known as 'gameplay experience' or 'player experience' have attracted a substantial interest in academic gaming literature. Gajadhar *et al.* (2008) subdivided player experience into player involvement and player enjoyment. Player involvement describes a player's focus and interest in terms of flow, immersion, gameflow, presence, and engagement while player enjoyment is a generic term that indicates the amount of pleasure or displeasure a player experiences during game play and includes concepts such as positive affect, competence, challenge, aggression and frustration (Gajadhar et al., 2008). Gameplay experience is a complex phenomenon as it has all sorts of attributes and can be challenging to evaluate. However, according to Takatalo *et al.,* evaluation of gameplay or player experience can become easier if the dimensions and attributes of such experience are clearly understood (Takatalo, Häkkinen, Kaistinen, & Nyman, n.d.). These dimensions are reviewed in the next section.

2.5.1 Evaluating UX in Gameplay

Immersion is an important concept widely used in discussing game play experiences and is often refers to the experience of being drawn into an alternative reality. Ermi and Mäyrä (2005) studied immersion in a gaming context and proposed a model which describes how people experience immersion while playing. In their model, immersion was subdivided into three distinct components: sensory, challenge-based and imaginative immersion. Sensory immersion relates to the multi-sensory properties of a game i.e. the extent to which the surface features of a game have a perceptual impact on the user. This dimension is easily recognizable and can be intensified by creating more compelling pictures or graphics, or playing on large screens or with a surround speaker system. Challenge-based immersion is the feeling of immersion that occurs when a balance between the challenges of the game and one's abilities is attained. Imaginative immersion occurs when one is absorbed with the stories and the world of the game, or empathizes with the characters in a game.

A qualitative study conducted by Brown and Cairns (2004) in which seven gamers were interviewed to find out what they mean when they talk about immersion provided a slightly different view on immersion. Analysis of the interview responses using grounded theory showed that for most participants, immersion describes the degree of involvement within a game. In total, three levels of immersion indicating increasing levels of involvement were identified: engagement, engrossment and total immersion. To enter the 'engagement' level, a player needs to overcome the barrier of game preference and game control by investing time, effort and attention in learning how to play the game and how the controls work. From this level, the player may further be involved with the game and enter the 'engrossment' level by overcoming the game construction barrier. Game construction refers to when game features combine in such a way that the players' emotions are directly affected by the game and the controls became "invisible" causing the player to be less aware of their surroundings and less self-aware than in the previous level. Finally, the player may be able to become further involved with the game and enter the highest level of immersion - total immersion, by overcoming the barriers of empathy and atmosphere. Total immersion was described by the participants as a sense of presence, being cut off from reality to such an extent that the game was all that mattered. Comparing the three levels, engagement and engrossment were likely to occur during game play while total immersion is a rare and rather fleeting experience.

Although immersion has links to other engaging game experiences such as flow, cognitive absorption and presence, Jennett and her colleagues view immersion as different in that it is concerned with the specific psychological experience of engaging with a computer game. They considered immersion to be '*the so-called prosaic experience of engaging with a videogame',* which implies that immersion happens if one gets drawn into a game. While immersion contributes to having a good game experience, it does not necessarily mean that the player has an optimal or fulfilling experience (Jennett, Cox, & Cairns, 2008).

In contrast, an experience that does indicate an optimal experience is ‘flow’ (K Poels, Kort, & IJsselsteijn, 2012). Flow is described as a state in which skills and challenges are perfectly balanced, leading to an optimal experience and involving high levels of cognitive absorption or deep concentration (Csikszentmihalyi, 1990). Additionally, flow makes people forget about themselves and become totally immersed in an activity (Csikszentmihalyi, 1990). Thus, immersion could be seen as a precondition for flow since it involves the loss of a sense of context, while flow describes a level of complete involvement (Nacke & Lindley, 2008). The concept of flow is considered to be very useful in deliberating about gameplay experience as the nature of digital games matches closely with activities typically conducive to a state of flow such as (1) having clear and concrete goals (2) providing feedback on the score reached or the progress made (3) enabling actions that can be adjusted according to skill level or capabilities and (4) possessing visual and auditory information or cues that can aid concentration and impede distraction (Sherry, 2004).

Sweetser and Wyeth (2005) adopted and extended Csikszentmihalyi’s conceptualization of flow in a game enjoyment context and proposed a ‘GameFlow’ model for evaluating enjoyment in games. The model consists of eight elements namely concentration, challenge, skills, control, clear goals, feedback, immersion and social. They argued that each element of flow contribute to game enjoyment as results from a study to validate the gameflow model showed that highly rated video games scored better in terms of their gameflow characteristics compared to games that had received low ratings. Although flow is an important mediator of game enjoyment, Poels *et al.* (2012) believes that equating flow to game enjoyment might be limited as game enjoyment represents a broader set of experiences besides flow.

While digital games can induce a broad range of different experiences most studies focus on what makes them enjoyable or fun because (1) Enjoyment is a sensation that keeps people interacting with a product and encourages them to re-interact with it in the future (Gürkök, Nijholt, Poel, & Obbink, 2013) and (2) Enjoyment is considered as the main motivation to play games (Takatalo et al., n.d.). Enjoyability has been defined as the degree of enjoyment that users reach when they voluntarily undergo an experience that interests them and gives them some amount of pleasure or release (Hu, Janse, & Kong, 2005). Different approaches have been proposed to understanding game enjoyment. Klimmt proposed an integrated conceptual model of game enjoyment argued that Enjoyability of a game may be determined by three factors at different levels. At the basic level, the play process is viewed as a series of quick and direct feedback loops between the player and the gaming system resulting from unique technological affordances of digital games that enable players to have an experience of effectance. At the intermediate level, the play process is viewed as a sequence of interconnected episodes which are triggered by the player's intrinsic motivations (for example curiosity) that unfold with a sense of suspense relief and increased self-esteem. At the last level, the play process is viewed as a whole characterized by the players active role in engaging with the narrative and their experience of perceived alternative reality in the gaming world (e.g. presence). Intrinsic motivation is another approach of studying enjoyment in games. In the context of educational games for children, Malone and Lepper developed a taxonomy of intrinsic motivation with four theoretical categories namely challenge, fantasy, control and curiosity (Malone, 1980). Also, Sherry and her colleagues extracted six game uses and gratifications dimension (competition, challenge, social interaction, diversion, fantasy and arousal) based on the results from surveys and focus group studies (Sherry, Lucas, & Greenberg, 2006). Another aspect of game enjoyment has to do with the digital gaming experience as a state of alternate reality such as presence, immersion, flow etc. Flow theory happens to be the most adopted framework by game designers and researchers as game enjoyment share similar characteristics with flow experience e.g. focused concentration, loss of self-consciousnes etc.

An important dimension to measure when carrying out UX research with children is enjoyment, often used as synonym for fun. This is mainly because fun is the major motivation for children to interact with technology(Stewart et al., 1999) and one of the important factors associated with games (Sim, Cassidy, & Read, 2013). Furthermore, children are unlikely to accept a technology if it does not provide a positive experience (Malone). These reasons motivated the choice of fun as the focus of the user experience aspect in this thesis. Fun have been argued to be a complex concept for example, someone's idea of fun may not be another person's idea of fun and a challenging game might be fun to one person while to another person it might be frustrating. However, several tools have been developed to enable the evaluation of fun with children as discussed in the next section.

2.5.2 Tools for Evaluating Children's Enjoyment

Evaluation process is an important phase of a product development mainly used in assessing suitability of a product or identifying features of the product that need improvement or redesign. Previously, adults were mainly involved as participants in the evaluation of products designed for children but the advent of Child Computer Interaction (CCI) has shifted the focus towards evaluating products for children using child participants leading to adaptations of existing methods and even creation of new methods to suit children's needs, abilities and skills. The reasons why children are asked for their opinions of interactive products are:

- Children and adults live in different worlds (Read & MacFarlane, 2006a) with different likes, dislikes, curiosities and needs (Druin, 2002a), and thus adults may not understand what children want.
- The recognition that children are actors and participants rather than onlookers in the society (Read & MacFarlane, 2006a)
- It is fun and rewarding for researchers (and even the children) when children are involved in the design and evaluation of their own products (Read & MacFarlane, 2006a)

Within the context of UX, a lot of evaluation tools exist for evaluating products with children. Most of the tools are specifically designed for use with children within certain age brackets and focus on evaluation of interactive products/games at different stages in a design cycle. The commonly used methods for evaluating children's enjoyment of interactive products include:

2.5.2.1 Survey

The method of eliciting information by questioning is commonly referred to as survey method and includes methods such as interviews, questionnaires and rating scales (Read & MacFarlane, 2006a). Through a survey, researchers may gather some information on children's opinions about a technology/product. Questionnaires are used for collecting large amount of quantitative data from large number of children in a highly economical way. Asking children questions at the end of an evaluation session may help researchers to get feedback on their thoughts however, It is important the questions are short, easy and simple and be kept to a minimum as children can easily get tired and may not be interested in answering the questions. It is also suggested to make the experience fun for the children and to limit writing as children may have spelling difficulties.

Fun toolkit is an example of survey method which can be used to gather technological opinions from children as young as four as well as teenagers (Read, Macfarlane, & Casey, 1999). The toolkit specifically measures three dimensions of fun: endurability, engagement and expectation. It originally consists of four tools namely Smileyometer, Funometer, Fun Sorter and Again-Again.

- The Smileyometer is based on a 1-5 Likert scale and uses pictorial representations as shown in Figure 2-1. It can be used before an experience to measure expectation and after an experience to apply a judgment score. Smileyometer seems to be the most widely used in evaluation studies with children because it requires limited reading ability, requires no writing and is easy and quick to complete, however it has been reported that the tool is more useful with older children (above 10years old) as there is a tendency for younger children to score most things as 'brilliant' on the Smileyometer (MacFarlane, Sim, & Horton, 2005; Read & MacFarlane, 2006; van Dijk, Lingnau, & Kockelkorn, 2012). Consequently, various adaptations of the tool to suit younger children have been utilized (Ferraz, Romão, & Câmara, 2010).

Figure 2-1: Smileyometer

- Fun sorter consists of one or more constructs and a table that has as many spaces in it as there are activities to be compared which can be used to rank items against the constructs. Children can either write the activities in the spaces or pictures cards can be made and placed on the empty grid especially with studies involving younger children with poor reading and writing skills. It is recommended that each construct be presented individually especially for children less than 8 or 9 years old and in cases where picture cards are used, it is important to ensure that the children understand what the cards represent (Read, 2007).
- Again-Again Table measures an aspect of fun related to 'returnance' described as the willingness of a child to use an interactive product, which the child considers to be fun, again. The Again-Again table consists of three columns headed 'Yes', 'Maybe' and 'No' with a list of the activities on the left hand side. The child ticks either Yes', 'Maybe' and

'No' for each activity having in each case considered the question 'Would you like to do this again' (Read et al., 1999). The Again-Again table has less cognitive load compared to the Fun sorter as the child considers each competing application/product on its own merits and is not required to rank them one against the other thus, making the tool especially well-suited to younger children.

- Funometer can be used in the same way as the Smileyometer to measure predicted and reported experience but unlike the Smileyometer, it uses a continuous scale as shown in Figure2-2. The Funometer and Smileyometer were found to be similar and as a result, Funometer has seldom been used in research studies with children (Read et al., 1999).

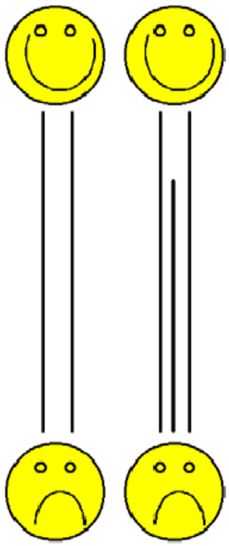

Figure 2-2: Fun Sorter

2.5.2.2 Problem Identification Picture Card (PIPC)

The Problem Identification Picture Cards (PIPC) method allows young children (5-7years) to express both usability and fun problems while playing a computer game (Barendregt, Bekker, & Baauw, 2007a). It combines thinking-aloud method with picture cards to ease the difficulties children have with verbalizing their thoughts such as forgetting to think aloud and mentioning problems to please a researcher as a result of being prompted by the researcher. The pictures for the picture cards are shown in Figure2-3 and represents different concepts including boring, don't know/understand, fun, difficult, takes too long, childish, silly/strange and scary.

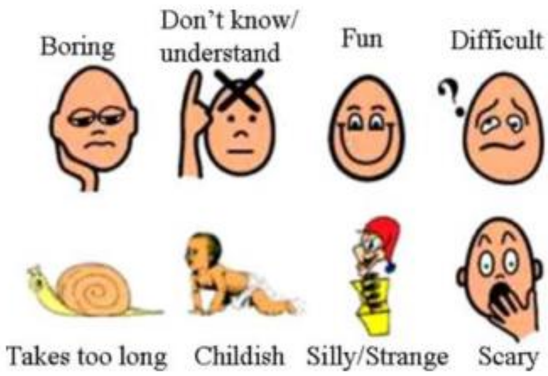

Figure 2-3: Problem Identification Picture Card (PIPC)

2.5.2.3 Children IMI Interest/Enjoyment Scale

The Children IMI interest/enjoyment scale is a multidimensional measurement device that is used in assessing the subjective experience of children related to a target activity. It is derived from the Intrinsic Motivation Inventory (IMI) and adapted to make it more suitable for school age children (van Dijk et al., 2012). It consists of seven positively formulated statements which are rated on a 5-point scale with 'Totally agreed' on the positive end and 'Totally disagree' on the negative end and also uses the pictorial representations as in the Smileyometer (Figure2-4). The Children IMI interest/enjoyment scale has been utilized in studies that looked at children's enjoyment and engagement (Karimi & Lim, 2010; Xie, Antle, & Motamedi, 2008).

Totally disagree   Totally agree

Figure 2-4: Children IMI interest/Enjoyment Scale

2.5.2.4 The Self-Assessment Manikin (SAM)

SAM is a non-verbal picture-oriented tool for assessing people's reports of affective experiences (Bradley & Lang, 1994). It is made up of 15 graphics characters representing three emotional dimensions namely arousal, pleasure and dominance (Figure2-5). Each dimension is represented using graphics that depict the emotional state: happy to sad smiley faces for pleasure, excited wide-eyed figure to a sleepy figure for arousal and lastly, a small to large character for dominance. Although SAM has been used with children aged $3^1/_2$ – 7 years old, it has been criticized for having large number of options displayed in the scale and the images might be difficult for very young children to interpret (Yusoff, Ruthven, & Landoni, 2013)

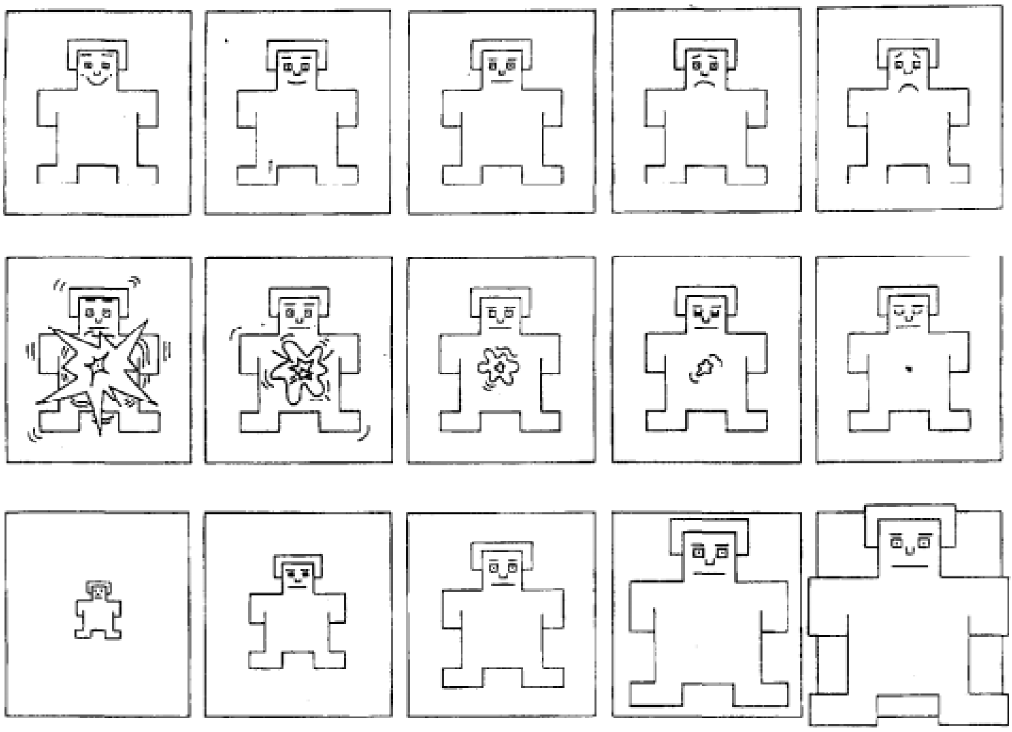

Figure 2-5: The Self-Assessment Manikin (SAM) used to rate the affective dimensions of valence (Top row), arousal (middle row) and dominance (bottom row)

2.5.2.5 Laddering

Laddering is a specific interview and data analysis technique which probes into the reasons why a product is preferred to another, thus revealing all possible elements of the ladder. Laddering technique was originally used in researching product preferences with adults, but has been shown to be useful when working with children aged 5 years and older (Zaman & Abeele, 2010). The initial step in laddering process involves eliciting the differences in products from users using the preference-consumption difference technique, where the interviewer asks the users which product is prefer and why. The preference-consumption technique enables the interviewer to identify the salient attributes which distinguish the preferrd products from others. After the initial attribute elicitation phase, the interviewer will further probe the users (as many times as possible) to try to reveal the explanatory consequences (i.e. reasons why certain product attributes are important) and values for the product preference consequently, creating a sequence or ladder.

2.5.2.6 Fun Semantic Differential Scale (FSDS)

The FSDS (Figure2-6) is another tool for measuring fun but it is mostly used with very young children between 3-5 years of age (Yusoff, Ruthven, & Landoni, 2011). It contains photographs of nursery school child with nine different facial expressions showing positive, neutral and negative feelings. The idea behind using the photographs of children of the same age is to make the tool intuitive to the children; it is expected that the child participating in an evaluation would recognize which emotion was being described and indicate which is relevant to them.

Figure 2-6: Two versions of the FSDS with picture of a boy (Wafy) and picture of a girl (Alisa).

2.5.2.7 This or That

This is a pairwise comparative scale which enables a researcher to ask a series of questions to establish children's preference between two products on a number of constructs. It consists of 5 question - four positively and one negatively worded questions. A typical question could be "which game was most fun, this or that?" and to answer the question, a child simply needs to point to either the product or a pictorial representation of the preferred product. A study that compared fun toolkit and the This or That method revealed that the, This or That method yielded similar results as the fun toolkit indicating that both tools are capable of measuring fun. However, some inconsistencies between the result of individual tools within the fun toolkit and some of the constructs being measured in the This or That method were also identified (Sim & Horton, 2012).

In this thesis, fun toolkit and children interest/enjoyment scale were selected to investigate the effect of ECA on children's gameplay experience (enjoyment) because they have been successfully used in research with the target users in this research i.e. children aged 10 years and above.

2.6 Conclusion

The chapter presented an extensive review of literature on adolescence, collaboration, input technologies and user experience. These areas are deemed relevant to the research reported in this thesis and have helped to identify the gap in knowledge and familiarize with works done within the research area.

3 CHAPTER THREE: RESEARCH METHODOLOGY AND DESIGN

3.1 Introduction

The aim of the research reported in this thesis was to explore collaborative behaviours participants aged 11-16 years old grouped in pairs and in co-located spaces exhibit to reach agreement while interacting with ECA games. In order to achieve this aim and answer the research questions earlier stated in Chapter one of the thesis, several research approaches and methods were used to collect and analyse data. In this chapter, the research approaches, methods and techniques applied in this research are discussed and the justifications for selecting specific methods are provided. In addition, the ethical implications, reliability and validity of methods used were reported.

3.2 Research Approaches

Within the field of HCI, the main approaches for carrying out research are user-centered approach, mixed method approach, quantitative and qualitative approaches. For the purpose of this research, mixed method and user centred research approaches were adopted and are discussed in the following sections:

3.2.1 User–Centered approach

Within the HCI, user-centered approach describes an approach to research which allows the involvement of real users in the design and evaluation of interactive products (Barendregt, Bekker, & Baauw, 2007b; P Markopoulos & Bekker, 2003). This research approach is believed to provide researchers and designers a better understanding of the needs, wants and requirements of the users. Within Child Computer Interaction, children's involvement in evaluation and design of interactive products has been classified into four different roles users, tester, informants and partners (Druin, 2002b). However, it has been argued that the levels of involvement of the children differ with the different roles but they all involve evaluation with children as evaluators (Eindhoven & Magnificus, 2006). A brief description of the different roles is provided below:

- **Users:** Children are observed whilst they use a particular technology in a natural setting and various methods such as observation, interviews, questionnaires etc. are then used to understand the impact of the technology on the children's experience. This can be done at the beginning, during or completion of a product development.

- **Testers**: In this role, children are observed carrying out tasks designed to test specific aspects of the prototype of a technology already created by an expert and feedback is obtained via interviews, questionnaires and other testing techniques.
- **Informants:** In this role, children are valued as experts and used to inform the design process before any part of the technology is developed as well as participate in the evaluation of the designed products providing feedback to designers.
- **Design partners:** In this role, children work as equal partners with the designers and give their opinions throughout the entire design process. While this role is similar to the informant design role, there is more involvement by the children, greater equality between the children and adult designers and a democracy of ideas (Kelly, Mazzone, Horton, & Read, 2006).

Within this research, participants were involved as both testers and users at different stages. At the initial phase of the research, the researcher created an ECA game (a high fidelity prototype) which served as a tool to explore the aim of the research reported in this thesis. During the evaluation of the game, participants were involved as testers whereby they played the game and feedback were obtained to improve several aspects of gameplay (chapter 4). Also, the participants were involved as users whereby they played the ECA game and their opinions where gathered using various methods in order to explore the collaborative behaviours they exhibited whilst interacting with the game and consequently provide answers to the research questions (chapters 5, 6 and 7).

3.2.2 Mixed methods approach

According to Teddlie and Tashakkori, mixed methods research approach emerged as an alternative to the contrast of qualitative and quantitative research approaches (Teddlie & Tashakkori, 2009). Mixed methods research is an approach to research where more than one type of research approaches in the type of questions, research methods, data collection, analysis, and inference techniques are employed with the ultimate goal of providing answers to the research question or set of research questions (Tashakkori & Teddlie, 2003). The methods may be a mix of quantitative methods, a mix of quanlitative methods or a mix of qualitative and quantitative methods used for data collection and analysis. Teddlie and Tashakkori classified the mixed method research approach into two distinct categories: true mixed and quasi mixed methods (Teddlie & Tashakkori, 2009). Typically, true mixed method approach involves the collection and analysis of data, integrating findings and drawing inferences using both qualitative and quantitative methods in a single study. On the other hand, quasi-mixed method approach makes use of two or more types of data in a study without integrating the data in any way.

In the research reported in this thesis, a quasi-mixed method approach was adopted as a mix of qualitative and quantitative data collection and analysis methods were used to draw inferences but with little or no integration of the findings. For example, the studies reported in chapter 5, 6 and 7 produced both quantitative data (from survey methods e.g. fun toolkit, questionnaire and log of participants' interactions) and qualitative data (e.g. from observation of participants during game play) however, the qualitative data provided insights into the collaborative behaviours adopted by the participants while playing the ECA enabled game while the quantitative data was useful in understanding the effect of ECA on participants gameplay experience.

3.3 Prototyping

Prototypes are low-cost representations of products that allow the evaluation of design ideas to obtain early user feedback on aspects of a design and are used heavily in the design of interactive systems (Buchenau & Suri, 2000; Soute, Lagerström, & Markopoulos, 2013). Three main approaches to prototyping have been identified in literature (Sommerville, 2001): evolutionary prototyping whereby an initial implementation is refined until it is satisfactory, throw-away prototyping whereby a prototype is discarded after evaluation and another developed from scratch and incremental development whereby individual system components are developed using evolutionary prototyping within an overall system architecture. Additionally, different types of prototypes have been used in interaction designs depending on the required fidelity i.e. how similar a prototype should be with respect to the intended interactive system (Virzi, 1989). These include:

- **Paper prototypes** – These are paper-based mock-ups of the intended design (Virzi, 1989)
- **Screen prototypes** – These are screen-based mock-ups of the intended design which provides little or no functionality.
- **Wizard of Oz** – Here, a human secretly carries out functionality not yet implemented in a system in order to give an impression of a fully functional prototype (Höysniemi, Hämäläinen, & Turkki, 2004).

- **Functional prototype** – Here, a fully functional product or system is developed through a rapid prototyping approach i.e. speedy creation of prototypes (Soute et al., 2013).

In this thesis, an ECA game was rapidly created to explore the collaborative behaviours participants aged between 11-16years old adopt to reach agreement. The game effectively acted as a functional prototype (Soute et al., 2013) and was developed in an evolutionary manner whereby an initial implementation is refined until it is satisfactory.

3.4 Research Methods

Whilst numerous research methods exist in literature, this review focuses on the methods used to achieve the aim of the research reported in this thesis. These include both qualitative and quantitative methods which evolved during the research experiments. The different methods are discussed in the preceding subsections

3.4.1 Observation:

This research method involves the *'systematic observation, recording, analysis, description and interpretation of people's behaviour'* (Saunder, Lewis, & Thornhill, 2009) which is popularly used in user based studies within HCI (Barendregt et al., 2007a). Observation is mainly used in exploratory research to attempt to provide answers to 'what is going on' type of questions in a wide range of social settings. There are different approaches to observation (Saunder et al., 2009) – traditional approaches (e.g. systematic and participant observation) and technology-mediated approaches (internet-mediated observation and videography)

- **Systematic observation:** Systematic observation is more concerned with the frequency of actions i.e. what is going on rather than why things happen. It essentially involves the assignment of observed talk and sometimes non-verbal activities (e.g. gestures) to a set of pre-defined categories (Mercer, Littleton, & Wegerif, 2004). This approach provides quantitative data which helps to quickly perform numerical comparisons and statistical analysis on large corpora of data (Wegerif & Mercer, 1997). Researchers have used this method to handle talk related data by effectively reducing them to pre-determined coded categories before performing statistical analysis (Howe & Tolmie, 1999; Teasley, 1995; J. Underwood & Underwood, 1999). Although systematic observation has proven useful in studying the nature of interactions amongst children working in pairs or groups, its downside is that it can limit a researcher's sensitivity to what happened during the collaboration process, thus making it difficult for the researcher to understand ways meaning is constructed amongst collaborators over time (Mercer, Littleton, & Wegerif, n.d.).

- **Participant Observation:** Participant observation has its roots in social anthropology and is qualitative (Saunders et al., 2009). Here, researchers learn about the activities of the people under study through observing and participating in those activities enabling them to share their experiences by not only observing what is happening but also feeling it. There are four types of participant observation method distinguished by two dimensions: whether the identity of the researcher is revealed (overt) or concealed (covert) and the extent to which an observer participates in the activities of the people being observed as shown in Figure 3-1.

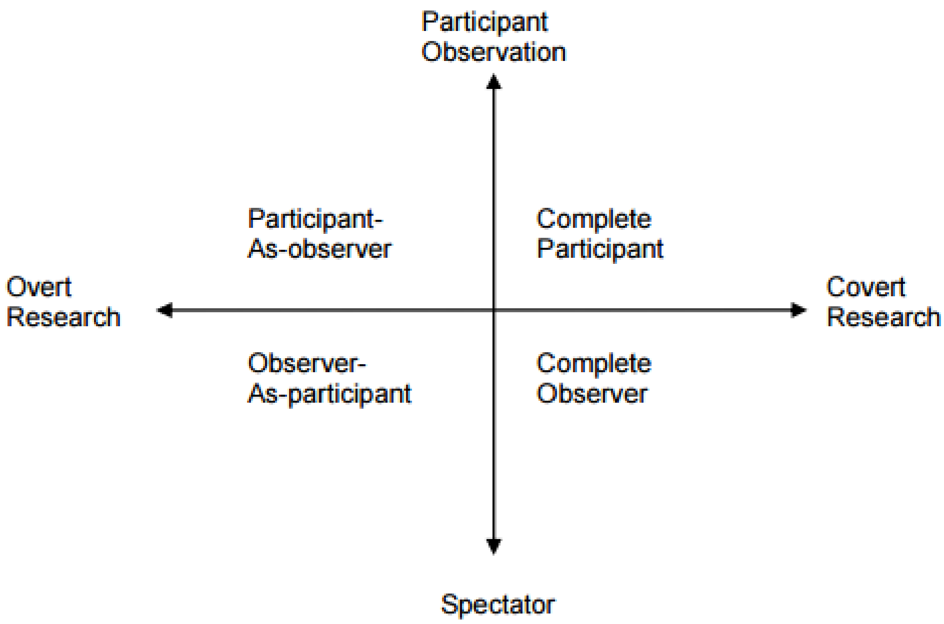

Figure 3-1: Typology of participant observation researcher roles (Gill & Johnson, 2010)

Complete participant: In this role the researcher attempts to become part of the group of people taking part in the research and do not reveal their true purpose to other members of the group

Observer-as-participant: In this role, the researcher observes the activities of the group being studied and makes known the purpose of the research to the group members. In some cases however, it may involve the researcher interacting with the participants.

Complete observer: This is similar to complete observation role where a researcher does not reveal the purpose of the research activity to those being observed however, it differs in as much as the researcher does not take part in the research activities of the group.

Participant-as-observer: In this role, the researcher takes part in the activities of the group as well as reveals the purpose of the research to the group members.

- **Internet-mediated:** This method also known as online ethnography adapts the traditional observation method by changing its mode of observing from oral/visual to textual/digital to allow researchers to observe or participate with members of an online community to collect data (Saunders et al., 2009).
- **Observation using Videography:** This involves recording moving images into electronic media to collect observational data. Video recording gives more flexibility and captures events in more details as compared to participant observation method. By videotaping events researchers are able to repeatedly view video footages. This enables researcher to see things which they had not seen at the time of recording or on previous viewings. In addition, repeated viewing of the video recording gives researchers time to ponder on the data before conclusions (DuFon, 2002).

In order to explore the strategies participants adopted while playing the ECA game (and provide answer **to RQ1**), the researcher initially adopted the participant observation method taking an observer-as-participant role whilst conducting 'overt' research. This approach allowed the researcher to gain understanding of the strategies adopted by participants during gameplay. However, adopting this method meant that the researcher was limited to writing down or recording brief interactions consisting of few short turns due to constraints on memory and inherently slower speed of writing compared to speaking (DuFon, 2002). Consequently, observation using videography was later adopted which allowed a more in-depth analysis of participants' behaviours while playing the ECA game.

3.4.2 Interview

Interviews are purposeful conversations between two people with the aim of collecting relevant information for the purpose of the research. Interviews have been classified in several ways for example depending on the number of participants involved (one-to-one or one-to-many) or whether it is standardized or not but a common typology for differentiating the types of interviews which is adopted in this thesis relates to the level of formality and structure

(Saunders, Philip Lewis, 2012). Hence categorizing interviews into three – structured, semi-structured and unstructured.

- **Structured interview:** Structured interviews use predetermined and standardized questions and have no room for improvisation. Normally, the interviewer would read out the questions and then record responses on a standardized schedule. This type of interview is often used when the interviewer is not necessarily the researcher.
- **Semi-structured interviews:** In semi-structured interviews, the researcher will have a set of pre-determined questions to be covered however, their use may vary from interview to interview. In other words, some questions may be omitted, the order of the question may vary and new questions introduced depending on the flow of the conversation.
- **Unstructured interviews:** Unstructured interviews are informal and typically used to explore in depth a general idea which a researcher is interested in. It does not require predetermined sets of questions although a researcher using this method would need to be clear about the aspect or aspects of research to be explored. This interview method is well suited for exploratory studies where a researcher is exploring new concepts.

Within this research, an unstructured interview was used to probe participants about the factors that influenced their interactions (providing answers to **RQ2**). This method was chosen because the questions asked were dependent on the outcomes of the interactions between pairs of participant. Therefore, the researcher did not need to prepare any sets of questions prior to the interview although it was clear to the researcher what aspect of research to explore using this method.

3.4.3 Questionnaire

Questionnaire is one of the most widely used data collection method within the survey strategy. It is a data collection method in which each person is asked to respond to the same set of questions in a predetermined order (De Vaus, 2002). Questionnaires mostly consist of open-ended questions which allow respondents to provide answers in their own way, closed-ended questions which provide a number of alternative answers for the respondents to choose from or a combination of the two types of questions. Questionnaires offer a quick way of collecting information and as responses are gathered in a standardized way are more objective compared to interviews (Saunders, Lewis & Thornhil, 2012). Within this research, questionnaires consisting of both closed-ended and open-ended questionnaires, were used prior to gameplay to collect participants' demographic information (pre-test questionnaire) and after gameplay to gather feedback on participants' thoughts and opinions on the ECA game (post-test questionnaire). The questions were useful in providing answers to **RQ4**.

3.4.4 Fun toolkit

As mentioned earlier in chapter 2 section 2.5.2.1, the fun toolkit is a survey instrument designed to assist researchers and developers to gather opinions about technology from children (Read, 2007). It measures several aspects of fun (endurability, engagement and expectation) and originally consists of four tools namely Smileyometer, Funometer, Fun Sorter and Again-Again. One of the objectives of this research was to explore the effects of ECA on the participants' game play experience (OBJ4). The dimension of game play experience that was focussed on in the research reported in this thesis was enjoyment or fun (Poels & Kort, 2007) because fun is an important factor associated with games and it motivates children to interact with technologies as highlighted in chapter2 section 2.5.1. In order to explore the effects of ECA on participants' gameplay experience and provide answers to **RQ4**, the Smileyometer, Again-Again table and Funsorter contained in the fun toolkit (Read et al., 1999) were used. For a detailed description of the tools see Chapter 2 Section 2.5.2.1. The fun toolkit was chosen because it requires limited reading ability (this does not mean that children are insufficient in reading but do not bother too much with reading, writing or too much activities. Therefore a measure that requires limited reading ability would minimize anything that would become cumbersome for the participants), requires no writing and is quick and easy to complete, consequently making it less cumbersome for the participants to complete (Read, 2007).

3.4.5 Children IMI Interest/Enjoyment Scale

As stated earlier in Chapter 2 Section 2.5.2.3, the Children IMI interest/enjoyment scale was derived from the Intrinsic Motivation Inventory (IMI) and is used to assess the subjective experience of children in relation to a target activity. It was used in this research to measure the participants' enjoyment of the two versions of the game prototype and interaction methods. It consisted of seven positively worded statements which were rated on a 5-point Likert scale with 'totally agreed' on one end and 'totally disagreed' on the other end:

- I enjoyed playing this game very much
- This game was fun to play

- I thought this was an exciting game
- This game held my attention very well
- I would describe this game as very interesting
- I thought this game was quite enjoyable
- While I was playing this game, I was thinking about how much I enjoyed it

3.4.6 Logging of participants interactions

During gameplay, the participants' interactions i.e. keypresses were automatically logged and used to quantitatively analyse the collaborative process. This approach was useful in providing more information on the strategies the participants adopted whilst interacting with the ECA game. The log files generated were represented graphically (Nurmela, Palonen, Lehtinen, & Hakkarainen, 2003) and served as prompts during the unstructured interview sessions.

3.5 Data Analysis Techniques

In this section, the various approaches used in analysing the data obtained using the selected research methods are presented.

3.5.1 Thematic analysis

Thematic analysis is a method for identifying, analysing and reporting patterns (or themes) within data (Braun & Clarke, 2006). These themes can be identified within data using either inductive or deductive approaches. Inductive approach is data driven i.e. the themes obtained are strongly linked to the data specifically collected for research purposes e.g. interview of focus group. Using this approach, a researcher codes the data without paying attention to themes that previous research work on the topic might have identified. On the other hand, deductive approach is driven by a researcher's theoretical interests in the research area and hence more explicitly analyst-driven. The themes can also be explicit or latent. Explicit themes are identified within the surface meanings of the data and the researcher is not interested in anything beyond what a participant said or wrote. This sort of thematic analysis progresses from description of the data, where the data are organized to show patterns, to interpretation, where attempt is made to theorise the significance of the patterns and their broader meanings usually in relation to previous literature (Braun & Clarke, 2006). A thematic analysis at the latent level goes beyond surface meanings of themes and starts to examine the underlying ideas, assumptions and conceptualizations that are theorized as informing or shaping the semantic content of the data.

Braun and Clarke provided guidelines consisting of six phases to assist researchers carrying out thematic analysis (Braun & Clarke, 2006). However, they warned that these are not rules and can be flexible to fit the research questions and data. Furthermore, they noted that researchers do not need to follow the outlines in a linear order (i.e. moving from one phase to another) but analysis should be recursive where a researcher move back and forth as needed throughout the phases. The six phases are highlighted below:

Phase1 - Getting familiar with your data: This involves immersing oneself in the data by repeatedly and actively reading the data and searching for meanings and patterns. Ideally, it is good practice to read through the entire data set at least once before coding. Transcription of verbal data such as interviews etc. also happens at this stage.

Phase2 - Generating Initial Codes: At this stage, initial codes are generated from the transcripts. Codes identify a feature of the data that is interesting to the researcher and represents the most basic element of the raw data that can be assessed in a meaningful way regarding the phenomenon being studied.

Phase 3 - Search for themes: In this phase, the codes are sorted into potential themes and all relevant coded data extracts within the identified themes are collated as well. It is also helpful to use visual representations such as tables, mind-maps to help sort the codes into themes.

Phase 4 – Reviewing themes: In this phased, the potential themes are refined either by dropping the ones that do not have enough data to support them or merging themes.

Phase 5 – Defining and naming themes: At this point, the final refinement of your themes which will be presented for analysis is done. The names of the themes need to be concise and immediately gives the reader a sense of what they are about.

Phase 6 – Producing the report: In this phase, the researcher performs the final analysis and writes up the report to give account of the story the data tells in a concise, coherent, logical and non-repetitive and interesting way.

Within this research, the data obtained from interviews and researchers notes were analysed following an inductive thematic analysis where themes were explicitly produced from the data. The researcher also followed the guidelines described above where the data were transcribed verbatim, coded using descriptive coding method and refined until the researcher is satisfied with the themes produced before reporting the data (chapter6 and 7). In descriptive coding method, the codes obtained are identifications of the what is talked or written about and not the abbreviations of the content i.e. the substance of the message (Saldana, 2012). This coding method was used because it is appropriate for all qualitative studies and particularly for a beginner in coding qualitative data.

3.5.2 Collaborative Networks

Collaborative network is a qualitative analysis approach for examining collaborative processes between pairs of individuals (Stanton & Neale, 2003). As discussed earlier in Chapter 2 section 2.3.3, the approach follows three steps. Firstly, the verbal communications of participants as well as the computer-based activities are recorded. Secondly, a coding scheme derived from the data is developed. Lastly, a descriptive data (verbal communications/actions) and their accompanying codes are then represented in the collaborative network (presented in tables) to highlight collaborative patterns of behaviours e.g. making enquiry and receiving response to enquiry, giving suggestions and suggestions accepted etc. Figure3-2 shows an excerpt of the collaborative networks from Stanton and Neale's work. The collaborative network is illustrative of the talk and actions of the pairs of children who participated in their study. The talks and actions of the pair of children were arranged row by row except for those that occurred concurrently (represented in the same row). This allows one to follow the progression of talk and actions over time. Furthermore, the arrows next to the codes allow a reader to follow sequences of related actions and verbalizations. Within this research, this approach was used to analyse the video data and identify the collaborative behaviours participants adopted while playing the ECA game.

Lhs transcript	Lhs code	Rhs code	Rhs transcript
		↓ Ve	Ill do some smoke
		↓ Ve	Ill put the choke on
		↙ Ve	Ill put some smoke
OK	C+ ↘		
Working on car windows	Ow	Vow	Draws smoke

Figure 3-2: Collaborative network excerpt from Stanton and Neale's study

3.5.3 Video Analysis

In order to analyse video data, consideration needs to be made on what approach to take. A number of approaches exist however the choice of an approach largely depends on the line of enquiry a researcher is interested in. Erickson, suggested three alternative approaches to video analysis (Erickson, 2006):

- **Whole-to-part inductive approach**: This approach is used to identify patterns in the data where there are no initial hypotheses, theories or predictions, thus employing a more grounded method.
- **Part-to-whole inductive approach:** In this approach, the video data is examined for specific types of events and is most relevant where the research is driven by existing theories or hypotheses about those events
- **Manifest content approach**: In this approach, specific interactions of interest which focus around particular subject are selected and examined.

In addition to the approaches for analysing video data, several tools have also been developed to assist researchers to analyse video data. Some examples of these tools include:

Transana: This is a popular software package designed to facilitate the transcription and analysis of text data, still images and media-based data (audio or video). With this tool, researchers can work collaboratively from different locations through sharing of analytic mark-up and access to shared video.

Nvivo: This tool is similar to Transana and is used to organize and analyse interviews, field notes, images, audio and video files.

Video Traces: This tool allows the creation of layers of voice and pointing/tracing on top of existing video recording which could be shared with other researchers or with those that featured in the video footage. The traces are often used as prompts for reflection.

Digital Interactive Video Exploration and Reflection (DIVER) system: This provides a suite of web-based exploration and annotation tools allowing several researchers working together to make selections and share their ongoing analysis of video data.

Elan: This is an annotation tool that allows researchers to create, edit, visualize and search annotations for video and audio data. It supports multimodal analysis and unlimited number of annotation tiers – a set of annotations that share the same characteristics. A tier can be 'independent' and 'time-alignable' in which case it is directly linked to a time interval of the media file or 'referring' in which case it is linked to another tier (parent tier).

Digital Replay System: This tool enables the synchronization of audio/video recordings with log files of interactions within computing environments, sms messages, GPS data or data from body sensors

As this research is exploratory with no initial hypothesis or predictions, the researcher adopted the whole-to-part inductive approach in the analyses of the video data. A descriptive narrative account of the entire video data was also provided to provide a recount of what happened during gameplay. To enable accurate transcription of the video data, Elan was used because it supports multimodal analysis.

3.5.4 Statistical Analysis

Descriptive statistics provide a way to accurately describe large dataset quickly and easily (Hinton, Brownlow, McMurray, & Cozens, 2004). The most common descriptive statistics used are

- **Measures of central tendency**: These include mean (average), median (middle value), mode (highest occurring value) and range (difference between the largest and the smallest values).
- **Measures of dispersion**: These include standard deviation (a measure used to quantify the amount of variation or dispersion of a set of values), variance (which measures how far a set of random numbers are spread out from their mean) and standard error (which measures the accuracy with which a sample represents a population)

Illustrative statistics are a visual representation of data and when used with descriptive statistics are quite useful in summarizing and comparing results (Hinton et al., 2004). Examples include bar chart, pie charts histogram, scatterplots etc.

Inferential statistics are used to infer from a sample data what a population might think or make judgements of the probability that an observed difference between groups is a dependable one or one that might have happened by chance in a study. Several inferential statistics including parametric and non-parametric tests are available however the choice of which one to use for analysis is dependent on the following assumptions (Hinton et al., 2004).

- The type of data obtained e.g. interval, nominal, ordinal or ratio
- If the sample properly represents the population (i.e. biased or not)

- Scores from each sample should be normally distributed
- Data must meet the homogeneity of variance assumption i.e. the population variance should be the same

Parametric tests are used if all the assumptions are met while non-parametric tests are used if one or more of the assumptions are not met. Examples of inferential statistics include:

Multiple regressions: This is a statistical tool used to predict the value of a variable based on the value of two or more other variables. The variable one needs to predict is called the dependent variable (or criterion variable) while the variables used to predict the value of the dependent variable are called the independent variables (or predictor variables). Multiple regression analysis is also used to determine the overall fit of a model and the relative contribution of each of the predictors to the model (Hinton et al., 2004).

T-test: It compares two samples to see if an experimental manipulation has an effect or not. It works by firstly calculating the difference between the mean sores of the two samples and secondly, an estimate of what the mean difference is expected to be when the null hypothesis is true. If the difference in means is smaller than the expected difference, it indicates that there is no evidence that the experimental manipulation is having an effect and thus the null hypothesis is accepted. However, if the mean difference is larger than the expected difference then it can be checked if it is large enough to reject the null hypothesis and claim that the experimental manipulation is having a statistically significant effect (Hinton et al., 2004). There are different types of t-test:

- **Independent samples t-test (or unrelated t-test):** This test is used when the samples are unrelated, with different participants in each sample
- **Paired t-test (or related t-test):** This test is undertaken when the samples are related with same participants in each sample.
- **Mann-Whitney U test:** This is a non-parametric equivalent of the independent samples t-test and is used when the assumptions are not met
- **Wilcoxon signed-ranks test:** This is a non-parametric equivalent of the paired sample t-test and is used when the assumptions of t-test are not met.

Correlation: This is used to test the degree to which the variation in the scores on two variables co-relate i.e. the extent to which the variation in the scores on one variable results in a corresponding variation in the scores on a second variable(Hinton et al., 2004). There are three types of statistical measures of correlation: Pearson correlation used when the assumptions listed above are met (parametric), Spearman correlation which is a non-parametric equivalent of the Pearson correlation used when one or more of the assumptions are violated and Kendal tau-b correlation, an alternative to Spearman's correlation, which measures the association between two ordinal variables and takes tied ranks into account. All of these statistical measures of correlation produce statistic that ranges from -1, a perfect negative correlation, to +1 indicating a perfect positive correlation while a value of zero indicates no correlation at all.

In this research, descriptive statistics (mode, median and range) and illustrative statistics (histogram and bar charts) were used to facilitate the understanding of data as well as to easily highlight the most important facts about participants' responses. Also, parametric tests such as multiple regression analysis, correlation and paired t-tests were used. Multiple regression was used to test the predictions on performance (chapter 7), paired t-test used to compare the first and second gameplay durations to see if there was a difference in the data (chapter 7) and Pearson correlation was used to check if the hypothesis that over time disagreement would decrease while agreement and no interaction increase (chapter 7).

3.5.5 Coding questionnaire and fun toolkit responses

The Smileyometer responses were coded in an ordinal way on a 5-point scale, where 5 = 'brilliant', 4 = 'really good', 3 = 'good', 2 = 'not very good and '1 = 'awful'. The Again-Again results were coded as 3 for 'yes', 2 for 'maybe' and 1 for 'no'. The Funsorters completed by the participants were coded as 3 for the highest ranked, 2 for the next and 1 for the lowest for each of the construct. The questionnaire responses were coded in a nominal way where numbers, with no numerical significance, were assigned to each option in a question.

3.6 Sources of data

Several sources of data were used within the research and these include

- Researcher's notes and video data which provided a rich information source with regard to the behaviours participants adopted whilst interacting with the ECA game (Chapter 5, 6 and 7).

- Audio files (or transcripts) from interview sessions conducted with pairs of participants at the end of each study sessions (Chapter 6 and 7). These provided useful data on the factors that influenced participants' interactions.
- Log file data which were automatically generated and stored by the computing environment during gameplay and served as an easily accessible database for analysing collaborative processes (Spada et al., 2005). The log file data were mainly used to identify activity patterns and participation structures (e.g. levels of physical participation) during collaboration and was also displayed graphically (Nurmela et al., 2003) serving as prompts during the interview sessions (Chapter 6 and 7).
- Responses obtained from participants through questionnaire, fun toolkit and Children IMI (Chapter 5, 6 and 7).

3.7 Other research concerns

When conducting research, there are other issues that need to be put into consideration. These include issues related to sampling (those to be recruited for the research), ethics (i.e. how to ethically involve the participants in the research), data type (what type of data to be collected) and reliability and validity of the data. In following subsections, these issues as pertaining to the research reported in this thesis are discussed.

3.7.1 Sampling

Sampling is a procedure that involves determining the location and participants of a study (Creswell & Clark, 2011). It has also been discussed as the small segment or sample of a bigger population on which a research is focussed (Teddlie & Tashakkori, 2009). There are two major sampling types identified for quantitative and qualitative research: purposeful and probability sampling. In purposeful sampling a researcher intentionally recruits participants having knowledge or experience of the key concepts being explored. In probability sampling, participants representing the population under study are randomly selected.

As the overall aim of the research reported in this thesis was to explore the collaborative behaviours exhibited by participants aged 11-16years old and grouped in pairs while playing an ECA enable game, a decision was made to use school children within the research age group. Also, as a large number of participants were required, a decision was also made to carry out the studies in locations such as schools and youth centres were participants within the research age groups could be found.

3.7.2 Ethical Considerations

Ethics concerns the morality of human conducts and within research refers to '*the application of a system of moral principles to prevent harming or wronging others, to promote the good, to be respectful, and to be fair*' (Sieber, 1993). Several participants aged between 11 and 16 years old were recruited in order to carry out the experimental studies within this research. As the user population is more vulnerable than adult, special ethical considerations are required when involving them in research studies.

Ethical approval was obtained for the entire research program from the University of Central Lancashire Ethics Committee (STEM) before the experiments began. The researcher obtained a CRB (Criminal Record Bureau) ethical clearance, currently known as DBS before carrying out studies with the participants. The main reason for doing this was to ensure that the researcher does not have any criminal issues that could put the participants at risks. Permission was obtained from the Head Teacher of the participating schools to conduct the research studies before allowing the participants to take part in the studies reported in this thesis. The process involved sending out letters which contained the details of the studies and consent forms for the parent/carers of the potential participants to sign and date prior to participation. The consent forms (Appendix 1A) were used to inform the parent/carers of the participants on the nature of the study, the activities they will participate in and the option to agree or disagree to be video/audio recorded and photographed. Consent was also sought in studies where participants' faces were recorded. The video and audio data were accessed by the researcher and those in the supervisory team and safely stored on the university network for the research period. In order to protect the participants' identities, the researcher ensured that the participants' faces captured in the pictures were distorted. For the same purpose, participant codes were used to identify each participating child in reporting findings from all the studies in this thesis. All the participants for whom consent has been obtained participated in the study. This ensured that participants do not feel left out which could increase the chance of inferiority complex occurring.

Appropriateness of the data collection techniques used in the studies in this thesis were evaluated by and agreed with a senior member of the ChiCI research group and the supervisory team. Participants were informed of the tasks they are expected to perform during studies and were also told they the right to withdraw at any time they felt uncomfortable without any penalty. Care was taken to put the needs of the participants and the school before the needs of the researcher even if this caused inconvenience to a study.

In cases where studies were taking place within the university, all safety and fire information was provided to both the participants and the teachers. Safety Refreshment and toilet facilities were also made available.

3.7.3 Reliability and Validity

Reliability refers to the ability for research results or responses to stay consistent and stable over time (Creswell & Clark, 2011). Within HCI, reliability is seen as the ability for an experimental study to be replicable by other researchers in other locations and still produce consistent, dependable and stable results (Lazar, Feng, & Hochheiser, 2010). According to Creswell and Clark, reliability of qualitative data relates to when multiple coders reliably code the same data and get the same results (inter-rater or inter-coder reliability), when a researcher codes data in the same way over time and gets the same result (stability) or when panel of expert assess the generated codes against a predetermined standard (accuracy). While exploring quantitative data, statistical measures such as reliability coefficient, internal consistency and test-retest comparisons could be used (Creswell & Clark, 2011).

Validity, on the other hand refers to the ability of a study to accurately measure what it is supposed to measure i.e. producing accurate information or results. Ways of checking for validity include (Creswell & Clark, 2011):

- **Content validity** – which assesses whether the questions used are representative of possible items
- **Criterion –related validity** – checks if the findings from a study relates to some externa standards for example scores on similar instruments.
- **Construct validity** – checks to see if the construct measures what is intended
- **Member-check validity** – taking the final results/themes obtained back to the participants to find out if the themes accurately reflects their input
- **Triangulation –** when data from multiple sources are used to confirm previous findings.

- **Peer Debriefing –** when an experienced person reviews and asks questions about a study to resonate the account from the view point of other researchers other than the actual researcher.

Within the research reported in this thesis, the researcher ensured the reliability and validity of the results by reviewing literature on the research methods to make sure appropriate data collection and analysis methods are selected and applied correctly. For example, carefully designing and piloting the questionnaires to ensure the questions are clear and accurately worded, using words that are familiar to and understood by the partiipants and having minimal interactions with the participants during study.

3.8 Conclusion

In this chapter, the researcher highlighted, discussed and provided justifications for the choice of methods (both for gathering data and analysis) used in the research reported in the thesis. These include fun toolkit, observation, interview, questionnaires, children IMI Interest/Enjoyment scale, collaborative networks and thematic analysis. The researcher progresses to discuss the design decisions and rationale adopted during the development of the ECA game and controllers for interacting with the game in the next chapter.

4 CHAPTER FOUR: DESIGN DECISIONS AND RATIONALE

4.1 Introduction

The overall aim of the research reported in this thesis was to explore the concept of ECA with participants aged between 11 and 16 years old in collocated spaces. In order to effectively achieve this aim, a game was chosen as a vehicle to study ECA to help motivate the target user group to engage with the research studies. The design of the game followed a user-centred approach where intended participants were involved in the game design as testers to evaluate the functionalities of the game. This chapter reports the design decisions/choices made in the development of the game as well as the design of the controllers for interacting with the game. Furthermore, user testing carried out to identify any errors within the game and correct any wrong design decisions is also reported.

4.2 Choice of Game and Justification

To enable exploration of ECA a simple game (based upon 'Space Invaders') was created that could easily be integrated with a range of interaction possibilities. The Space Invader game was chosen as a basis of its simplicity. It was anticipated that such a simple game would take little time for participants to learn (with very minimal control inputs) and allow for focus on the collaborative aspects of the gameplay whilst offering some level of engagement. Additionally, the game can be controlled with three inputs (left, right, fire), which simplified gameplay and agreement on controller input.

4.3 Game Description

The game basically consists of a set of aliens arranged in rows and columns that steadily move from left to right of the screen as they advance towards the bottom of the screen. At the bottom of the screen are a 'cannon' and four shields that the cannon can hide behind such that it is not visible to the invaders. A player is able to move the cannon horizontally across the screen and shoot one bullet at a time from the cannon at the aliens. Only one bomb can be visible on the screen at any given time. If the cannon's bullet hit an alien, the alien is destroyed and removed from the screen. Additionally, a player scores points for each alien destroyed. The player must destroy all of the aliens on the screen before they reach the bottom of the screen else the cannon will be destroyed and the game ends. The aliens drop bombs downwards at the cannon. Unlike the cannon's bullets, there can be several alien bombs on the screen at a given time. If an alien bomb hit the shield, part of the shield as well as the bomb is destroyed. As a result, the bases are slowly disintegrated by the bombs. The cannon's bullets that hit the bases are treated the same as the alien bombs. The game ends when all the aliens are dead, when the bomb hits the cannon or when the aliens hit any of the shields at the bottom of the screen.

4.4 Initial Game Requirements

An expert design approach was adopted during the initial design of the game where requirements were solely gathered and decided upon by the researcher. These requirements include:

4.4.1 Game versions

Two versions of the game were developed: collaborative and single-player. The single-player version allows individual play while in the collaborative version, players must agree (in their controller inputs) in order to control the 'cannon' and earn points together e.g. both players must be pressing the fire button at the same time in order for the cannon to fire. The single-player version was intended to be used for training purposes during user studies while the collaborative version served as a tool for exploring ECA. For simplicity, both versions of the game have just one level. For the purpose of this research a timer which displays how long in seconds the game had played for was included in the game.

4.4.2 Input Technologies

Three different interaction techniques were chosen to represent a range of different interaction possibilities: traditional, tangible and embodied. The traditional controller was a typical wired PC-based game pad with buttons and a d-pad (Figure4-1). The tangible controller was a Wiimote disguised inside a plastic cylinder (Figure4-2); the original concept for this device was bicycle hand bars. The Wiimote was used in order to sense movement wirelessly with ease and was hidden to prevent participants from realizing that it was a standard game controller that they were likely to be familiar with. It was also a way of achieving tangible in a low cost and reliable developer friendly way. The embodied interaction method was a dance mat Sony PlayStation controller (Figures4-3) that supported body based interaction and which has not been widely used in studies with children with one exception - the KidPad project where a Magic Carpet with 12 floor sensors was used to interact with a collaborative storytelling tool (Stanton, Neale, & Bayon, 2002). These controllers were chosen because they support away from the desktop interaction and have a strong potential for enabling collaborative interactions with digital applications for co-located users. Other practical constraints such as cost and ease of integration also influenced the choice of the technologies. The three controllers have the ability to influence collaboration in different ways. In terms of maintaining awareness of partner's actions (Gutwin & Greenberg, 2001), the tangible controller provides great support for visibility of user's actions due to its size and the way it is used during interaction (i.e. held right in front of the user and tilted when playing the game). The dancemat provides less support for visibility of user's actions compared to the tangible controller as it is placed on the floor and users would have to look further away to see what their partner is doing. The traditional controller involves close finger pressing which makes less obvious users actions during interactions.

Figure 4-4-1: Game pad measuring 5X4 inches and showing the three different control inputs.

Figure 4-4-2: Wiimote hidden in plastic bar measuring 16 x 2 inches

Figure 4-4-3: Dance mat Sony PlayStation controller measuring 36 X 30 inches

A 14-inch Lenovo Ideapad S400 laptop running Microsoft windows8 operating system was used to play the game during each user study conducted and reported in this thesis. The laptop had an in-built Bluetooth which was used to connect the Wiimotes to the laptop. In addition, WiiFlash server version 0.4.5 software was used for communication between the Wiimotes and Adobe Flash CS6. Arduino Uno (a micro-controller board) and Joy-to-key keyboard emulator were used to connect the dance mat and gamepad to the laptop respectively. The arduino code (i.e. code for simulating keyboard keys) was written in C# and can be seen in Appendix2A.

4.4.3 Interaction Map

In order to assist participants in synchronously agreeing on controller inputs the concept of an 'interaction map' was decided upon (Figure4-4). The interaction map consists of three objects; two triangles pointing to the left and right side of the screen (representing the left and right directions respectively) and a large circle (representing the 'fire' command) in between them. Two sets of distinctly coloured dots were used to represent each child's key presses. These dots are displayed accordingly when participants interact with their controllers (they are intentionally small to support scaling to more than 2 simultaneous players). The intention was to enable participants to see their own control inputs alongside those of their co-players during gameplay.

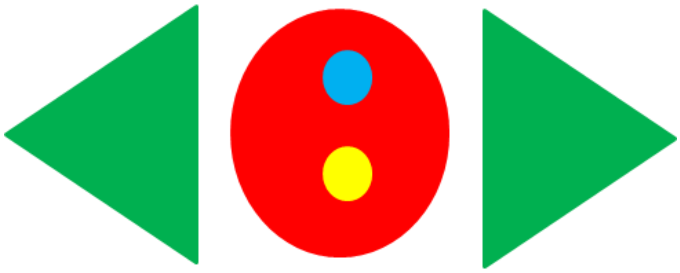

Figure 4-4-4: Interaction map showing two players firing at aliens

A different style of interaction map was required for the tangible input methods as it relied on a tilting movement rather than button presses. The visualization, shown in Figure4-5, not only made the actions of other players visible but also assisted users in understanding the degree of physical tilt of the controller required to generate the left/right movement inputs.

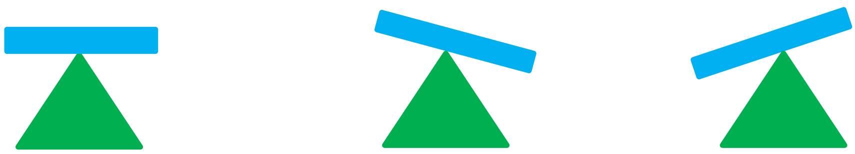

Figure 4-4-5: Visualization for Wiimote Input: Move right (Left), No input (Centre), Move left (Right)

4.4.4 Game development Technology

While various game development software programs such as C^{++}, java, $C^{\#}$ exist, Adobe Flash CS6 was used to rapidly prototype the game and enable support for multiple controller input and different types of controllers. An object oriented approach was adopted during game development as opposed to coding singly to make the coding clean and not all muddled up and for easy debugging (Rosenzweig, 2011). The codes for the game can be seen in Appendix2B.

4.4.5 Logging

In order to effectively log each participant's interactions during game play (key presses), a logging system was created. The logging system as shown in Figure4-6 was used to obtain a text file (log data) of every participant's interactions with the game. Three different interactional states were identified and used to log when pairs of participants agree or disagree in their controller input. These include 'no interaction' where no keys are being pressed, 'interacting but not in agreement' and 'interacting but in agreement'. For the purpose of this research, period in agreement is defined as when both participants in a pair are doing the same thing during interaction i.e.

- moving right at the same time
- moving left at the same time or
- firing at the same time

Period in disagreement is defined as when either one of the participants is interacting with the game or when both participants in a pair are not doing the same thing during interaction i.e.

- not moving right at the same time
- not moving left at the same time or
- not firing at the same time

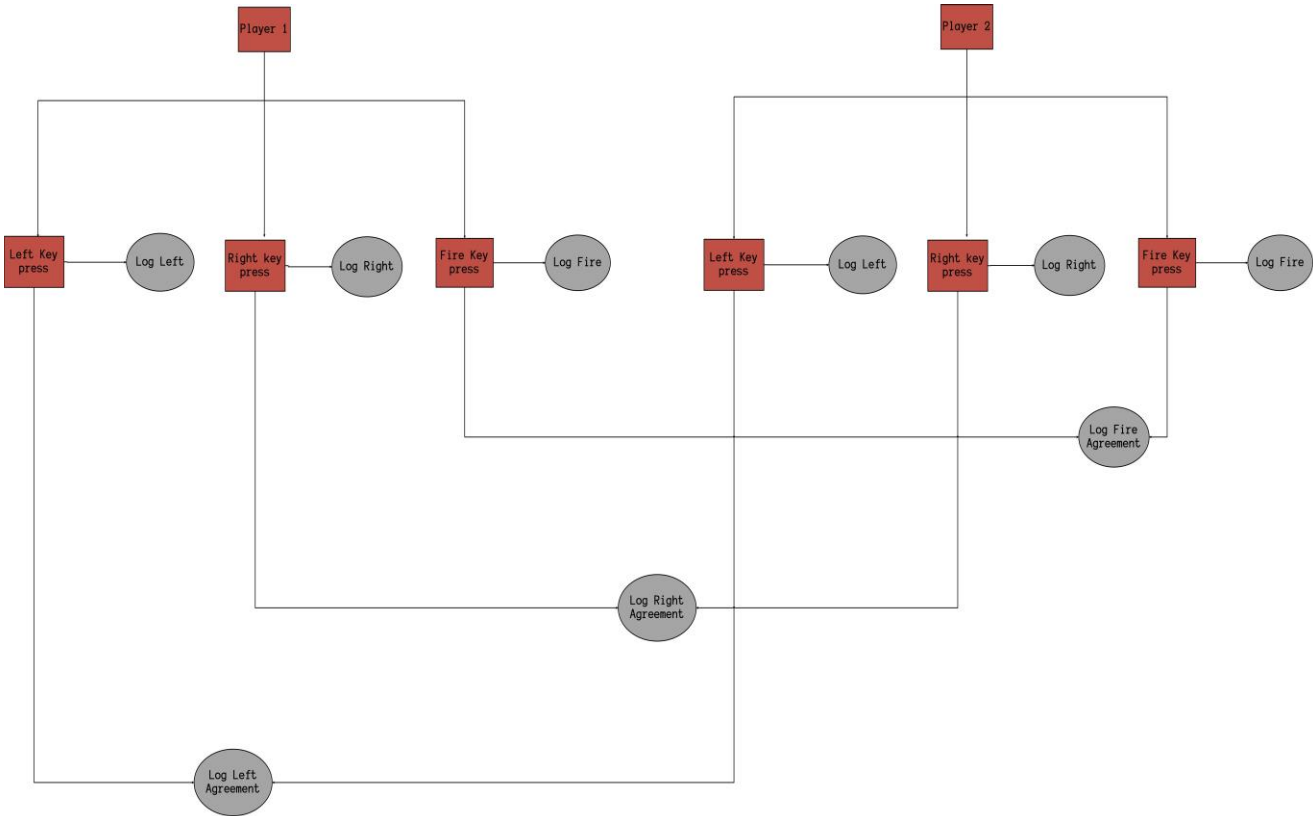

Figure 4-4-6: Logging of children's interactions

4.4.5.1 Evolution of the Logging

The primary aim of logging players' interactions was to obtain relevant data for analyzing ECA (e.g. how long each group were in agreement). However, during the course of the user studies reported in this thesis, it was realized that the initial logging method was inadequate and the need to log participants' interactions differently was highlighted. The logging evolved twice: in the second pilot study reported in Chapter 6 page 93 and the Main study reported in Chapter 7 page 120.

4.5 Game Testing

The game was informally tested by the researcher in order to fix bugs and ensure the game works as intended. Additionally, the game was piloted twice before the development of the interaction techniques. In the first trial, 15 pupils aged 7-8 years played the single-player version of the game individually using a keyboard. In a second trial 42 pupil aged 11-15 grouped in pairs played the collaborative version of the game using game pads. Each trial lasted around 2 minutes, the expected gameplay time to be used in later studies. A short questionnaire was used at the end of each trial period to elicit feedback on several aspects of the gameplay. The main feedback from participants in both pilot studies was that they wanted the game to be more attractive, fun and challenging (in addition there were some more exotic suggestions for extending the gameplay (Appendix2C and Appendix2D). In response to these trials small changes were made to improve gameplay (rate of fire, speed of movements with the game), more engaging images (snowman, birds etc.) were added in to the game, a darker background was used, and a simple mechanism of bonuses within the gameplay was added (Figure4-7). The game designer took a decision to include images of snowman and birds because it was thought that having a snowman and birds might give the game an element of novelty. However, the potential impact of changing the original game characters was not studied in detail.

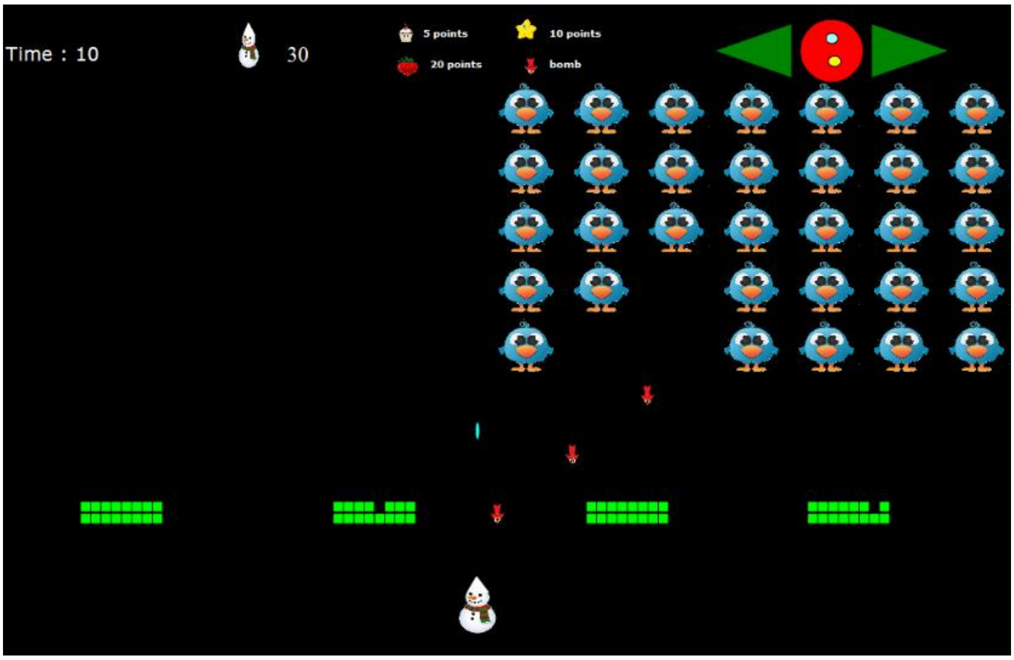

Figure 4-4-7: Replication of Space Invader Game

After the design of the interaction techniques, the game was again piloted with two senior staffs in ChiCI group experienced in game design for technical related issues. It was recommended that since understanding how agreement is reached is important in this research, the enemies should be made to drop bombs more often, the bombs should move quickly and enemy movement should be increased over time to ensure participants interacted often with the different control inputs rather than firing at the enemies from one position. Consequently, the game was adjusted to accommodate the above recommendations. Figure4-8 is a graphical representation of the entire processes and steps involved in the design of the game.

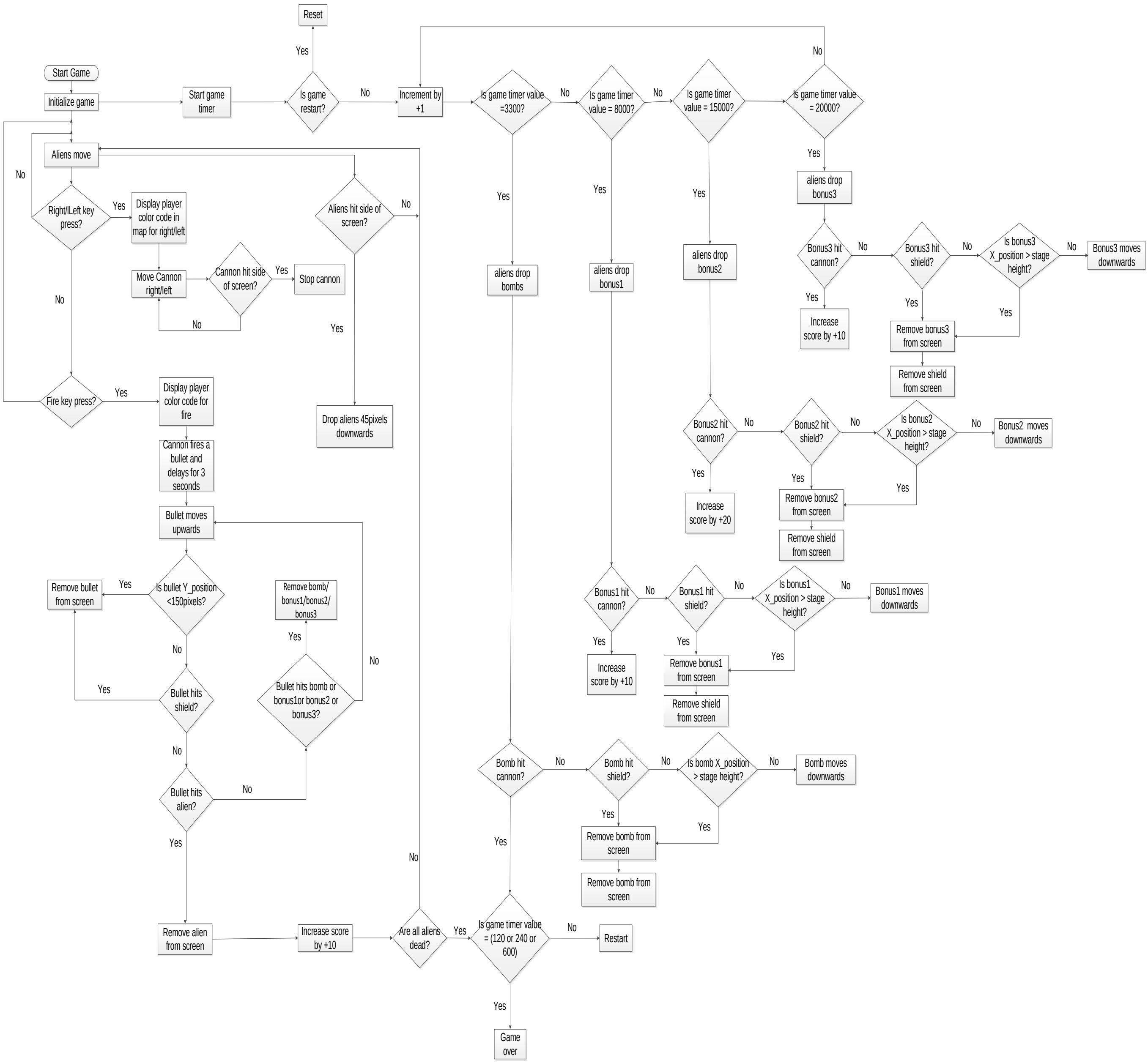

Figure 4-4-8: Game Flow Chart

4.6 Conclusion

This chapter reported the design decisions and their justifications taken during creation of the game used in this research as well as the controllers for playing the game. It also reported the evolution of the logging used to record participants' interactions with the game and the user testing studies which served as a means to identify and correct technical errors and wrong design decisions. Following on in the next chapter is the first pilot study carried out to explore ECA in co-located spaces.

5 CHAPTER FIVE: PILOT STUDY 1

5.1 Introduction

The aim of the research reported in this thesis was to explore the collaborative behaviours exhibited by participants between the ages of 11-16 years to reach agreement while interacting with an ECA game. An additional aim was to explore the effects of ECA on participants' game play experience. The study reported in this chapter was an initial attempt to explore the aims mentioned above. It was carried out with a small sample size in order to gather information, allow for extensive data analysis as well as test the appropriateness of the data collection methods and readiness of study materials as well as monitor the operation of the study design. It also served as a preliminary step to see if the technologies (game and input methods) chosen for the research were appropriate. The selected methods and their justifications as well as the discussions of the findings of the pilot study are presented.

5.2 Method

5.2.1 Participants and Setting

The pilot study took place in one of the labs at the University of Central Lancashire in a MESS day Format where a whole class of 30 children accompanied by their teacher visited the lab and moved between different activities in small groups of five. A typical mess day involves a 'whole school class' taking part in several activities designed by several researchers in an ordered manner within the university labs or in their own school (Horton, Read, Mazzone, Sim, & Fitton, 2012). Twelve participants aged between 14 and 16 years old participated in the study. The participants were grouped in pairs by their teacher resulting in two boy-boy groups, two girl-girl groups and two mixed groups. To maintain anonymity of the participants, participant codes (PI-P12) and group codes (A-F) were used.

5.2.2 Research Design

In this study pairs of individuals were observed while they interacted with an ECA enabled game using three game pad, dance mat and tangible controller. A within-subject design approach in which pairs played both the single and collaborative versions of the game using the three controllers (game pad, dance mat and tangible) was used in the study. In order to counterbalance for learning effect, a 3x3 Latin square design approach (Breakwell, Hammond, & Fife-Schaw, 2000) was used to select the order in which every pair played. This resulted in four groups playing the game using game pad first; four groups playing the game using dancemat first and four groups playing the game using tangible controller first.

5.2.3 Evaluation Instruments and Analysis

In this study, a 'mixed methods' approach (Tashakkori & Teddlie, 2003) was adopted whereby a range of data collection and analysis methods (both qualitative and quantitative) was used to explore ECA. This approach was beneficial in providing rich findings and answering the research questions of this research and as quantitative or qualitative approaches alone is insufficient. Additionally, the mixed method approach ensured that the limitations of one approach were offset by the strengths of the other. The methods include logging of participants' interactions with the game, researcher observation of the participants during gameplay and survey methods such as questionnaires and fun toolkit. These methods and how they were analysed are described below.

5.2.3.1 Questionnaire

In this study, both pre-test and post-test questionnaires were used. The pre-test questionnaire was used prior to the start of gameplay to obtain participants' demographic information such as age, gender and previous experience in technologies and gaming (Appendix3A). It was important to explore the types of games the participants play and the controllers they are familiar with because it was thought that the participants' prior experience with the technologies could affect the way they collaborate and their gameplay experience. Consequently, the frequency of use (FUS) scale as validated by (Kano, Horton, & Read, 2010) was used to measure how often the participants played computer games on various platforms. The FUS scale was chosen not only because it is used to measure frequency of use but also because it can easily be understood and effectively used by children even those as young as 7 years old. The FUS scale is a 4-point Likert scale and was coded as 4 for 'everyday', 3 for 'a few times a week', 2 for 'once a week', and 1 for 'never'. The post-test questionnaire was used at the end of each evaluation session to gather the participants' thoughts and opinions on the technologies. The researcher wanted to find out if familiarity with partner will have an effect on the participants' collaboration. It was also interesting to know if the participants noticed the map on the screen and whether they knew the purpose of the map. Additionally, the researcher was interested in knowing which version of the game the participants preferred and enjoyed playing. Consequently, the post-test questionnaire contained questions related to familiarity with partner, awareness of the interaction map on the screen and questions on preference for and enjoyment of the game. The participants' responses to the questions were entered into a table for analysis and simple statistics like counts and percentages were used. Both the pre-test and post-test questionnaires were piloted with two senior staffs in ChiCI group experienced in designing questionnaires for children to ensure they are appropriate for the age group.

5.2.3.2 Fun toolkit

The Smileyometer has been successfully used in studies that investigated children's enjoyment of interactive products (Read, 2007; Sim, Macfarlane, & Horton, 2004; Sim, MacFarlane, & Read, 2006; van Dijk et al., 2012). The Smileyometer was used in this research to obtain participants' subjective fun experience after playing the game. It was coded in an ordinal way on a 5-point scale, where 5 = 'brilliant', 4 = 'really good', 3 = 'good', 2 = 'not very good and '1 = 'awful'. Again-Again table was used to measure the participants' willingness to play the game again. Again-Again table has been shown to be a valuable tool to use alongside the Smileyometer especially in evaluating with children aged 10 years old and over (van Dijk et al., 2012). The Again-Again results were coded as 3 for 'yes', 2 for 'maybe' and 1 for 'no'. The Funsorter is a tool devised to encourage children to rank items against one or more constructs in order to record children's opinions of a technology or activity (Read & MacFarlane, 2006b). The constructs used in this study are 'most fun', 'easiest to play' and 'liked the most'. Read highlighted the importance of using picture cards which represents what the participants can understand (Read, 2007). Consequently, in this study the participants completed the Funsorter using picture cards with icons of controllers they had played the game with during the study sessions (Figure4-1). The Funsorters completed by the participants were coded as 3 for the highest ranked, 2 for the next and 1 for the lowest for each of the construct.

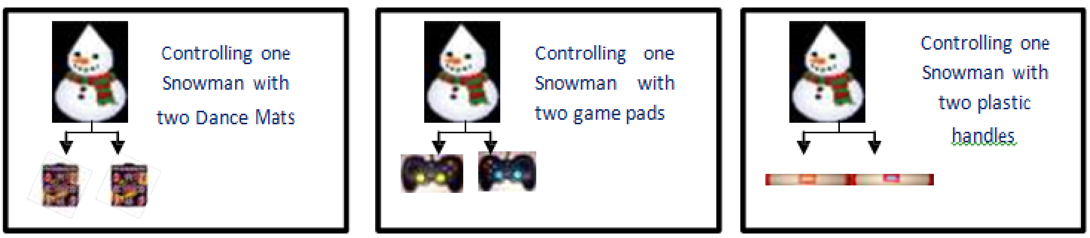

Figure 5-1: Picture cards

5.2.3.3 Observation

Observational method was adopted in this study to explore the participants' collaborative behaviours exhibited during interaction with the ECA enabled game (OBJ1). The method involved the researcher's observation of the participants whilst playing the game with the three different controllers and taking notes of the strategies adopted during interaction as they unfold. This approach was useful as it provided a quick way to gain insights into the strategies adopted by the participants during game play. The data collected during the study were analysed with another researcher experienced in coding qualitative data to reduce bias. The researchers adopted an inductive thematic analysis method(Braun & Clarke, 2006) where the observational data (notes) were unanimously coded and categorized into themes (i.e. the researchers coded the data separately and the codes obtained were compared and agreed upon). The themes obtained were taken to a third party (senior researcher) for validation.

5.2.3.4 Logging of participants interactions

In this study, every participant's key presses (left, right and fire), the time in real-time each key was pressed and the date were logged (Table4-1). It was observed that the log files were not designed in a way to provide useful data from the key presses. Hence, some vital parameters such as times when pairs were in agreement or disagreement etc. which are necessary for analysis required in this study were missed out. This problem was corrected in the second pilot study as shown in Chapter 5 section5.2.3.3.

Table 5-1: Extract of participant log file

Date	Player	Action
26/3/2013-12:43:18:	1	moves right
26/3/2013-12:43:19:	2	shoots a bullet
26/3/2013-12:43:19:	1	moves right
26/3/2013-12:43:19:	2	shoots a bullet
26/3/2013-12:43:20:	1	moves right
26/3/2013-12:43:20:	2	shoots a bullet
26/3/2013-12:43:20:	2	shoots a bullet
26/3/2013-12:43:20:	1	moves left

5.2.4 Procedure

The study began by each pair completing a pre-test questionnaire on their experience in technologies and gaming. The participants were then asked to stand in a marked area two meters away from a screen onto which the game was projected. This ensured that the participants' positions from the screen remained the same across groups. The game was projected on a large screen to afford easy interaction with game units and provide large interactional space to promote collaboration among the participants. The researcher then explained the rules of the game and that the game would be played using three different controllers. For training purposes, each participant in a pair played the single player version individually for 30seconds before playing the collaborative version once for two minutes. Each pair completed an evaluation form consisting of the post-test questionnaire, Smileyometer and Again-Again Table (Appendix3B), one per participant at the end of each session to capture their opinions on the technology The evaluation form also contained questions related to collaboration, familiarity with partner, awareness of the interaction map that was included on the screen, preference for and enjoyment of the game. Afterwards, each pair completed a Funsorter (Read et al., 1999) based on which controller they 'liked the most', 'was most fun' and 'was easiest to play with' on the scale best to worst using the picture cards as shown Figure4-1 in section 4.2.3.2. The researcher observed the participants all through the entire sessions and attempted to engage them in informal discussion about how they reached agreement at the end of each session.

5.3 Results

5.3.1 Participants profile

Results of this study provided background information on the participants and their familiarity with technologies. The background questionnaire revealed that most of the participants had previous experience with different types of computer games for example shooting games (42%), physical fitness (42%), adventure games (50%), and also had prior experience playing games with tangible controller (50%), gamepad (75%), PS2/PS3 controller (67%) and keyboard (50%), except for just one participant that did not play games at all (Appendix3C). There was a high familiarity with touch screens, as 50% of the participants claimed they played games on touch screen devices every day. To check the effects of partner familiarity on collaboration, information on how well each pair knew each other was collected. Results showed the participants' answer to the questions: *Do you spend time with your partner inside school, how often do you play with your partner at school, and how long have you known your partner.* All the participants claimed they knew each other albeit not especially well; pairs in Group F knew each other but never played together (Appendix3D). While it is possible that the participants spent time together outside school, it was not considered in the research reported in this thesis.

5.3.2 Understanding Collaborative Behaviours

The themes obtained from the thematic analyses of the participants' behaviours during study sessions (Appendix3E) provided insights into the types of collaborative behaviours exhibited by the participants before, during and after interaction with the game (Appendix3F). In this work we use $X_{tangible,}$ $X_{gamepad}$ and $X_{dancemat}$ to represent groups playing the game with the three different controllers. X ranges from A- F and represents the various groups that participated in the study. Also, we used C_i to represent the participants where $_i$ range from 1 – 12.

Before the start of game only a single group (Group D) attempted to strategize, with one of the participants observed instructing his partner on how they would play the game as described in the quote "*I count one and you tilt left, two right, three shoot.*" This observation occurred in the $D_{tangible}$ condition and in the first ordering (i.e. pairs in the group played with the dance mat first). The pairs in the group were both boys, have known each other for 3 years and spend time with each other at school. Both pairs in the group have previous experience with PS2/PS3 controller, keyboard and game pad; additionally, just one of the participants has previous experience with wiimote, Nunchunk and balance board.

During game play, one of the Participants in groups B, C, D and E while playing with the tangible controller and groups A, B and D while playing with the gamepad were seen to direct their partners on what direction to go and their partners responded for example, one of the pairs in $B_{tangible}$ was observed giving instructions to his partner on what action to take as seen in the quote "*Left, right, left, left shoot…*" In this work, we term this dominating behaviour. We characterize this as dominating behaviour because one of the pairs controlled the interaction through verbal instructions while the other passively obeyed. In contrast, participants in $C_{gamepad}$ condition were observed to begin play silently without engaging in any discussion but 10 seconds into game play, one of the participant suggested to the partner a strategy they could adopt to play as seen in the quote "*Ok, maybe I shout and you press shoot.*" Furthermore, pairs in conditions $A_{tangible,}$ $A_{dancemat,}$ $B_{dancemat,}$ $C_{dancemat,}$ $D_{dancemat,}$ $C_{gamepad}$, $D_{gamepad}$, and $F_{gamepad}$ were observed to glance intermittently at each other's controllers before looking at the screen. This could be as a result of mere curiosity, in response to activities on the screen or to copy partner's actions. The interaction map served as a means to check if pairs were aware of each other's actions and to see whether they used it to collaborate. The participants were asked (using a questionnaire) if they noticed the interaction map on the screen. As shown in Appendix3G, all the participants (10 (83%)) apart from those in group D (2(17%)) indicated they noticed the map on the screen. This result was supported by the analysis of the participants' behaviours as one of the participants in $E_{gamepad}$ was observed to notice the interaction map on the screen. Also, 7 (70%) of those that noticed the map thought they knew the purpose of the map while 3 (30%) did not. However, it cannot be confirmed here if the participants used the map to inform decision on what actions to take as no further probing was made. One of the participants in $F_{gamepad}$ used 'telling by showing' strategy as the participant was observed to show his partner what to do using his controller while the partner watched. Participants in $A_{dancemat}$ and $D_{gamepad}$ asked for help from the researcher regarding the controller while one participant in $B_{gamepad}$ was observed to point at the screen on two occasions during game play. Furthermore, various affective behaviours such as jumping, laughing, shouting, dancing, high levels of concentration, excitement and frustration were observed.

Although the post-game play behaviours of the participants were not analysed in detail, it was observed that participants in $C_{dancemat}$ and $D_{gamepad}$ argued after game play. The arguments were related to how the pairs interacted during game play for example in the quote of participants in the $C_{dancemat}$ condition as shown below:

P5: "*I asked you to press…*"

P6: "*No, you were supposed to press…*"

The participants' responses during the informal discussion with the researcher are shown in Appendix3H. As seen in the table, the participants' responses confirmed some of the behaviours observed by the researcher such as copying from partner and dominating behaviours. Participants in Group E mentioned that they used the movement of the birds to decide what direction to go.

As shown in Table4-2, all the strategies identified in the pilot study were observed when the participants played with the game pad; four were observed when they played with the dancemat and two when they played with the tangible controller. An explanation for these observations could be that with the game pad, the physical effort of interaction is much more lower compared to tilting the tangible controller or moving the feet on the dancemat therefore, the participants were lightly cognitively loaded and focussed more on the task at hand (Ang Siang, Zaphiris, & Mahmood, 2007). Furthermore, it is likely that unfamiliar methods i.e. dancemat and tangible controller proved more challenging (as they were learning to use the controllers while playing the game) that was why the participants had less opportunity to think about their strategies.

Table 5-2: Summary of strategies the participants adopted while playing the ECA game

Strategies	Game pad	Tangible	Dance mat
Dominating	√	√	√
Suggestion	√	–	–
Arguing	√	–	√
Looking at each other's Controllers	√	√	√
Ask help from researcher	√	–	√
Noticed Map	√	–	–
Not Talking (playing silently for 10 seconds)	√	–	–
Telling by showing	√	–	–
Pointing at screen	√	–	–
Strategy negotiation before gameplay	–	√	–

5.3.3 Participants' Game Play Experience

One of the objectives of the thesis (OBJ4) as stated earlier in Section is to investigate participants' enjoyment while playing an ECA enabled game with the game pad, dance mat and tangible controller. The Smileyometer was used to assist the participants to express their feelings about playing the game with three different controllers. Figure4-2 shows the participants' rating of how much fun they experienced while playing the game with the three controllers (the data were coded as 1= awful, 2=not very good, 3=good, 4=really good and 5=brilliant). The median response for the gamepad is 4 with the participants response ranging from 'good' (min=3) to 'brilliant' (max=5), tangible controller is 4 with the participants response ranging from 'not very good' (min=2) to 'brilliant' (max=5) while that of the dancemat is 4.5 with the participants response also ranging from 'not very good' (min=2) to 'brilliant' (max=5).

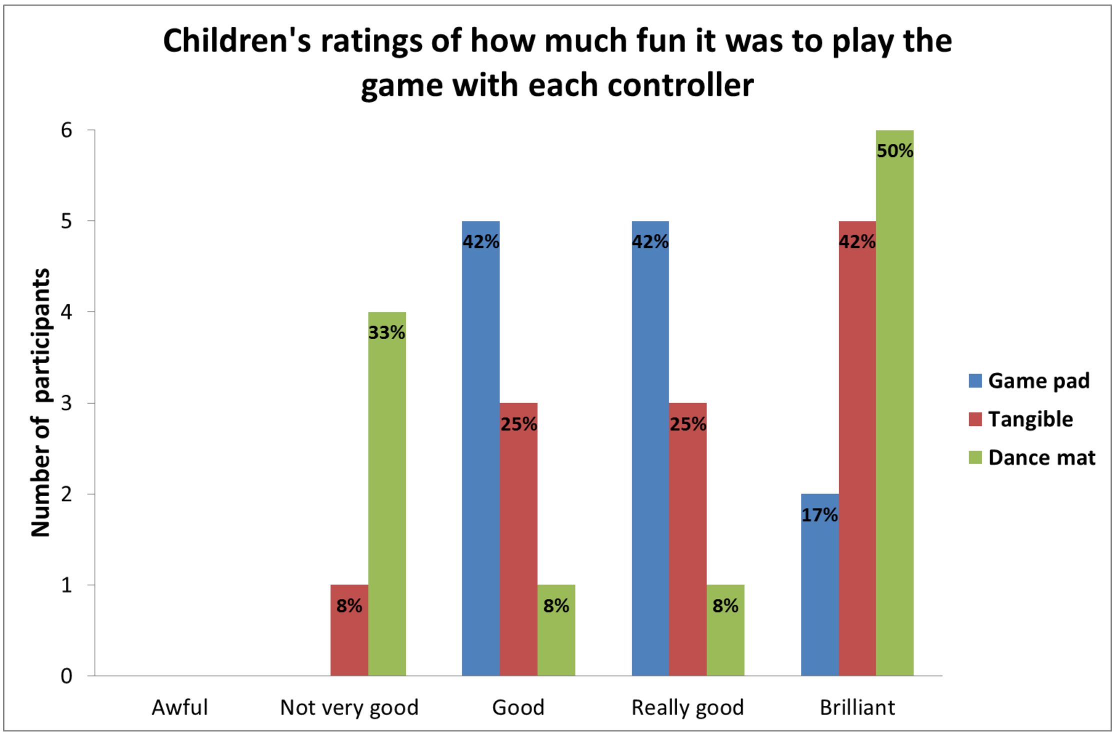

Figure 5-2: Participants' ratings of the three controllers.

The Smileyometer and the Again-Again results were presented in TableA as shown in Appendix3I. The table was represented in this format to show results across both metrics. Inspection of the table shows that all those that rated the tangible controller and the gamepad as 'brilliant' (5 and 2 participants respectfully) indicated that they would like to play the game again with the tangible controller and the game pad. 6(50%) of the participants rated the dance at as 'brilliant' however, 2(33%) of those who thought the dance mat was brilliant would not like to play the game again with the dance mat while the remaining 4(67%) were undecided. Furthermore, 4(34%) of the participants rated the dance mat as 'not very good' but 3(75%) of the participants that rated the dance mat as not very good indicated that they would not like to play the game again with the dance mat while one participant (25%) was undecided.

Figure4-3 shows for each construct ('liked the most', 'was most fun' and 'was easiest to play with'), how many participants ranked each controller highest. Similar to the results obtained using the Smileyometer, dance mat appeared to be the most fun controller as 8(67%) of the participants ranked the dance mat highest on the 'most fun' construct compared to 3(25%) for tangible and 1(8%) for game pad. Also, the game pad seemed to be the controller that was easiest to play the game with as 7(58%) of the participants ranked it highest on the 'easiest to play' construct compared to 5(42%) for tangible. None of the participants indicated that the dance mat was easiest to play the game with. In addition, 5(42%) of the participants ranked both the tangible controller and game pad highest on the 'like the most' constructs while 2(16%) ranked the dance mat as highest on the same construct.

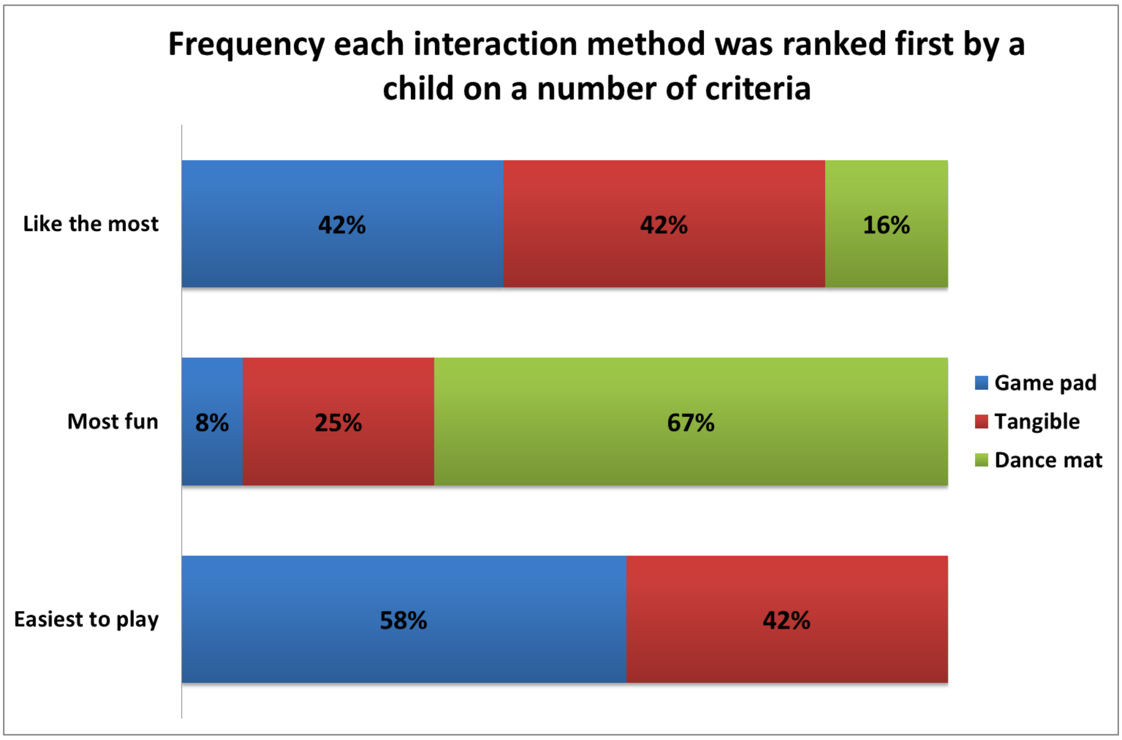

Figure 5-3: Participants' rankings of the three controllers

TableB in Appendix3I shows the participants' rankings of the three controllers according to the constructs 'liked the most', 'was most fun' and 'was easiest to play with'. The table was represented in this format to show result across the three constructs. Comparing the participants' responses across TableA and TableB (Appendix3I), it can be seen that all those who ranked the dance mat lowest on 'most fun' construct of the funsorter rated the dance mat as 'not very good' using the smileyometer. Also, 6(75%) of those that ranked the dance mat highest on the 'most fun' construct of the funsorter rated the dance mat as 'brilliant' using the smileyometer. Furthermore, 6(50%) of the participants who ranked a controller highest on the 'most fun' construct ranked the same controller as highest on the 'liked the most' construct whereas 6(50%) of those that ranked a controller highest on the 'easiest to use' construct ranked the same controller as highest on the 'liked the most' construct. Additionally, 4(33%) participants ranked the same controller as highest on the three constructs.

5.3.4 Enjoyment vs. Preference

In order to investigate if there was a relationship between participants' preference for and enjoyment of the collaborative element of the game, the participants were asked whether they preferred the single-player to the collaborative version of the game. They were also asked whether they enjoyed playing the single-player more than the collaborative version of the game. The participants' responses to the questions can be seen in Appendix3J. Inspection of the table shows that the participants (11 (58%)) who preferred the single-player version of the game also enjoyed playing the single-player version of the game. Similarly, the participants (7 (34%)) who preferred the collaborative version of the game also enjoyed playing the collaborative version of the game. Only one participant was undecided as the participant was unsure whether he preferred or enjoyed playing the single-player or collaborative version of the game. The participants were further probed by asking for a brief explanation of their responses. Responses to the probe (Appendix3J) show that the contributing factors to the participants' enjoyment of the collaborative element in the game were challenge, competition, fun and teamwork (as stated by pairs in Groups A, B and D, and one participant in Group E). However, the participants (one participant in Groups F and E, and both pairs in Group C) that enjoyed playing on their own stated that it was easier as playing alone promoted independent play. One participant in Group F acknowledged that playing with a partner was fun but could also be difficult.

5.4 Discussion

The primary aim of the pilot study was to test the chosen data collection methods and the study materials to ensure they are appropriate for the type of research reported in this thesis. The mixed methods approach adopted in this study provided a means to address the objectives of the research through a combination of both qualitative and quantitative data collection methods. The researcher observation of the participants during game play provided useful data which enabled the exploration of the behaviours the participants exhibited while interacting with an ECA enabled game using three different controllers. The findings from this study revealed a range of collaborative behaviours (occurring before, during and after game play) exhibited by the participants. These include:

- **Giving directions/instructions** where a participant directs or instructs the partner e.g. "*I count one and you tilt left, two right, three shoot"*
- **Making suggestions** where a participant puts forward an idea to the partner *e.g. "Ok, maybe I shout and you press shoot".*
- **Playing silently** where a participant does not communicate via talking during interaction with game.
- **Glancing at partner's controllers** where a participant takes a quick look at partner's controller
- **Awareness of the map on the screen** where a participant points at the map on the screen and makes verbalizations
- **Asking for help from the researcher** where a participant asks for information from researcher
- **Arguing** where the participants discussed their interactions during game play with each giving their own different opinions.
- **Pointing at the screen** where a participant points at the screen
- **'Telling by showing'** where a participant shows partner what to do using the own controller while the partner watched.

These behaviours are important as they give a clue on the possible behaviours that could be adopted by the participants while playing an ECA enabled game. It was speculated that the participants' collaborative behaviours will vary for the three controllers: gamepad, dancemat and tangible. All the behaviours identified in this study were present in the gamepad condition, four of the behaviours in the dancemat condition and a few (two of the behaviours) in the tangible condition.

The participants appeared to be enthusiastic and engaged well with the activities in the study, with some shouting, laughing and jumping while others focused all their attention on the gameplay. Participants' preference appears to influence their enjoyment of the collaborative element of the game reason being that it was fun, challenging, competitive and promoted teamwork. These results are in line with study that have looked at player enjoyment of digital games (Gajadhar, Kort, & Ijsselsteijn, 2008). The dance mat appeared to be the most fun controller while the game pad was easiest to play the game with. It cannot be concluded in this study which controller was liked most by the participants as 42% of the participants ranked both the tangible controller and game pad highest on the 'like the most' constructs. A high familiarity with the game pad (75% of the participants) could be the reason for the participants ranking the game pad as easiest to use controller. The researcher did not include the dance mat in the pre-test questionnaire so cannot say if the participants were novices or experts in the use of dance mat (this is investigated in future studies). The reason the dancemat was not included in the pre-test questionnaire in this study was because initially the researcher wanted to use balance board as opposed to dancemat for the study. However, due to the technical difficulties experienced with the balance board, the researcher opted for an alternative, dancemat which was omitted (not intentionally) in the pre-test questionnaire. This issue was resolved in the subsequent studies. In this study, it was observed that controllers the participants ranked lowest on the funsorter was rated as 'not very good' using the smileyometer and those ranked highest on the funsorter were rated as 'brilliant' using the smileyometer. Whilst this result is limited in the number of participants, it is in line with conclusions of previous research that the fun sorter on the construct of fun measures the same thing as the smileyometer (J.C. Read, 2007). In addition, those (6 (50%)) that ranked a controller highest on the 'most fun' construct ranked the same controller as highest on the 'liked the most' construct whereas those (6 (50%)) that ranked a controller highest on the 'easiest to use' construct ranked the same controller as highest on the 'liked the most' construct. This suggests that controllers that are fun or easy to use influenced some of the participants' decision on the controller they liked most. On four occasions same controllers were ranked highest on the three constructs indicating that the participants showed no variability in the scores across the three constructs. This could be as a result of some of the participants not understanding the differences between the constructs (Read & MacFarlane, 2006b). Contrary to the conclusions of Read *et al.* (1999) which indicated that people would like to do fun things again, preliminary results showed that dance mat is a fun controller that participants liked, but they would not like to use it again. However, during the conduct of this study, two of the participants complained of intermittent faults in the operation of the dance mat and this may have affected their response to this question. This is explored in future studies.

There are several reasons for adding visualizations in games and these have been highlighted in literature (Bowman, Elmqvist, & Jankun-Kelly, 2012). In this study we used a very simple visual representation, a map to provide a visual feedback of each participant's interaction with the game. It was thought that inclusion of visualization in the game may help the participants to be aware of their own and partner's action thus improving interactions. Results from this study showed that the participants noticed the map and were aware of its function in the game. However, it cannot be concluded if the participants who noticed the map actually used it to reach decision on control during game play.

5.5 Conclusion

This chapter reports a pilot study conducted to test the suitability of the selected data collection methods and readiness of the study materials designed to address the objectives of the thesis. Results showed that the participants did not have any major issues playing the game with the controllers. Various data collection methods such as researcher observation of the participants during interaction, fun toolkit and questionnaires were used in the study to provide useful data to understand the concept of ECA. These methods were quite suitable; the participants did not seem to have any issues completing the evaluation forms however, the researcher appreciates the limitations of human observation which includes the possibility to miss out some behaviours of the participants during game play (Mark Saunders, Philip Lewis, 2012). It was concluded that video recording would be a more appropriate tool to record the participants' behaviours in subsequent studies (Chapter 6 and 7). Also, it was thought that longer duration might provide the participants with more time to interact with the game hence allowing the researcher a longer study period to observe the participants.

The key insights drawn from this study are as follows:

- A range of collaborative behaviours were observed while the participants played a digital game with ECA. These collaborative behaviours which are of interest when designing for ECA include giving instructions and suggestions, playing silently, glancing at each other's controllers, awareness of the map on the screen, asking for help from the researcher, pointing at the screen and 'telling by showing'. In this study, it was observed that these collaborative behaviours manifested before, during and after game play.
- Contrary to the conclusion of Read *et al.* (1999) that people would like to use what they considered fun again, it was accidentally observed (due to faulty dance mat during game play) that there was disparity between what controller the participants liked and the ones they would like to use again. This would be investigated further in subsequent

studies.

- The participants found the game pad to be the easiest controller to play the game with while the dance mat was the most fun controller. Conclusions were not reached on the controller that was liked most by the participants.
- It was observed that the participants' preferences affected their enjoyment of the game as those who preferred to play game alone enjoyed them whilst those who preferred playing in groups enjoyed group games. However, validation studies would explore this further especially in larger and varied study population.
- In this study, the controllers that are fun or easy to use influenced some participants' decision on the controller they like most.
- Majority of the participants (83%) noticed the interaction map on the screen and were aware of its function in the game. However, it could not be confirmed in this study if they used the map to reach decision on how to play.

The next chapter reports a similar study conducted with modification to the data collection methods and gameplay duration. The idea is to see whether newer behaviours will be observed and capture every strategy as it unfolds to more effectively measure ECA.

6 CHAPTER SIX: PILOT STUDY II

6.1 Introduction

The first pilot study described in the previous chapter was an initial attempt to explore the collaborative behaviours participants exhibited while interacting with an ECA enabled game and served as a platform to test the methodologies for measuring ECA as well as monitoring the operation of study design. Various methods including observing the participants during game play, administration of questionnaires before and after gameplay and logging of participants' interactions during gameplay were adopted. However, it was discovered that these methods were limited in capability to fully investigate the participants' collaborative behaviours during interaction. For example, it was thought that the researcher would have missed out certain behaviours by merely observing the participants and jotting down notes. Furthermore, the structure of the participants' key presses recorded in the log files did not allow for any meaningful data analysis. Hence, a second pilot study was required to address the shortcomings of the methods used in the first pilot study. These include modifying the log file data to enable meaningful analysis and using observational method such as video recording to identify child's collaborative behaviours during gameplay. Additional methods such as unstructured interview (to enable the researcher provide answer to the research question: what factors influenced participants' collaboration?) and Children IMI Interest/Enjoyment Scale (to compare participants enjoyment of the two game versions) were also adopted. This chapter presents the second pilot study which is aimed at further exploring the strategies the participants adopted during gameplay with modified data collection methods. Additionally, the study served as a pilot for analysing video data as well as a confirmatory study to see if the results obtained reinforce those obtained in the first pilot study.

6.2 Method

The second pilot study was redesigned to address the limitations posed by the previous methods used in the first pilot study: video camera was used to record the participants' behaviours during game play, the participants' key presses were logged in such a way to aid more meaningful data analysis and further methods such as unstructured interview, collaborative networks and Children IMI interest/enjoyment scale were used. In this section, the areas where methods used in the preliminary study changed as well as the new methods adopted in this study are highlighted.

6.2.1 Participants and Setting

The second pilot study also took place in one of the labs at the University of Central Lancashire in a MESS day format where a whole class of 30 children accompanied by their teacher visited the lab and moved between different activities in groups of five. Eight participants aged 15 years old (six boys and two girls) participated in the study. The participants were selected and grouped in pairs by the class teacher resulting in groups of three boy-boy groups and one girl-girl group. Group codes (A-D) and participant codes (P1 – P8) were used for the sake of anonymity.

6.2.2 Research Design

As with the first pilot study, a within-subject design approach in which pairs played both the single and collaborative versions of the game using the three controllers: game pad, dance mat and tangible controller was used (Figure5-1 - Figure5-6). The order of controllers was similar to that of the first pilot study except for two groups (C and D) whose preferences for controllers determined the order in which they played with the controllers.

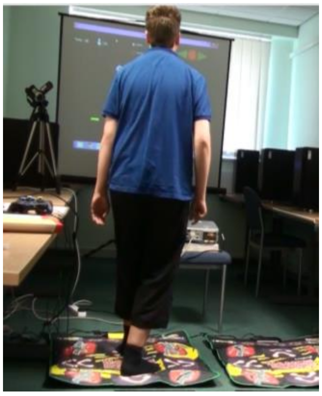

Figure 6-4: Participant playing single player version of game with dance mat

Figure 6-3: Participants playing collaborative version of game with dance mat

Figure 6-1: Participant playing single player version of game with tangible controller

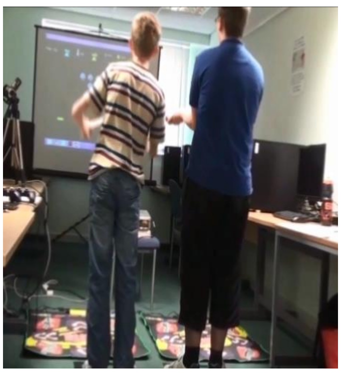

Figure 6-2: Participants playing collaborative version of game with tangible controller

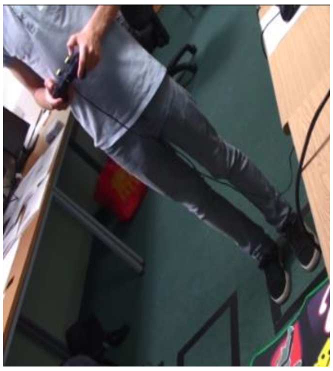

Figure 6-6: Participant playing single player version of game with game pad

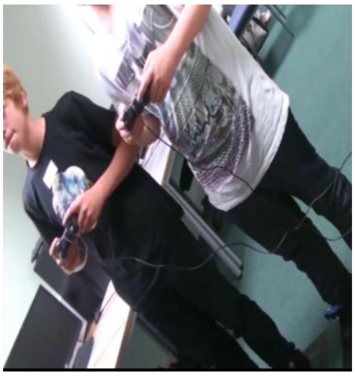

Figure 6-5: Participants playing collaborative version of game with game pad

6.2.3 Evaluation Instruments and Analysis

6.2.3.1 Observation

In this study, a video camera (placed at a corner in the lab behind the participants in order to protect their identities) was used to record participants' behaviors including their talks and body movements as opposed to real-time observation of the participants by the researcher during game play. This approach provided the researcher with a rich set of data which may not have been fully captured by merely observing the participants and jotting down behaviors as they occurred. It also provided an opportunity for the researcher to view the video footage repeatedly to aid analysis consequently preventing premature interpretation of the data (DuFon, 2002). The video data obtained from this study was analysed using a whole-to-part inductive approach (Erickson, 2006) whereby the video data was scrutinized to identify the strategies the participants adopted to reach decision and control. The video data was transcribed using Elan, a free software developed by the Max Plank Institute of Psycholinguistics (Wittenburg, Brugman, Russel, Klassmann, & Sloetjes, 2006). Elan was chosen because it supports multimodal annotation and creation of infinite number of tiers as shown in Figure5-7. In total, 1 hour of video data was obtained but in order to identify the strategies the participants adopted to reach agreement and control only the sections where they played the collaborative version of the game using the three controllers were annotated. The annotation scheme used consisted of 75 parent tiers. The parent tiers included orthographic transcript of the participants' conversations (verbal annotation), hand gestures, eye-gaze of each participant while playing with each controller (non-verbal annotation) and the leg movements of each participant while playing with the dance mat. Verbal and non-verbal annotations were distinguish according to controller type as it was envisaged that different strategies would be adopted for each controller. Furthermore, an in-depth narrative description of each video recorded session was performed (Appendix4A). These provided a recount of what happened during participants' interactions with the game. The narrative descriptions included behavioural moves and transcript of the participants' talk to portray how they collaborated with each other to reach decision and control.

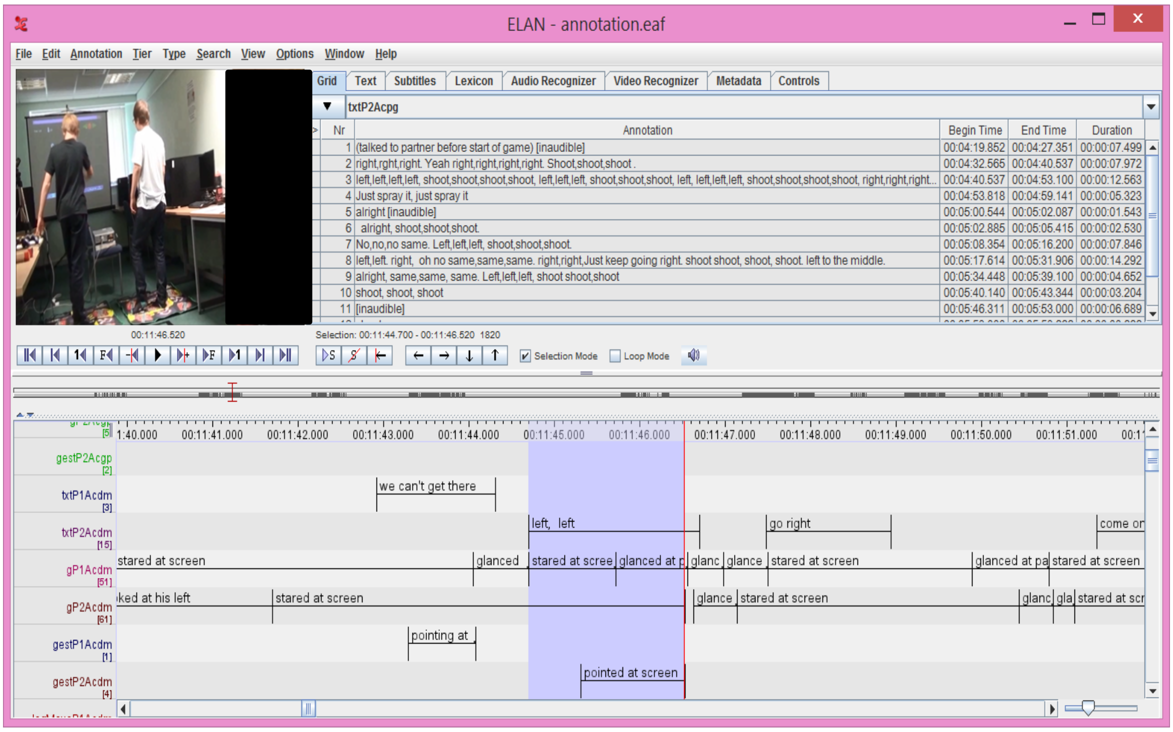

Figure 6-7: Screenshot of the subset of the Elan tiers used in the study and example of the multimodal annotation (player2 communicated with partner by talking and pointing at the screen and also focused his gaze on the screen).

6.2.3.2 *Collaborative Networks*

In addition, a more in-depth qualitative approach (known as 'Collaborative Networks') was taken to examine the collaboration process (Stanton & Neale, 2003). The collaborative networks have been successfully used in analysing children's collaborative interactions and were helpful in highlighting the strategies the participants adopted to reach decisions during game play. A coding scheme grounded in the video recording of the participants' interaction was also developed by the researcher over a series of iterations as shown in Table5-1.

In this study, the talks and actions of pairs of participants alongside their accompanying codes were represented within the collaborative networks to give a clear picture of the behaviours the participants exhibited during interaction with the game (Appendix4B).

Table 6-1: Coding Scheme

Verbal Interaction	Code	Explanations and examples
Giving direction/instruction	Gi	Partner directs or instructs e.g. *Go left. Shoot, shoot, shoot*.
Suggestion	Su	Partner makes a suggestion e.g. *Let's move this way. Let's fire it for a bit.*
Disagreement	D	Partner gives counter instruction, rejects suggestions or makes negative comments. *e.g. No*
Agreement	Ag	Partner affirms to instructions given, accepts suggestions or makes positive comments *e.g. Yeah, I know.*
Explanation	Ex	Explaining own or partner's action/intent e.g. *Trying to get the ones at the bottom left. I was too busy trying to get the last few.*
Peripheral Verbalization	Pe	Verbalizations not related to collaboration e.g. *Here we go, it worked.*
Not Talking	NT	Playing silently, no communication via talking
Noticed Map	Nm	Verbalizations related to the map on the screen or those accompanying pointing at the map on the screen e.g. *You can see err, if you look at the top right, you can see when we are pushing the button at the same time.*
Enquiry	E	*Asking for information from researcher/partner e.g. Should we turn right?*
Response	Res	Response to partner's enquiry *e.g. Yeah.*

6.2.3.3 Logging of participants interactions

In order to find out how the participants interacted and collaborated during game play, each child's key presses (left, right and fire) were logged in one text file and the times when pairs of participants agree or disagree in their controller input were also logged but in a separate text file (Appendix4C). The log file data collected during the study sessions provided quantitative measures about the participants' interactions and performance. The interactional states (section) were used to determine periods when pairs were in agreement or disagreement within the game play sessions. In this study, number of key presses was used as a metric to measure agreement. For agreement to be logged within a period of time t, two same keys (left and left, right and right or shoot and shoot) must be pressed. Hence,

$$2Keypresses\ (from\ both\ players)\ = Agreement$$

If both players were in agreement throughout the entire gameplay i.e. in a case where there is a perfect (optimal) collaborative agreement, then

$$\frac{Total\ Keypresses}{2} = Total\ Agreement$$

Then it follows that,

$$\frac{Total\ Keypresses}{Total\ Agreement} = 2$$

In order to measure the performance of each group using each controller (game pad, dance mat and tangible), the sum of both participants' key presses in each group was divided by the total number of times they were in agreement. If performance for a group tends towards 2, then it shows that the group collaborated well but if it moves away from 2, then it signifies a poor collaboration for the group.

6.2.3.4 Unstructured Interview

Unstructured interview can be helpful in an exploratory study to find out what is happening and understand the context (Saunders, Philip Lewis, 2012). In this study, unstructured interview was adopted to enable the participants collaboratively reflect on their interactions with the game. The aim was to understand what influenced the participants' interactions during game play. During the interview sessions, the data generated from the log files were used to plot graphs of

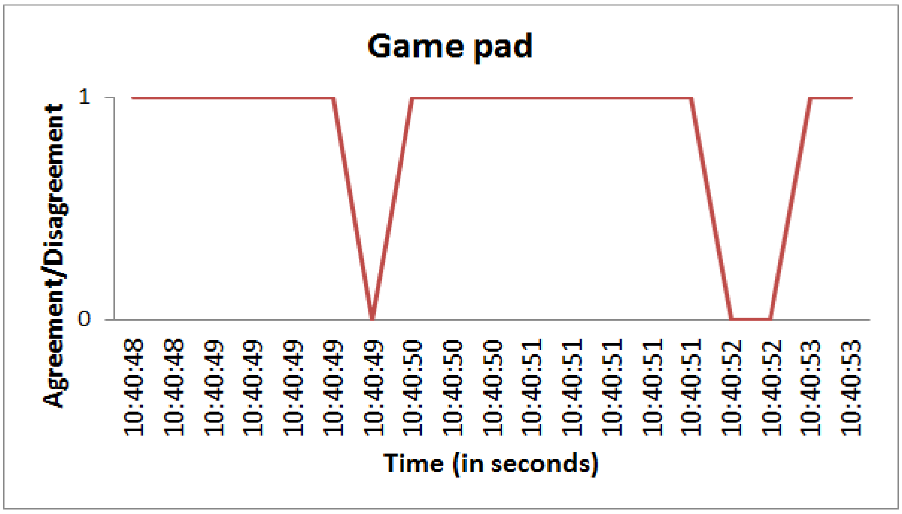

Figure 6-8: Excerpt from Group A's Graph of Agreement and Disagreement per Time in real time (hh:mm:ss) while playing with the game pad. 1 represents 'Agreement' and 0 represents 'disagreement'

agreement/disagreement against time for each controller to give an idea of how often each group agreed/disagreed. The Figure5-8 is an example of the graphs of participants' interactions used during the interview sessions. The graphs were plotted using excel and presented like this because the researcher had the data from the log files and needed a way to create the graphs very quickly. These graphs provided a visual representation of how well each group interacted while playing the game with the three interaction techniques (game pad, tangible and dance mat).

As discussed earlier in Chaper2 section2.2.2, Mack, Giarelli and Bernhardt (2009) highlighted the importance of using prompts during interview sessions with adolescents especially those who have not yet attained the formal operational level of thought. Hence, in this study, graphs generated from the log files were used as prompts during the interview sessions to show the participants their performance and see if it will help them discuss as a group what went on during the process and to provide more thoughtful and detailed explanations to what influenced their interactions. Open-ended questions were used during the interview sessions and these varied for each group depending on the outcome of the participants' interactions represented in the graphs. Typical questions include Q1 and Q2 derived from the graphs of agreement/disagreement against time for pairs in Groups A and B respectively whilst playing the game with the dance mat as shown in Figure6-9 and Figure6-10.

Q1: "*It shows from the beginning that you were in disagreement but later reached agreement. At some points during game play, you also disagreed in your controller input. What caused this to happen*?

Q2: "*Wow, you did really well - this chart shows that you were in agreement right from the onset and only disagreed towards the end; how did you do that*?"

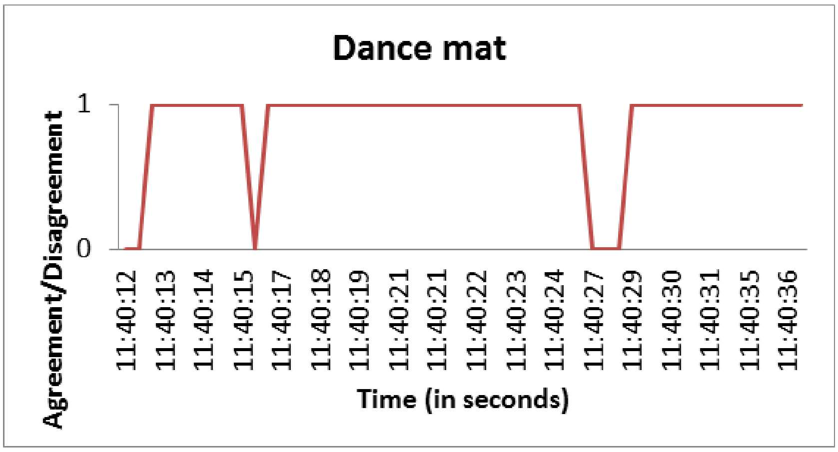

Figure 6-9: Excerpt from Group B's Graph of Agreement and Disagreement per Time in real time (hh:mm:ss) while playing with the dancemat. 1 represents 'Agreement' and 0 represents 'disagreement'

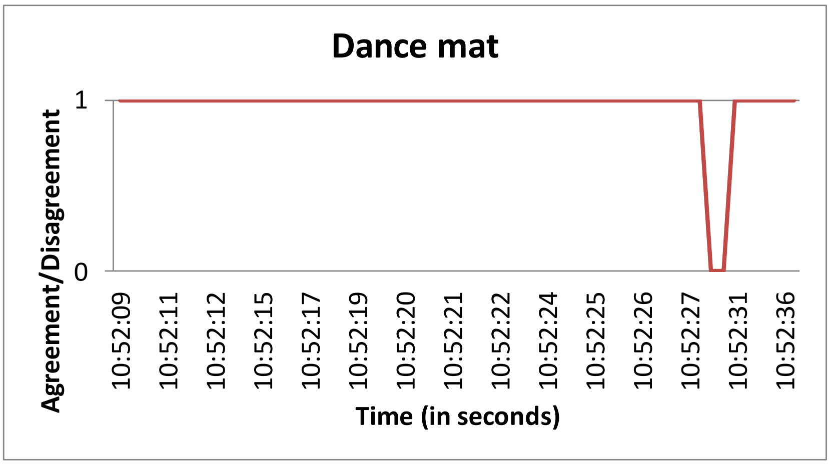

Figure 6-10: Excerpt from Group A's Graph of Agreement and Disagreement per Time in real time (hh:mm:ss) while playing with the dancemat. 1 represents 'Agreement' and 0 represents 'disagreement'

The participants' responses during the interview sessions were transcribed verbatim and analysed by the researcher using thematic analysis (Braun & Clarke, 2006). The researcher adopted an inductive approach during the analysis process where the participants' responses were unanimously coded with another researcher experienced in coding qualitative data to reduce bias (i.e. the researchers coded the data separately and the codes obtained were compared and agreed upon). The participants' responses were categorized into themes (Appendix4D) which were taken to a third party (senior researcher) for validation.

6.2.3.5 Children IMI Interest/Enjoyment Scale

To further explore the participants' gameplay experience the Children IMI interest/enjoyment (Appendix4E) scale was adopted in this study. The scale was used to compare participants' enjoyment of the two versions of the game for each controller. This was aimed at exploring the participants' gameplay experience within the context of ECA. Each item in the Children IMI interest/enjoyment scale was coded in an ordinal way 1-5 where 5 represented 'totally agree' and 1 represents 'totally disagree'(Xie et al., 2008). The 'average scores' for the participants' responses for each game version and controller type were then calculated by averaging the scores for the items in the subscale and then divided by the number of participants in the data set.

6.2.4 Procedure

The study began with each pair completing a background questionnaire (same as the one used in the initial study in section 4.2.3.1). The researcher believed that the participants needed more hands on practice and that newer strategies could emerge by increasing the duration of game play. Hence, the single player and collaborative versions of the game were increased to one and four minutes respectively. The play pattern for this study is similar to those used in the initial study except that each participant completed an evaluation form consisting of the Children IMI interest/enjoyment scale after each training session and after playing the collaborative version for each controller. The reason for this was to compare the participants' subjective ratings of fun for the two versions of the game. The order of play for the two game versions were not counter balanced since the single player version was used for training purposes. Each pair completed a post-test evaluation form and Funsorter same as the one used in the initial study at the end of each session. The participants were then interviewed using the graphs generated from the log file data obtained during game play as prompts. The interview sessions were audio recorded and the gameplay sessions were video recorded. The camera used to record the gameplay sessions was positioned at one end of the room such that participants' leg movements, hand movements and body movements were visible without capturing their faces to protect the participants' identities.

6.3 Results

6.3.1 Participants' Profile

As mentioned in section 5.2.1, eight participants (six boys and two girls) all aged 15 years old took part in this study. All the participants had prior experience playing games with keyboard, 63% with game pad, 75% with PS2/PS3 controller, 50% with wiimote, and 12% with dance mat. 75% of the participant indicated they spend time with the other member of their group (partner) inside school while 25% indicated they do not spend time with their partner inside school. While it is possible that the participants spent time together outside school, it was not considered in the research reported in this thesis. All the participants indicated that they have known their partner since starting high school (i.e. 4 years minimum).

6.3.2 Understanding Collaborative Behaviours

The same notations ($X_{tangible,}$ $X_{gamepad}$ and $X_{dancemat}$) as in section 4.4.2 were used to represent groups that played the game with the three different controllers. However, X ranges from A-D and i from 1-8. Segments of the collaborative networks (Appendix4B) are presented in tables to illustrate extracts of participants' speech and action. The far right and left columns of the tables show the speeches and actions of the participants standing to the right and left of the gameplay screen. The middle columns show the resulting codes using the coding scheme from Table5-1 Section 5.2.3.2. An event following another is represented in the row below it and action or talk occurring at the same time is represented on the same row. This allows one to follow the progression of speech and action over time. The arrows by the side of the codes enable one to follow the order of the participants' verbalizations and actions. For clarity,

↙ Represents the speech turn of the child on the far left

↘ Represents the speech turn of the child on the far right

↓ Shows the same child continued verbalization

Prior to start of game play, it was observed that participants in $A_{tangible}$, $B_{tangible}$, $C_{tangible}$, $D_{tangible}$, $A_{gamepad}$ and $D_{dancemat}$ engaged in negotiations in order to adopt strategies for game play. For illustration purpose, Table5-2 shows excerpt from $B_{tangible}$'s transcription. As shown in that table, P3 suggested to P4 the direction they should start from. Initially, P4 did not accept the suggestion but clearly said what direction he wanted to go. P3 disagreed and went further to provide some explanation to his suggestion which made P4 to accept the suggestion.

Table 6-2: $B_{tangible}$ - Negotiation before game play

P4_Time	P4_Transcript	P4_Code	P3_Code	P3_Transcript	P3_Time
			↙ Su	Alright, so do you want to go from left[tilts left] to right [tilts right]and like sort of err… almost like a routine really	21:11.609
21:14.785	I will go to the right	D ↘			
			↙ D	No, you have to go at the same time	21:17.686
21:18.723	Alright	Ag ↘			
			↙ Ex	Cos it's just one little thing and we have to move both hands at the same time to get it to move	21:19.376
21:24.773	Ok	Ag ↘			

During gameplay, several occasions of conflicts (disagreement) were observed within groups and across controllers. Whilst some of the conflicts were resolved quickly (e.g. as seen in $B_{gamepad}$'s excerpt in Table5-3, it took the pairs 2 seconds to resolve the conflict), others were resolved with explanations as seen in $B_{dancemat}$'s excerpt in Table5-4.

Table 6-3: $B_{gamepad}$ – Conflict resolved

P3_Time	P3_Transcript	P3_Code	P4_Code	P4_Transcript	P4_Time
32:37.900	Shoot, shoot, shoot	Gi ↘			
			↓ D	Right	32:40.242
32:40.813	Alright	Ag ↘			

Table 6-4: $B_{dancemat}$- Conflict resolved with explanation

P3_Time	P3_Transcript	P3_Code	P4_Code	P4_Transcript	P4_Time
			↙ Gi	Oh, right, right, right, right[steps right]	39:49.316
39:51.030	Left, left, left[steps left]	D ↘			
			↙ Ex	Oh, I want to go right cos I want to get the bomb	39:52.341
39:55.342	Ok	Ag ↓			

There were also several non-conflict situations where a participant affirmed to partner's instructions without further explanations as seen in $A_{gamepad}$'s excerpt in Table5-5. There were indications of dominating behaviours in $A_{gamepad}$, $A_{dancemat}$ and $D_{dancemat}$ where one of the pairs controlled the interaction through verbal instructions while the other passively carried out the instructions. However, this did not continue throughout the rest of the game play session.

Table 6-5: $A_{gamepad}$- Non-conflict situation

P1_Time	P1_Transcript	P1_Code	P2_Code	P2_Transcript	P2_Time
			↙ Gi	Left to the middle	05:28:622
05:32.627	Left	Ag ↘			
			↓ Ag	Alright	05:34.448

Also, there were cases where suggestions were made by a participant to the partner during game play, but these suggestions were not always followed. In one case, explanation was required to convince the partner to accept the suggestion as seen in $B_{dancemat}$'s excerpt in Table5-6.

Table 6-6: $B_{dancemat}$ – Giving suggestion with explanation

P3_Time	P3_Transcript	P3_Code	P4_Code	P4_Transcript	P4_Time
			↙ Pe	Ok, this is not moving	41:27.792
41:32.545	If you stand on it then it should do it	Su ↘			
			↙ Pe	I've been doing it and it's like… (pointing at the screen)	41:37.867
41:39.131	Maybe because you are pressing two. Think about it because you are pressing that one as well	Ex ↓			

On one occasion, one of the participants in $A_{dancemat}$ enquired from the partner about the game controller (dance mat): P2 – "is it not working?" The same participant in $A_{dancemat}$ also enquired once from the researcher about the game controller (dance mat): P2 – "*is that err, shooting? [Pointing at his controller]*" Only $A_{gamepad}$ used telling by showing strategy where one participant showed his partner what to do using his controller while the partner watched. On many occasions, participants gave verbal instructions and pointing instructions (deictic gestures) to their partners during game play. Silent play where participants played for a period of time without talking to each other was evident in all groups. Also participants in $B_{gamepad}$'s were observed negotiating a strategy during game play as shown in Table5-7.

Table 6-7: $B_{gamepad}$ –Negotiating a strategy during game play

P3_Time	P3_Transcript	P3_Code	P4_Code	P4_Transcript	P4_Time
			↙ Su	What we could do is just one person, one person does what they want to do and the other person comes through	32:57.815
33:05.746	No	D↓			
33:06.068	That's not a good idea cos one person would not come through very well	Ex↘			
			↓D	No	33:09.104
			↙ Ex	They'll be like….	33:09.676
33:10.018	And two, it would be boring for the other person who did what they wanted and I'm guessing you'll be the person doing what you want to do	Ex↘	↙ Ag	[laughs] That probably will be the best…	33:12:959

Furthermore, it was observed that participants in $A_{dancemat}$, $B_{dancemat}$, $C_{dancemat}$, $D_{dancemat}$, $B_{gamepad}$, $B_{tangible}$ and $D_{tangible}$ made enquiries from their partners regarding game play and in some cases received responses from their partners as shown in $B_{dancemat}$'s transcript in Table5-8.

Table 6-8: Bdancemat - Enquiry and response to enquiry

P3_Time	P3_Transcript	P3_Code	P4_Code	P4_Transcript	P4_Time
			↙ E	Did we get it? *[stepping on the left button of the dance mat]*	40:10.900
40:11.974	I'm not sure.	Res↘			

It was observed that on two different occasions pairs in $C_{gamepad}$ (girl-girl group) touched each other's controller to make the partner do the same thing. However, each participant responded in a way that did not allow the partner to dominate as seen in Table5-9.

Table 6-9: $C_{gamepad}$ – Not allowing partner dominate

P5_Time	P5_Transcript	P5_Code	P6_Code	P6_Transcript	P6_Time
			↙ PAT3	[Glanced at P5's gamepad and touched P5's gamepad]	45:33.580
45:35.198	Get off!	Pe			

The participants were asked (using questionnaire) if they noticed the map on the screen and whether they knew the aim of the map. Responses from the participants indicated that they all noticed the interaction map on the screen and knew the purpose of the map apart from P7 in Group D that did not respond to the question (Appendix4F). This was reinforced by the responses of participants in Group D to the question *"How did you agree in order to play?"*(Appendix4F) and transcript of the participants in Group B while playing with the gamepad and dance mat respectively:

P3: *"…if you look at the top right you can see when we are pushing the button at the same time…So I can see when you are pushing left, pushing right."*
P4: *"You can see it on the top bit [pointing at screen]"*

In addition, various affective behaviours such as jumping, shouting, dancing, laughing, high levels of concentration, signs of excitement and frustration were observed.

Summarily, various behaviours were observed across groups of participants and the three controllers (tangible, gamepad and dance mat) as shown in Table5-10. These behaviours are similar to those observed in the previous study but with new behaviours that emerged in the current study and include: conflict resolution, not allowing partner to dominate and dietic gestures. This result could be as a result of longer duration of game play (4mins) in the current study and the possibility of the researcher missing out certain behaviours by just observing the participants and taking notes as reported in the first pilot study (chapter 5).

In the current study, all the strategies were observed for various groups while playing with all the three controllers except for ‘Not allowing partner dominate’ and ‘telling by showing’ which occurred only in the gamepad condition in Groups A and C. Examination of the table to see how the strategies emerged in each controller condition and ordering, revealed that in Groups A and C (with the same ordering) participants negotiated strategy before game play while using the tangible controller. Additionally, in the same groups conflict resolution and domineering behaviours were observed while playing with the game pad and dancemat respectively

Table 6-10: Summary of the strategies adopted by the participants during game play (G=Game pad, D= dance mat, T= Tangible)

	Group A			Group B			Group C			Group D		
	Order of play			Order of play			Order of play			Order of play		
	G	D	T	T	G	D	G	D	T	T	D	G
Strategy negotiation before game play	√		√	√					√	√	√	
Conflict resolved	√	√		√	√	√	√		√			
Non-conflict	√			√	√	√					√	
Giving Suggestions/suggestions accepted		√		√	√	√			√		√	
Dominating behaviours	√	√	√		√			√			√	
Not allowing partner dominate							√					
Telling by showing	√											
Enquiry/Request and response to request/enquiry		√			√	√				√	√	
Deictic gestures	√	√	√	√	√	√						√
Noticed Map					√	√						
Playing silently	√	√	√	√	√	√	√	√	√	√	√	√

The researcher looked at which strategies emerged in each controller condition and then looked at the ordering to see if there was any difference. The analysis did not show any strong evidence to suggest that the ordering of controller influenced the strategies adopted. Whilst there were some instances of the same strategies being adopted in the same gameplay condition and in the same ordering, however, there is not enough data to perform any meaningful analysis. Besides, there were not enough groups for fully balanced Latin square.

6.3.3 Participants' Gameplay Experiences

Figure5-11 shows the participants' rating of how much fun they experienced while playing the game with the three controllers. As in the first pilot study, no one rated any of the three controllers as 'awful'. The median response for the gamepad is 5 with the participants response ranging from 'not very good' (min=2) to 'brilliant' (max=5), tangible controller is 3 with the participants response ranging from 'not very good' (min=2) to 'really good' (max=4) while that of the dancemat is 4 with the participants response ranging from 'good' (min=3) to 'brilliant' (max=5).

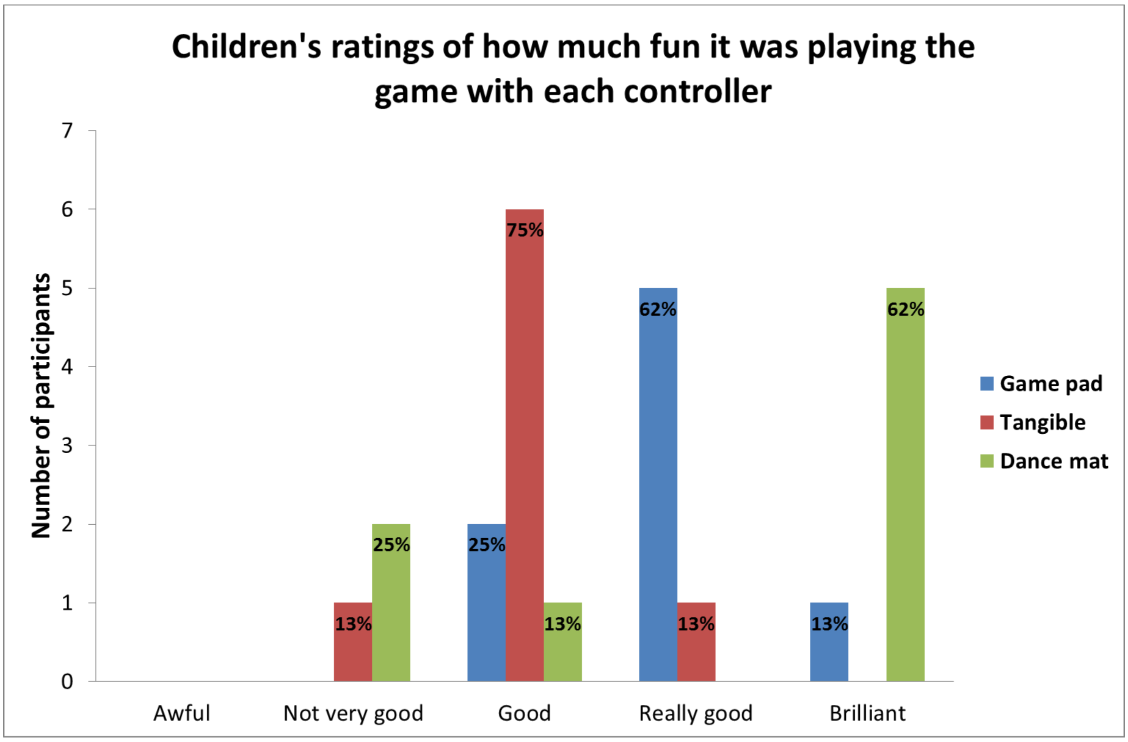

Figure 6-11: Participants' ratings of the three controllers

The Smileyometer and the Again-Again results were presented in the table in Appendix4G. The table was represented in this format to show results across both metrics. Inspection of the table showed that the only participant (P1) who rated the game pad as 'brilliant' indicated that he would like to play the game again with the game pad. Furthermore, 5(62%) of the participants rated the dance mat as 'brilliant' but 2(40%) out of those who thought the dance mat was brilliant would not like to play the game again with the dance mat while the other 3(60%) were undecided. Figure5-12 shows for each construct ('liked the most', 'was most fun' and 'was easiest to play with'), how many participants ranked each controller highest. Similar to the results obtained using the Smileyometer, the dance mat appeared to be the most fun controller as 6(75%) of the participants ranked the dance mat highest on the 'most fun' construct compared to 2(25%) for game pad. None of the participants ranked the tangible controller as 'most fun'. The game pad appeared to be the easiest to play controller and the one liked most by the participants as 6(75%) of the participants ranked the game pad highest on the 'easiest to play' constructs and 5(62%) of the participants ranked the same controller highest on the 'like the most construct'. None of the participants ranked the dance mat as 'easiest to play'.

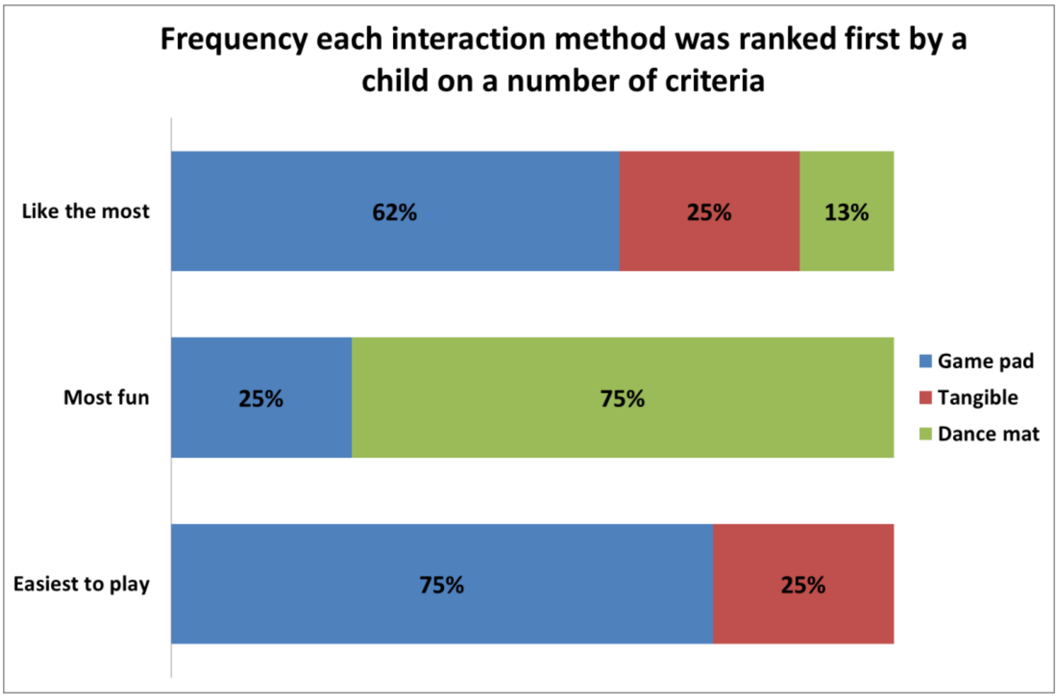

Figure 6-12: Participants' rankings of the three controllers

TableA in Appendix4G shows the participants' rankings of the three controllers according to the constructs 'liked the most', 'was most fun' and 'was easiest to play with'. The table was represented in this format to show result across the three constructs. Comparing the participants' responses across the TableA and TableB in Appendix4G, it can be seen that the participant (P3) who ranked the dance mat lowest on 'most fun' construct of the funsorter rated the dance mat as 'not very good' using the smileyometer. Also, 5(83%) of those that ranked the dance mat highest on the 'most fun' construct of the funsorter rated the dance mat as 'brilliant' using the smileyometer. Furthermore, 7(88%) of those that ranked a controller highest on the 'easiest to use' construct ranked the same controller highest on the 'liked the most' construct. On one occasion, a participant ranked the dance mat highest on the 'most fun' and 'liked the most' constructs. To compare the participants' enjoyment of the single-player and the collaborative versions of the game across controllers, the average scores for the participants' ratings using the Children IMI interest/enjoyment scale were calculated (Appendix4H) and represented graphically as shown in Figure5-13. The results between the single player (3.19 for game pad, 3.13 for tangible and 2.92) and collaborative conditions (3.39 for game pad, 3.45 for tangible and 2.78 for dance mat) were very similar indicating no clear differences in the participant's enjoyment of the two versions of the game.

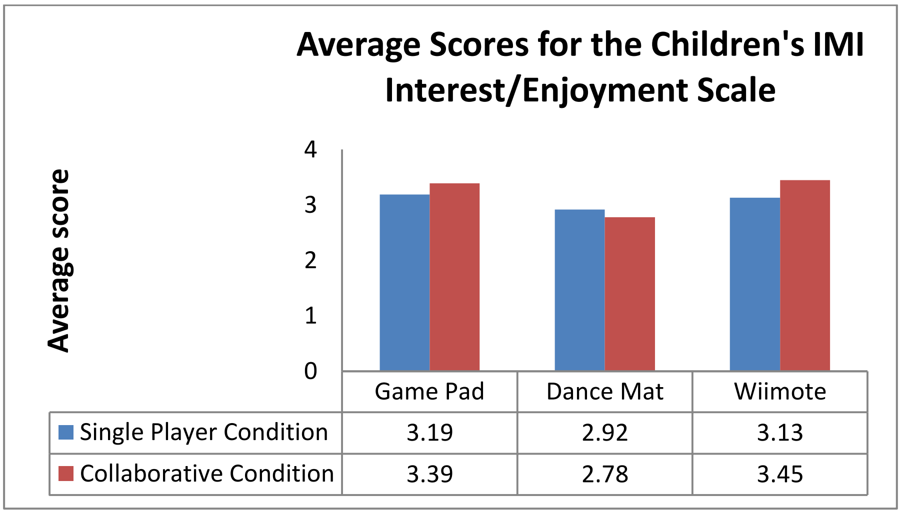

Figure 6-13: Average scores for Children's Interest/Enjoyment Scale

6.3.4 Enjoyment vs. Preference

Similar to the results obtained in the previous study, those who preferred to play alone enjoyed playing alone (13%) while those who preferred to play with their partners enjoyed playing with their partners (62%).

6.3.5 Performance

In order to investigate the controller the participants performed best with while interacting with the ECA enabled game, performance for each group was calculated by dividing the sum of the key presses of pairs in each group by the total number of times the pairs in the groups were in agreement (Appendix4I). The results for each controller were summarized in Table5-10. All the groups performed best with game pad and worst with dance mat apart from Group A that performed best with Dance mat and worst with tangible. Pairs in Groups A, C and D performed better than those in Group B in the use of game pad and tangible but in the use of dance mat, only participants in Group A performed better than those in Group B.

Table 6-11: Group performance with three controllers

Group	*Performance*		
	Dance mat	*Game pad*	*Tangible*
A	*2.56*	*2.61*	*2.79*
B	*4.16*	*3.35*	*3.47*
C	*4.45*	*2.22*	*3.45*
D	*5.13*	*2.33*	*3.25*

6.3.6 Interview Responses

The graphs of the participants' interactions used during the interview sessions can be seen in Appendix4J. The interactional states described in Chapter 3 section 3.4.5 were used to obtain the periods when pairs were in agreement (represented as 1) or disagreement (represented as 0). The graphs were presented like that because the researcher needed a way to quickly create the graphs from log file data and try out the initial ideas to gain some insights and understandings. Presented in this section are the themes generated from the thematic analysis of the participants' responses during the interview sessions with the quotes from the raw data indicative of each theme.

6.3.6.1 Strategy

All groups developed strategies to play the game and most of these strategies occurred across controllers. While some ($A_{gamepad}$, $A_{tangible}$, $B_{tangible}$, $C_{tangible}$, $D_{dancemat}$) did this in advance others ($B_{gamepad}$, $C_{gamepad}$, $D_{gamepad}$, $D_{tangiblei}$, $A_{dancemat}$, $B_{dancemat}$, $C_{dancemat}$) developed strategies during game play. One of the participants (P1) in Group A (while playing the game with dancemat) identified that their initial strategy which involved use of the game features influenced how they collaborated using dance mat. According to P1: *"…it was just that we decided pressing where they [aliens] wanted to go and then we will say to the other person go right…"* In addition, pairs in Group B (while playing the game with dance mat) had no initial strategy however they noticed the map during game play and used it to collaborate as stated by one of the participants in the group *"I think we were both trying to do different things and then we looked up at the little bars, the circles which showed us what each other was doing. And then we thought, oh alright I would do what each other was doing."* There was no strong evidence to suggest that the ordering of controller influenced the strategies adopted. There were some instances of the same strategies being adopted on the same gameplay conditions and ordering but there is not enough data for any kind of meaningful analysis. Furthermore, there were not enough groups for fully balanced Latin square.

6.3.6.2 Synchronicity of Response

Synchronicity of response relates to synchronous agreement between players interactions which occur when players press the same keys simultaneously. In this case, agreement is recorded if a key is still pressed down by one player by the time another player presses the same key. There seemed to be no serious problems related to this issue as the key presses generated agreement severally during game play. It would have been impossible to play the game if the participants did not agree in their controller input. One of the participants P7 in Group D while playing with the dance mat mentioned that the periods where they agreed was as a result of their quick reaction to each other's interactions with the game: *"when there were long spaces [i.e. where they agreed in their controller input], I think we responded really quickly…"* and P6 in Group C while playing with the game pad: *"we were both pressing it very fast..."* One of the participants P1 in Group A indicated that it took them more time to get into agreement while playing with the dance mat. Initially, they used the alien movement to decide where to go but had to re-strategize probably because their initial strategy seemed not to work as seen in the transcript: "*Uhmm, well it was just that we decided pressing where they [aliens] wanted to go and then we will say to the other person go right. So it takes us more time to react*". One of the participants P6 in Group C also mentioned that it took them *"…a bit [a longer time] to get together…"* as they needed to coordinate their interactions while playing with the dance mat. Furthermore, P6 in Group C indicated that it was difficult to coordinate key presses while playing with the game pad: *"…I don't think we were pressing the red button at the same time very easily".* This issue with the game pad may have arisen due to the typically very short duration of button.

6.3.6.3 Collaboration

Difficulty working together was identified as one of the issues encountered by some pairs during interaction. P2 in Group A stated that *"It's harder to work together than work alone"* while playing with the dance mat. Also, the same participant encountered similar problem while playing with game pad however, this seemed to be less of a problem after the participants had learned how to agree in their controller input as seen in the transcript *"It's still the exact same* *reason but because it's sort of working together…and you learn how to do it easier so you're just moving out more and shooting.*"

6.3.6.4 Interaction Issues

This refers to the challenges posed by the controllers as the players interacted with the game. Pairs in group D reported experiencing some hardware problems while playing with the dance mat as stated by P7: *"I think the dance mat was a little bit unresponsive in some places …"* and that this resulted in a slow response during interaction: *"I think it was a little bit jerky moving, so we have to be a bit slow in, in places".*

6.3.6.5 Ease of Use of Controller

This refers to the players' ability to easily interact with the controllers. The gamepad was reported as the easiest: "*I think it's more of a case the buttons are easier to press…, it's easier to go on and off, on and off..."* (P4 Group B).

6.3.6.6 Accidental Interactions

This refers to when players generate game control inputs not planned or intended. Pairs in Group C and Group A found that they accidentally tilted the Tangible and that this influenced how they collaborated. This is evident in responses of P5 in Group C *"I kept slipping going that way without realizing"* P6 in Group C *"Yeah, it's hard to get it really straight"* and P1 in Group A: *"…sometimes you just accidentally tilt it."*

6.3.6.7 Awareness of actions

This refers to how clearly a controller can be seen by the players during interaction. P4 in Group B stated that the size of the tangible controller caused them to easily see what each other was doing as seen in the comment *"Yeah, cos it's so big. It's easy to see what the other person is doing. Cos you can see them going like that [gestures]".* Awareness of others play an important role in the fluidity and naturalness of collaboration and can be easily maintained in a collocated situation such as the one reported in this research compared to a non-collocated situation e.g. groupware (Gutwin & Greenberg, 1996).

6.3.6.8 Familiarity with Controller

This refers to the degree of familiarity the participants felt with the controllers. P7 in Group D felt that the game pad had strong single player connotations for them: *"it might be that when you've got that kind of controller, your immediate response is to play a single player cos that's how you normally play it at home."* Although P8 in the same group is familiar with the tangible controller, the appearance made him use it differently as seen in his comment *"even though these are wiimotes, they look different so you try and play it differently."* This was surprising as the wiimote was concealed in a plastic bar (as stated in chapter 3 section3.4.2). Conversely, unfamiliarity was found to foster collaboration, in relation to the tangible and dance mat. P7 in Group D stated *"I think with the other two you have to work as a team cos you have never used that kind of equipment before."*

6.4 Discussion

The findings from this study revealed a range of different collaborative behaviours exhibited by the participants whilst playing a multiplayer game that supports ECA. These behaviours were similar across controllers (i.e. they were observed in various groups using the three controllers apart from 'Not allowing partner dominate' and 'telling by showing' which occurred only in the gamepad condition) and in some cases transferred from one controller to another within groups. The behaviours observed in this study confirmed those of the preliminary study but also revealed other collaborative behaviours that were not evident through researcher observation of the participants' interactions. The inclusion of video recording enabled the researcher to record and monitor events to gain more insights into the strategies adopted by the participants while playing the game. The qualitative analysis of the collaboration used an approach known as 'collaborative networks' which provided a framework for analysing the video footage from the study and developing understanding of the collaborative behaviours. The collaborative networks consisted of descriptive data such as participants' talk and action and their accompanying codes (obtained from the coding scheme) and were used to highlight patterns of behaviours within this study. Most pairs demonstrated truly collaborative behaviours such as negotiations, verbal suggestions, explanations, enquiries and response to enquiries. Soliciting help from a partner through questioning (which occurred a few times in groups A, B and D), offering help to partner through gesturing with input device (which occurred once in Group A) and conflict resolution (an indicator of good collaborative interaction (Roschelle & Teasley, 1995) and occurred a few times in groups A and B) were also evident in the study. Non-conflict (agreement) situations where partners did not require further explanations to agree featured most commonly throughout gameplay. Evidence of dominating behaviours was observed in some groups where a participant gave instructions and the other did not respond verbally but carried out the instructions. However, this dominating behaviour did not persist for the entire game play sessions and typically ended with the other player disagreeing or giving their own instructions.

Within Group C, two instances were observed where a participant attempted to dominate by interacting with their partner's controller, but these attempts where ineffective. While more research is needed these observations imply that ECA could help empower people that are being dominated and encourage more equitable participation, this may be particularly desirable especially in educational settings.

The participants appeared to be enthusiastic and engaged well with the activities in the study, some shouting, laughing and jumping while others focused all their attention on the gameplay: these observations were similar to those obtained in the previous study. The Children's interest/enjoyment scale which compared the participants' enjoyment of the two game versions gave very little differences in result but also the questionnaire included questions on whether the participants preferred and enjoyed playing the game alone or with their partners. The questionnaire revealed that one participant (13%) preferred to play alone and did not enjoy playing with their partners while 62% (five participants) of the participants did not prefer to play the game alone and enjoyed playing with their partners. As expected, there appears to be a relationship between participants' preference and enjoyment of the collaborative element of the game reasons being that it was fun, challenging, engaging, and promoted teamwork. These results are in line with those obtained in the previous study (chapter 4 section 4.3.4). While the number of those who participated in this study was small, Figure5-12 showed that the dance mat was clearly the most fun controller. The data also implies that the game pad was easiest to play the game with. These results could be due to the novelty factor as majority (all apart from one child) of those who participated in the study had no previous experience with the dance mat. Also, a high familiarity with the game pad could be the reason for the participants ranking the game pad as easiest to use controller. It was observed that controllers participants ranked lowest on the funsorter was rated as 'not very good' using the smileyometer (in four cases) and those ranked highest on the funsorter were rated as 'brilliant' using the smileyometer (all cases). Whilst this result is limited to the number of participants in the study, it confirms that of the first pilot study and is in line with conclusions of previous research that the fun sorter on the construct of fun measures the same thing as the smileyometer (Read, 2007). In addition, the participants that ranked a controller highest on the 'most fun' construct ranked the same controller as highest on the 'liked the most' construct whereas those that ranked a controller highest on the 'easiest to use' construct ranked the same controller as highest on the 'liked the most' construct. Similar result was obtained in the first pilot study and this suggests that controllers that are fun or easy to use influenced some participants' decision on the controller they liked most.

Furthermore, contrary to the conclusions of (Read, MacFarlane, & Casey, 2002) which indicated that people would like to do fun things again, results from this study showed that dance mat is a fun controller (due to novelty factor) that the participants liked, but they would not like to use it again. This confirms the result obtained in the first pilot study and could be attributed to lack of prior experience with the dance mat (only one participant had prior experience with dance mat) causing frustration i.e. participants finding it challenging to put their foot in the right place on the mat while engaged in the game. The dance mat may have proved frustrating as, compared to the game pad for example, it requires more practice to interact accurately, is more tiring to use, and the pace of interaction is naturally slower due to the larger body movements (gross movement of legs compare to fine movement of thumbs or wrist).

In a study that investigated the effect of personalized electronic quest on children's enjoyment (van Dijk et al., 2012), strong correlations were reported between the results of Again-Again and Smileyometer for younger children while weaker or no correlation was reported for older children (those above 10 years old). In their study, the older children rated the Smileyometer questions very high and still sometimes answered 'no' and 'maybe' to the questions on the again-again. This result is similar to the one obtained in the current study and it can be argued that due to the fact that the participants in the current study (11-16 years old) are more cognitively advanced and judgemental compared to younger children (0 -10 years old), they were able to reveal (through the use of fun toolkit) how much they enjoyed playing the game with the dance mat as well as express their doubts on whether they would like to play the game again with the dance mat.

In this study, performance was measured by adding up the number of key presses of both participants in each group divided by the total number of times they were in agreement. Performance was used to find out how well each group collaborated in the three play conditions (i.e. game pad, dance mat and tangible). Results from the calculation showed that all the groups (apart from Group A) performed best with the game pad, followed by the tangible and then the dance mat. This is not surprising as most of the participants were familiar with game pads (having previously played games with game pads) and all apart from one participant had no previous experience playing games with the dance mat. This may also explain the reason why the participants found the dance mat fun but would not use it again as they performed worst with the controller. The hypothesis that familiarity with partner would have an effect on the participants' performance was not supported by the result as all the participants have known each other for an average of four years but minor differences were observed across groups and within controllers as shown in Table5-12.

In this study a very simple visual representation, a map, was used to provide a visual feedback of each participant's interaction with the game. It was anticipated that the interaction map would support more effective collaboration through awareness of own and partner's actions (Bowman et al., 2012). Results from this study (questionnaire, interview, and video) showed that the participants noticed the map and were aware of its function in the game. How prominently this featured in the participants' strategies is unclear (only pairs in Group B discussed it) and further exploration in this areas is required.

A set of eight core themes which influenced the participants' interactions were identified in this study. These themes span a range of levels and can be used to inform future work in the area of ECA in a range of possible application scenarios such as gaming and learning.

6.5 Conclusion

This chapter reports a similar study to the first pilot study but with modification to the research methods. The video recording provided a set of rich data for analysing the participants' collaborative behaviours in enforced situation. The interviews offered a way to understand what influenced the participants' interactions and the log file data generated during game play were displayed graphically and served as prompts during the interview sessions with the participants. Necessary precautions were taken by the researcher to ensure the interaction techniques did not malfunction during study sessions.

Analysis of the data obtained not only produced useful information for the design of future studies but also highlighted the limitations of the study design (timing and setting), methods and tools used in the study. Timing was a key issue faced in the study. The researcher was allocated 30mins however, each session took between 35-40 minutes to complete which put the researcher under pressure to finish on time. This problem could be attributed to numerous evaluation forms used in the study.

The following conclusions were drawn from this study:

- Various collaborative behaviours were identified however, no clear differences were observed between the interactions methods used in the study. The inclusion of video recording in the methodology and use of collaborative networks in the analysis of the data provided an avenue to analyse the participants' behaviours in detail thus revealing collaborative patterns which were not evident through researcher's observations of the participants. Conclusively, this study supports the use of video analysis to effectively explore ECA.
- The interview sessions with the participants revealed a set of eight main issues which influenced their interactions during game play. These issues span a range of levels likely to the side of the interaction and might be more general when applying ECA outside of space invaders to other applications.
- Similar to the result of the first pilot study, the dance mat was the most fun controller and the game pad was easiest to play the game with.
- Results of the first pilot study showed that the participants would not like to use a controller they found to be most fun again. It was thought that the result was due to the intermittent fault in the operation of the dance mat. However, similar results were obtained in the second pilot study with the dance mat in good working condition. This result suggests that contrary to the conclusion of Read *et al.* (Read et al., 2002), participants may not necessarily want to use things they considered fun again.
- In line with the results of (van Dijk et al., 2012), the Smileyometer is a valuable tool to use alongside Again-Again table especially for adolescents.
- Similar to the result obtained in the first pilot study, the controllers that are fun or easy to use influenced some participants' decision on the controller they like most.
- In line with the result of the first pilot study, the participants' preferences affected their enjoyment of the game - those who preferred to play game alone enjoyed them whilst those who preferred playing in groups enjoyed group games.
- Again, the participants noticed the interaction map on the screen and were aware of its function in the game. However, it was unclear in this study how prominently the use of

the interaction maps featured in the participants' strategies. This would be further explored in subsequent studies.

- In this study, the participants performed best with the game pad and worst with the dance mat. It was thought that this could be due to high familiarity with game pad and unfamiliarity with dance mat.

The next chapter reports a study which is aimed at evaluating the strategies participants adopted while playing the space invaders game with ECA on a larger and more varied user groups. Similar methods used in this study (video, log files, questionnaire, interview, fun toolkit) are adopted however, the areas where they vary will be highlighted.

7 CHAPTER SEVEN: MAIN STUDY

7.1 Introduction

The study reported in this chapter was conducted to explore the behaviours exhibited by participants between the ages of 11 -16 years old to reach agreement while interacting with an ECA game as well as the effects ECA have on their gameplay experiences with larger and different user population in order to draw up more conclusive results. Lessons were learnt from the second pilot study with regards to the data collection methods used and improvements were made to the data collection methods. These improvements included modifying the way participants' key presses were logged to improve the look of the graphs used during interview sessions, modifying the questionnaires to obtain more relevant data from the participants and dropping the Children IMI interest/enjoyment scale and the tangible controller and dance mat. In this chapter, the study design and the results from the study are reported. The discussions of the results are presented in the next chapter (Chapter 8).

7.2 Method

In the first and second pilot studies reported in chapter 4 and 5 of this thesis, three interaction methods including gamepad, tangible controller and dance mat were used by the participants to interact with the ECA game. One of the major challenges the researcher encountered was difficulty in balancing the study design alongside running the studies. Besides, it took a lot of time to set up and run the studies and consequently, a small number of participants took part in the studies. In order to reduce the time it takes to run the main study and get larger number of participants, a decision was made to move forward with one controller. The game pad was chosen because the participants in previous studies reported it to be the easiest to play the game with compared to the dance mat and tangible controller. Furthermore, game pad is a familiar controller and using a controller participants are familiar with would enable them to focus on collaborating rather than on the controller. The Children Interest/enjoyment scale was also dropped as it produced no clear differences in the participants' enjoyment of the two versions of the game in the previous study. In this section, the methods used in this study are presented and areas where they differ from methods used in the previous study are highlighted.

7.2.1 Participants and Setting

This study took place at five different youth centres within Coventry, UK over the summer period. Children usually gather at the youth centres during their leisure periods to meet with friends and participate in different activities. Sixty-eight participants (aged between 11 and 16 years old) were selected and grouped in pairs by the support workers at the youth centres depending on their willingness to participate. During the study sessions, it was observed that participants in some groups (9 groups) did not play the collaborative version of the game for 10minutes because their parents took them away or they got bored and did not want to carry on playing (this is one of the challenges of working with children). Consequently, it was decided to present results from only 25 groups consisting of twelve boy-boy groups, twelve girl-girl groups and one mixed group who played for 10 minutes. Group codes and participant codes were used for the sake of anonymity.

7.2.2 Evaluation Instruments and Analysis

7.2.2.1 Observation

In this study, a video camera placed in front of the participants was used to record their behaviors including their talks, facial position and body movements. This approach has been shown to be useful in the analysis of ECA (chapter5). Analysis of the video data also followed a whole-to-part inductive approach (Erickson, 2006) whereby the video data was scrutinized to identify the strategies participants adopted to reach decision and control. Transcription of the video data was again performed using Elan, a free software developed by the Max Plank Institute of Psycholinguistics (Wittenburg et al., 2006). As stated in in Chapter5 section 5.2.3.1, Elan was chosen because it supports multimodal annotation and creation of infinite number of tiers. In total, 6.5 hours of video data was obtained but in order to identify the strategies the participants adopted to reach agreement and control, only the sections (5.3hours) where they played the collaborative version of the game were annotated. The annotation scheme used consisted of ten parent tiers per video session. The parent tiers included orthographic transcript of the participants' conversations, hand gestures, eye-gazes, facial expressions and body movements. Furthermore, the participants' head positions (facial directions) were coded and then counted in order to gain insights into the participants' attention during game play.

7.2.2.2 Collaborative Networks

Similar to the second pilot study, collaborative networks was used to examine the collaboration process (Stanton & Neale, 2003). The collaborative networks were useful in highlighting the strategies participants adopted to reach decisions during game play. The coding scheme developed in the second pilot study (Table5-1 chapter 5 section 5.2.3.2) was also used in this study.

7.2.2.3 Questionnaire

Similar to the previous studies reported in chapter4 and chapter5, both pre-test and post-test questionnaires were used in this study. The pre-test questionnaire was similar to the ones used in the previous studies however, the structure was changed in order to collect more relevant information on the participants' game play experiences (Appendix5A). Frequency of Use (FUS) scale was also used to measure how often the participants played computer games on various platforms but the measures were altered to 'daily', 'weekly', 'monthly' and 'yearly' to help understand whether gameplay experience influenced ECA. The post-test questionnaire was similar to those used in earlier studies but with additional questions that attempted to find out whether the participants used the interaction map during interaction as well as if they experienced any issues with reaching agreement and with the controller during game play. The reason was to understand whether the interaction map proved useful in enabling collaboration. Additionally, participants were asked to rate the two versions of game on five point scale from 'very hard' to 'very easy'. This question was intended to compare the two versions of the game on the basis of how difficult or easy they were for the participants to play. The data collected through the questionnaires were entered into SPSS and analysed.

7.2.2.4 Logging of participants interactions

In order to find out how the participants interacted and collaborated during game play, each participant's key presses (left, right and fire) and the times when pairs of participants agreed or disagreed in their controller input were again logged in a text file. However, the structure of the log file differed from the one in the second pilot study (section) in that the log files contained the times a particular key was pressed and released as well as the times when pairs agreed and disagreed in their controller input as shown in Figure6-1. The log file was structured in this manner to enable a more detailed and appropriate analysis.

Date	Time	Action
2014-10-10	17:24:48.599	Player2_shootKeyPress_Start
2014-10-10	17:24:48.789	Player2_shootKeyPress_Stop
2014-10-10	17:24:50.100	Player1_shootKeyPress_Start
2014-10-10	17:24:50.288	Player1_shootKeyPress_Stop
2014-10-10	17:24:50.385	Player2_shootKeyPress_Start
2014-10-10	17:24:50.565	Player2_shootKeyPress_Stop
2014-10-10	17:24:50.626	Player1_shootKeyPress_Start
2014-10-10	17:24:50.641	Player2_shootKeyPress_Start
2014-10-10	17:24:50.775	Player2_shootKeyPress_Stop
2014-10-10	17:24:50.820	Player1_shootKeyPress_Stop
2014-10-10	17:24:50.865	Player2_shootKeyPress_Start
2014-10-10	17:24:50.992	Player2_shootKeyPress_Stop

Figure 7-1: Log file extract

The interactional states (agreement, disagreement and no interaction) were used to determine periods when pairs were in agreement or disagreement within the game play sessions. In the second pilot study, the number of times a key was pressed per the number of times agreement was reached was used as a metric to measure agreement (chapter 5, section 5.2.3.3). However, in any period of agreement there will be a short delay between the first and second player's pressing (and also releasing) the same button. In this research, this is refered to as 'latency' and defined as the time interval between one key press and agreement press i.e. how long it took a player to press a key while the other player's same key is pressed down. Latency was put into consideration when measuring agreement in this study. To illustrate, Figure6-2 shows the key states of pairs of two participants (P1 and P2) interacting with an ECA game for a period T. The pairs were in agreement within the period t_1 and t_2 but not all the time P2's key was pressed down within the shaded areas. Hence, to get a good measure of agreement the percentage of agreement (i.e. ratio of time a key was held down and pairs were in agreement compared to the entire time a key was pressed down multiplied by 100) was used and calculated as follows:

$$\frac{t_1 + t_2 + \dots t_n}{P_1(t_1 + t_2 + \cdots t_n) + P_2(t_1 + t_2 + \cdots t_n)} \times 100$$

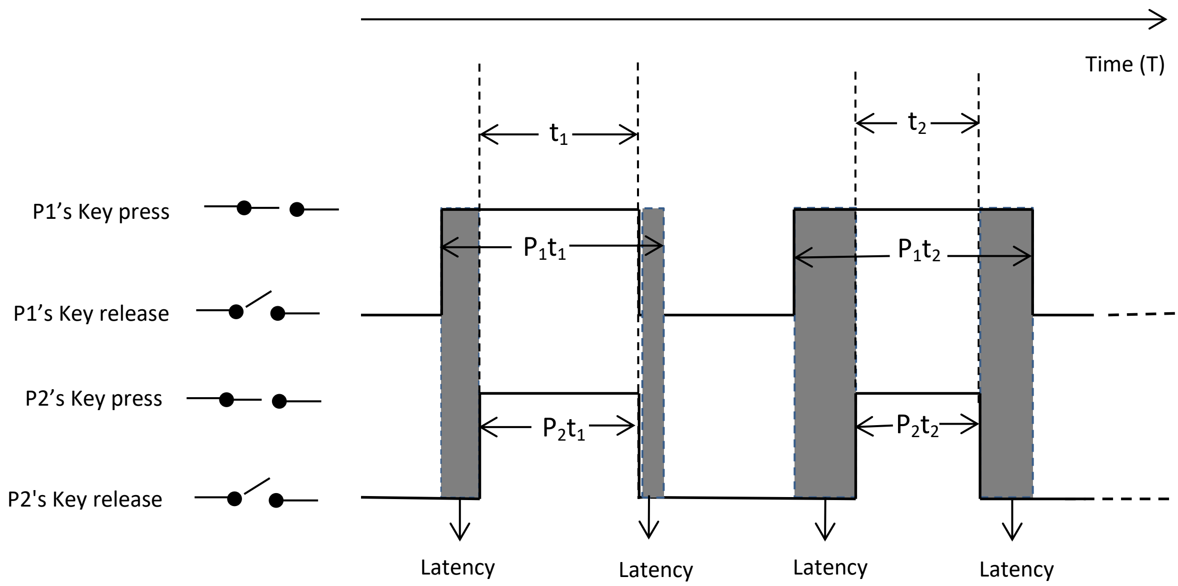

Figure 7-2: Explanation of how agreement is reached

Disagreement occurs when two different keys are pressed down at the same time (for example when player one presses right button and player 2 presses left button on their controllers at the same time) or when only one player is interacting with the game (e.g. either pressing right, left or fire). Thus, percentage disagreement is calculated by obtaining the ratio of time a key was held down and pairs were in disagreement state compared to the entire time a key was pressed down multiplied by 100

The log file data was converted to a .csv file in Excel and exported to MySQL, then a stored procedure (Appendix 5B) was used to change the time in hh:mm:ss.sss format to milliseconds. An analysis code written in Java using NetBeans IDE with JDBC and MySQL (Appendix5C) was then used to obtain the percentage of agreement. To investigate if performance increased over time, the total time each pair was in the three interactional states (agreement, disagreement and no interaction) for every 10seconds window was obtained using the Analysis code in Appendix5C. Then the moving average times for each state was obtained in excel and represented graphically using GNUPlot.

7.2.2.5 Unstructured Interview

Unstructured interview was also adopted in this study to understand what influenced the participants' interactions during game play. The graphs of the participants' key presses against time were plotted using the log files generated from their interactions and used during the interview sessions as prompts to show the participants their performance and see if it will help them discuss as a group what went on during the process and to provide more thoughtful and detailed explanations to what influenced their interactions. An example of the graph used during the interview sessions is shown in Figure6-3. The graphs were plotted using GNUPlot and presented in this way to give a clear picture of how each group interacted during game play.

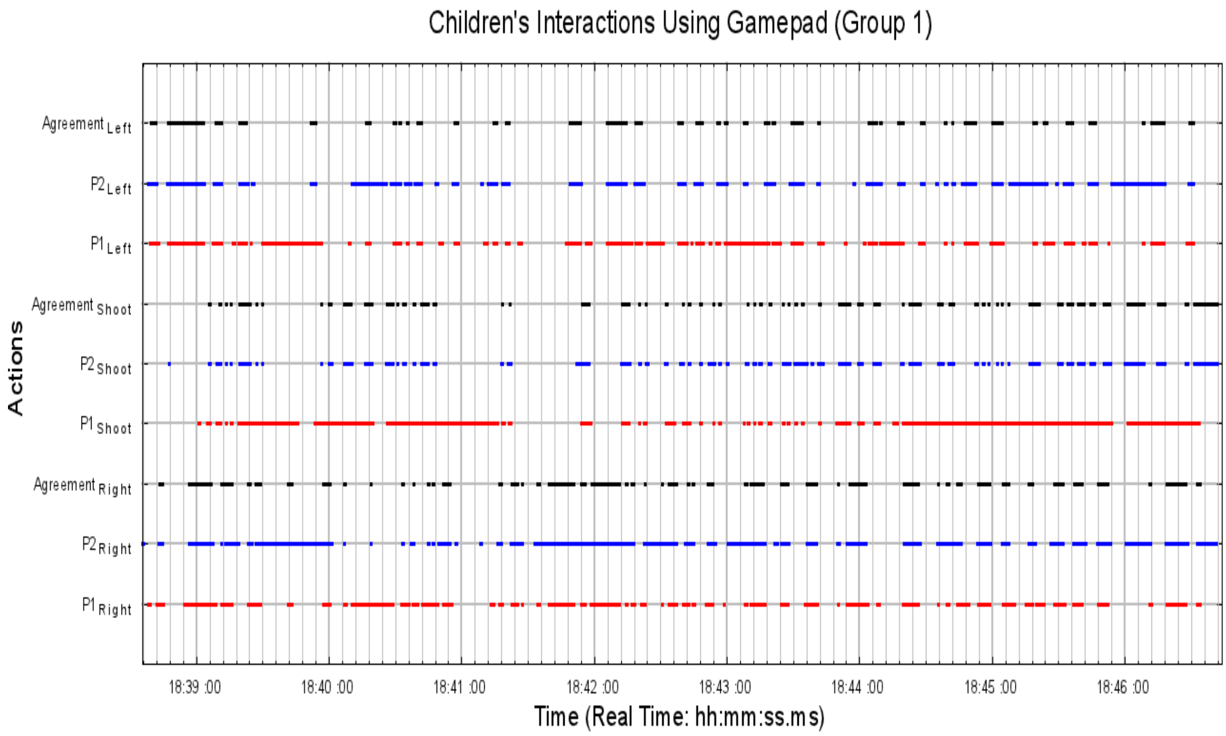

Figure 7-3: Example of graph used during interview sessions with the participants

7.2.3 Procedure

The study began with each pair completing a background questionnaire on their experience in technologies and gaming. The participants were then asked to stand in a marked area two meters away from where the computer screen was placed. This ensured that the participants' positions from the screen remained the same across groups. Two set-ups were arranged side by side which allowed two pairs of participants to play the game standing side by side during study sessions as seen in Figure. The researcher then explained the rules of the game and that the game would be played using the game pad. For training purposes, each child in a pair played the single player version individually for one minute before playing the collaborative version of the game. It was believed that providing the participants with a longer game play duration would allow the researcher a longer study period to observe the participants and to see if collaborative behaviours changed with longer periods of play and over time. Hence, the collaborative version of the game was increased to ten minutes (some participants however, did not play the collaborative version of the game for 10mins). A delay of 5seconds was provided in-between gameplays for each pair to ensure they play the game for the game duration. Each pair completed a post-test evaluation form at the end of each session. The participants were then interviewed using the graphs generated from the log file data obtained during game play as prompts. The interview sessions were audio recorded and the gameplay sessions were video recorded.

Figure 7-4: Two pairs of participants playing side-by-side during study sessions

7.3 Results

7.3.1 Participants' Profile

Table6-1 shows the group composition of the participants in the study arranged according to how they played together. As shown in the table, the participants were aged between 11-16 years old with mean age of 16.5. Also, 10 sets of two groups played together during the study sessions while the remaining 5 played on their own.

Table 7-1: Group composition of participants (x represents groups that played on their own)

First set			Second set		
Group	**Gender**	**Age**	**Group**	**Gender**	**Age**
G1	girl/girl	12/12	×	×	x
G2	boy/boy	14/15	G3	girl/girl	11/11
G4	boy/boy	15/15	G5	girl/girl	11/11
G6	boy/boy	15/15	G7	girl/girl	13/13
G8	girl/girl	16/16	G9	girl/girl	13/14
G10	girl/girl	11/12	G12	girl/girl	15/16
G11	girl/girl	13/13	×	×	x
G13	boy/boy	15/15	G14	boy/boy	16/16
G15	boy/boy	16/16	×	×	x
G16	boy/boy	14/14	×	×	x
G17	girl/girl	15/15	×	×	x
G18	boy/boy	13/13	G19	boy/boy	11/11
G20	boy/boy	12/12	G21	boy/boy	11/11
G22	girl/girl	12/12	G23	girl/girl	12/12
G24	boy/girl	13/12	G25	boy/boy	12/13

The table in Appendix5D shows the responses of the participants on how often they play games using various interaction methods. A large number of indicated they play games on tablets, iPads, iPhones and androids everyday by touching the screen (26 (54.2%)) and tilting the device (23 (46%)). 33 (70.2%) of the participants indicated that they had never played games by pressing the button on the WiiU, 32 (64%) of the participants had never played games using balance boards, 31 (67.4%) of the participants had never played a game by moving the WiiU while 23 (46%) of the participants indicated that they had never a game using dance mat and by pressing the button on a PSP respectively. Only 6 (12%) and 12 (25%) of the participants indicated they had never played games by pressing buttons on a PlayStation controller and Xbox controller respectively.

The participants were asked to state which controller was their favorite and least favorite. The idea was to know which controller was liked most by the participants. As shown in Figure6-5 and Figure6-6, 25 (54.6%) of the participants indicated that PlayStation controller is their favorite controller while 15 (38.5%) of the participants indicated that the Wiimote is their least favorite controller.

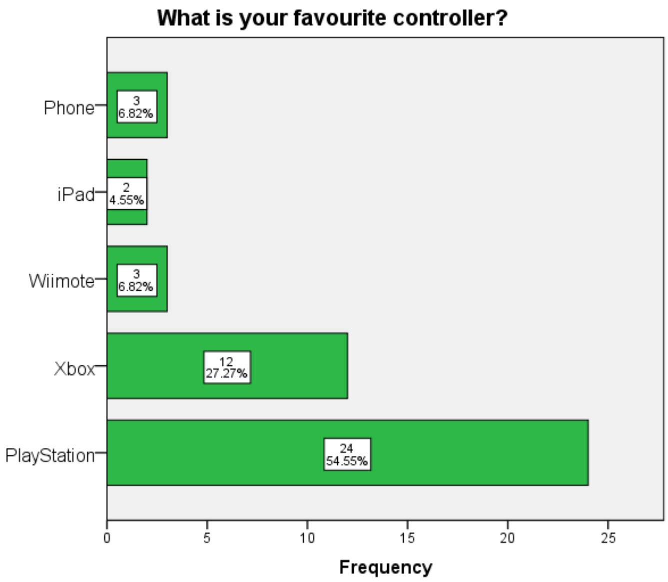

Figure 7-5: Participants' favorite controllers

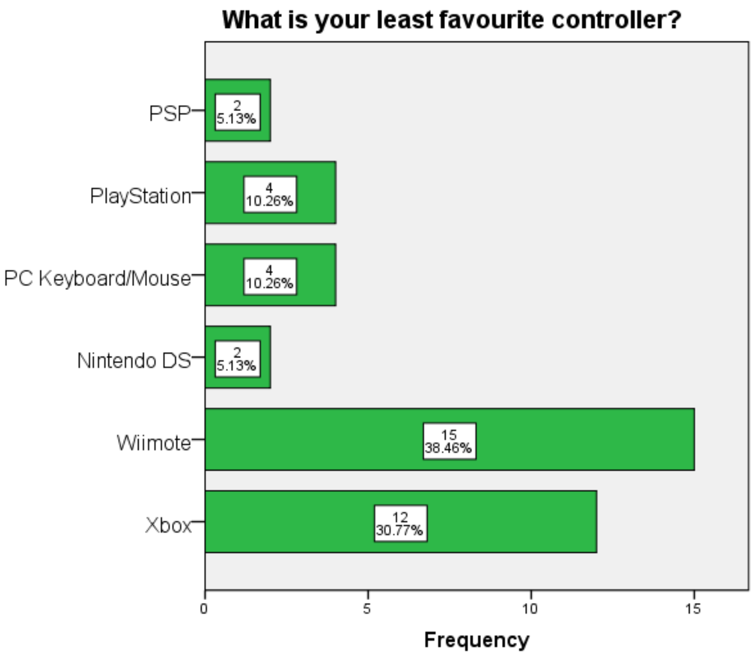

Figure 7-6: Participants' least favorite controller

Table6-2 shows how long (in years) those who participated in this study have known their partners and whether they spend time with their partners at school. It can be seen from the table that all participants have known each other for a range of years (<1-16years) albeit not especially well; 32 (64%) of the participants spend time with their partners inside school while

18 (36%) others do not. While it is possible that the participants spent time together outside school, it was not considered in the research reported in this thesis.

Table 7-2: Familiarity with partner

Group	Gender	Age	How long they have known each other (in years)	Spend time with partner at school
G1	girl/girl	12/12	1	√
G2	boy/boy	14/15	3.5	√
G3	girl/girl	11/11	11	√
G4	boy/boy	15/15	4	√
G5	girl/girl	11/11	11	√
G6	boy/boy	15/15	4	x
G7	girl/girl	13/13	2	√
G8	girl/girl	16/16	5	√
G9	girl/girl	13/14	2.5	x
G10	girl/girl	11/12	11.5	√
G11	girl/girl	13/13	2	√
G12	girl/girl	15/16	4.5	√
G13	boy/boy	15/15	15	x
G14	boy/boy	16/16	5	x
G15	boy/boy	16/16	16	x
G16	boy/boy	14/14	3	x
G17	girl/girl	15/15	15	√
G18	boy/boy	13/13	2	√
G19	boy/boy	11/11	11	x
G20	boy/boy	12/12	1	√
G21	boy/boy	11/11	<1	√
G22	girl/girl	12/12	1	x
G23	girl/girl	12/12	1	√
G24	boy/girl	13/12	1.5	x
G25	boy/boy	12/13	1.5	√

7.3.2 Understanding Collaborative Behaviours

As previously stated (section 6.2.2.1), the video data was examined by the researcher to identify the strategies the participants adopted to reach decision and control. Out of the 25 groups that played the collaborative version of the game for 10minutes, 8 groups spoke mostly in Czech/Slovakia with few occurrences of communication in English. However, the researcher observed that the pairs in the group that communicated mostly in Czech/Slovakia did not behave radically different from the other groups; similar behaviours were observed.

Consequently, their speech was not translated and analysed (but their body language and facial expression were analysed). In this section we present the behaviours (segments of collaborative networks represented in tables) which reinforce those previously identified in the second pilot study reported in chapter 5 of this thesis as well as new behaviours which emerged in the current study. The talks and actions of pairs of participants alongside their accompanying codes (as shown in Table6-1 in chapter 6 section6.2.3.2) were represented within the collaborative networks to give a clear picture of the behaviours the participants exhibited during interaction with the game. Group codes G_i were $_i$ ranges from 1 to 25 were used to represent each group while participant codes P_i where $_i$ ranges from 1 -50 were used to represent each participating child in this study. Also for data protection, all instances where people's names were mentioned were replaced with X.

Prior to start of initial game play, it was observed that six groups (G2, G4, G16, G18, G21, and G25) attempted to negotiate strategies for game play. For example, in G25's transcription shown in Table6-3, P50 suggested to P49 how they should play and P49 accepted the suggestion.

Table 7-3: G25 (boy (12) - boy (13)) - Strategized before game play

P49_Time	P49_Transcript	P49_Code	P50_Code	P50_Transcript	P50_Time
			↙ Su	Alright, we just say, say fire if you want to fire. Say left if you want to go left and say right if you want to go right.	00:01.890
08:26.098	OK	Ag ↘			

During gameplay, several occasions of conflicts (disagreement) were observed in all groups apart from G1 and G24. Some of the conflicts were resolved quickly while some took longer to resolve for example, it took pairs in G16 2 seconds to resolve the conflict as seen in Table6-4 while it took pairs in G6 10 seconds as seen in Table6-6. In some cases, conflicts were resolved with explanation as seen in G6's excerpt in Table6-5. There were also cases where the conflicts were not resolved because the game ended as seen in G19's excerpt in Table6-6.

Table 7-4: G16 (boy (140 – boy (14)) - Conflict Resolved quickly

P40_Time	P40_Transcript	P40_Code	P39_Code	P39_Transcript	P39_Time
			↙ Gi	Alright, stay there. I will sort of go right...	07:39.000
07:40.524	Go left, go left	D ↘			
			↙ E	What are you doing?	07:41.490
07:42.100	We need to kill that one!	Res ↘			
			↓ Ag	Yeah	07:43.023

Table 7-5: G6 (boy (15) – boy (15)) - Conflict resolved with explanation

P11_Time	P11_Transcript	P11_Code	P12_Code	P12_Transcript	P12_Time
			↙ Gi	Move, move, move!	02:20.945
02:22.461	Yeah, I was moving, I was moving	Ag ↘			
			↙ Ex	*[shows partner controller]* You were moving that way. You were supposed to move that way	02:23.686
02:25.855	Alright	Ag ↘			

Table 7-6: G6 (boy (15) – boy (15)) - Conflict taking longer to resolve

P11_Time	P11_Transcript	P11_Code	P12_Code	P12_Transcript	P12_Time
			↙ Gi	Right, right, right, right	01:03.540
01:05.846	Stay here and shoot	D↓			
01:09.739	Move before you shoot	Gi ↘			
			↙ Gi	Go left, go left?	01:12.899
01:14.031	I'm pressing it	Ag ↘			

Table 7-7: G19 (boy (11) – boy (11)) - Conflict not resolved due to end of game

P37_Time	P37_Transcript	P37_Code	P38_Code	P38_Transcript	P38_Time
			↙ Gi	Move	01:32.520
01:03.563	Shoot, shoot, shoot, shoot	D ↘			
			↙ Gi	This way [show controller to P51]	01:34.263
01:35.155	[Sighs] We died	Pe ↘			

There were also several non-conflict situations which occurred in all groups apart from G1 and G7 where a child affirmed to partner's instructions without further explanations as seen in G3's excerpt in Table6-8. There were indications of dominating behaviours in all groups where one of the pairs controlled the interaction through verbal instructions while the other passively carried out the instructions. Again, this did not continue throughout the rest of the game play session. On many occasions, participants gave verbal instructions and pointing instructions (deictic gestures) to their partners during game play. This occurred in all groups apart from G1. Also, some groups pointed at the screen to express their frustration, draw their partner's attention to the interaction map, while making enquiry or buttress a point (e.g. G25 (49): "*There was a star there*"

Table 7-8: G3 (girl (11) – girl (11)) - Non-conflict situation

P9_Time	P9_Transcript	P9_Code	P10_Code	P10_Transcript	P10_Time
			↙ Gi	Press fire!	11:58.058
11:59.274	I am	Ag↓			

Suggestions were made on several occasions by a child to the partner during game play in all the groups apart from G1, G4, G7, G18, G19 and G24. Only on three occasions were these suggestions not accepted. Furthermore, it was observed that participants in all groups apart from G5 and G24 made enquiries from their partners. Some groups made enquiries regarding gameplay and in some cases received responses from their partners as shown in G19's transcript in Table6-9. Only participants in G1, G3, G4, G6 and G7 made enquiry from their partners regarding game duration.

Table 7-9: G19 (boy (11) – boy (11)) - Enquiry and response to enquiry

P37_Time	P37_Transcript	P37_Code	P38_Code	P38_Transcript	P38_Time
			↙ E	How did we die?	04:12.919
04:13.864	Cos we were probably killed by the birds	Res↘			

All participants made enquiry from the researcher apart from G3, G5, G6, G18 and G24 made enquiries from the researcher during gameplay. Some participants asked the researcher questions regarding game duration (e.g. P13 (G7): *"Miss how long do we have to play this for?"*), game play (e.g. P37 (G19): *"Are we gonna move at the same time?"*), quitting game (e.g.

P8 (G4): *"Can I quit?"*) and about the research (P42 (G21) "*What do you do research for?*"). It was observed that one of the pairs in G1, G3, G5 and G17 touched the partner's controller to make the partner press the same key. This behaviour occurred five times in G5, three times in G17 and once in both G1 and G3. Only the participants in G1, G3 and G17 responded in a way that did not allow the partner to dominate as seen in G3's excerpt in Table6-10. The child in G5 did not attempt to stop the partner from touching her controller in all the five occasions the behaviour was observed.

Table 7-10: G3 (girl (11) – girl (11)) - Not allowing partner dominate

P5_Time	P5_Transcript	P5_Code	P6_Code	P6_Transcript	P6_Time
15:35.699	Fire! [Glanced at P10's gamepad and touched P10's gamepad]	Gi ↓ PAT3 ↘			
			↓ Pe	I can hit it! *[moves controller away from P9 and laughs]*	15:37.063

Generally, all the groups communicated (by talking) severally at different points during game play however some groups communicated for longer periods compared to other groups. Participants in G1 played silently for 55seconds at the beginning of game play before engaging in a brief conversation with each other. In total, they had a talk time of 37seconds making them the least communicative group followed by those in G24 with a talk time of 75seconds. G24 was a boy/girl group while G1 was a girl/girl group and a brief chat with the girls at the end of game play revealed that one of the girls was shy.

The participants were asked (using a post-gameplay questionnaire) if they noticed the map on the screen and whether they knew the aim of the map. The majority of the participants (44 (88%)) indicated that they noticed the interaction map on the screen while the remaining 6 (12%) did not. This was reinforced by participants in G4, G5 and G17 and illustrated in the transcript of the participants in G4 below:

P7: "*…I'm blue. Look at the top in the right circle [pointing at screen]. Did you see it?*"

P8: *[stares at the screen]*

33 (75%) of the participants that noticed the interaction map claimed to know the purpose of the map and also used it to interact while the remaining 17 (25%) did not. 15 (45%) of the participants who noticed the map thought the purpose of the map was to create awareness of each other's interactions with the game, 7 (21%) thought the aim of the map was to assist them during collaboration while the remaining 11 (34%) thought it was to show direction.

7.3.2.1 New Behaviours observed

The preceding section (section 6.3.2.1) presented behaviours which correspond to those obtained in the previous studies conducted in chapter 4 and chapter 5 of this thesis. However, examination of the video recordings of participants during game play in the study reported in this chapter revealed new behaviours which did not manifest in previous video analysis (chapter 4 and chapter 5). The researcher re-examined the entire video data collected for each group in the entire studies (apart from the first pilot study because researcher observation method was used and only notes taken during analysis were available) to ensure that the newly observed behaviours were not omitted in some groups which had already been analysed prior to when the behaviours was observed. Reported in this section are the new behaviours which emerged in the current study.

7.3.2.1.1 Giving Encouragement

It was observed that participants in G3, G4, G5 and G7 encouraged or motivated their partners during game play as illustrated in G5's excerpt in Table6-11. While the participants were told they could stop playing at any point they wished, P9 encouraged P10 to carry on playing even though P10's finger hurts.

Table 7-11: G5 (girl (11) – girl (11)) - Giving Encouragement

P9_Time	P9_Transcript	P9_Code	P10_Code	P10_Transcript	P10_Time
13:23.791	This way, this way *[shows P14 her controller]*	Gi ↘			
			↙ Pe	My finger is aching *[shakes arm]*	13:25.342
13:27.508	But we just have to carry on shooting!	Pe ↘			

7.3.2.1.2 Mixed gender domination

Mixed gender domination was observed in only G24. G24 was a mixed group with the boy being more dominating, giving instructions severally to the partner during game play (the girl instructed the partner only twice).

7.3.2.1.3 Aggressive behaviour

There were cases where the game ended and participants exhibited behaviours which can be described as 'aggressive behaviours'. In this thesis, aggressive behaviours can be defined as situations where a participant behaves in an angry way towards a partner and these include shouting at partner, hitting or pretending to hit partner and blaming partner. In this study, these were observed twice in G2 and four times in G4 and these were all boy-boy groups. For illustration purpose, Table6-12 shows excerpt from G4's transcription. As shown in that table, just before the game ended P8 had previously instructed P7 to go right. He then got upset when the game ended and screamed at P7 and also hit P7 on his head. P7 responded by instructing P8 to stop hitting him and also hit P8 back on the head. The researcher did not intervene as there were no concerns the participants will come to harm; the participants were play fighting and not physically hurting each other.

Table 7-12: G4 (boy (15) – boy (15)) - Aggressive Behaviours

P8_Time	P8_Transcript	P8_Code	P7_Code	P7_Transcript	P7_Time
04:49.692	Right, right, right *[Game ends]*	Gi ↓			
04:51.270	*[shouts]* Right!	Gi ↓			
04:52.473	*[glanced at P11 and hits P11's head]* Right! *[shouts]*	PAT4↓ Gi ↘			
			↓ PAT4 ↙ Pe	*[glanced at P12]* Stop hitting me! *[hits P12 on the head]*	04:53.184
04:53.684	Right *[shouts]*	Gi ↓			
04:56.657	*[points at screen and stares at P11]* You are crap at this game man!	PAT4 ↓ Pe ↘			
			↓ Pe	The game is crap!	04:59.601

7.3.2.1.4 Tutoring behaviour

Participants in G3, G5, G18 and G19 displayed 'tutoring behaviour' were one child in a pair did not correctly press a key and the other child intervenes and corrects the partner. In one case, a child in G18 was observed tutoring the partner even before game play as shown in Table6-13.

Table 7-13: G18 (boy (13) – boy (13)) - Tutoring behavior

P35_Time	P35_Transcript	P35_Code	P36_Code	P36_Transcript	P36_Time
00:07.641	*[shows P50 his controller]* … By the way, that's left *[presses left button],* that's right *[presses right button]* and that's shoot*[presses shoot button]*	Ex ↘		*[stares at P49's controller]*	
			↙ Pe	*[laughs]* but I've just played it	00:11.873
00:12.698	Yeah, I know. Just forgot! *[laughs]*	Pe ↓			

7.3.2.1.5 Inter group interactions

Table6-14 shows the groups that played together and those that interacted between themselves. As shown in the table, there were several occurrences of inter group interactions observed between some groups where participants in one group enquired from the members of the group about their scores (for example G5 (P9): *"What's your highest? We can beat it!"*), game play as seen in Table6-16 or simply talked to the other group about how they played (for example G5 (P9): *"Wow, here is the point. She is been doing it more!"*). These inter group interactions in some instances went beyond enquiries and involved one participant from one group tutoring another group (e.g. G17 (P33): "*Left this way [points left], right that way [points to the right]*" or use of derogatory verbalizations between G5 and G6 as seen in Table6-15. It is important to mention that G17 played side by side with a boy-boy group aged 12 years old (one of the groups who played for less than 10minutes and thus were not analysed).

Table 7-14: Between group interaction

First set			Groups that Interacted	Second set		
Group	Gender	Age		Group	Gender	Age
G1	girl/girl	12/12	×	×	×	x
G2	boy/boy	14/15	√	G3	girl/girl	11/11
G4	boy/boy	15/15	√	G5	girl/girl	11/11
G6	boy/boy	15/15	×	G7	girl/girl	13/13
G8	girl/girl	16/16	v	G9	girl/girl	13/14
G10	girl/girl	11/12	√	G12	girl/girl	15/16
G11	girl/girl	13/13	×	×	×	x
G13	boy/boy	15/15	√	G14	boy/boy	16/16
G15	boy/boy	16/16	×	×	×	x
G16	boy/boy	14/14	×	×	×	x
G17	girl/girl	15/15	√	x	×	x
G18	boy/boy	13/13	√	G19	boy/boy	11/11
G20	boy/boy	12/12	√	G21	boy/boy	11/11
G22	girl/girl	12/12	√	G23	girl/girl	12/12
G24	boy/girl	13/12	×	G25	boy/boy	12/13

Table 7-15: G5 (girl (11) – girl (11)) and G4 (boy (15) – boy (15)) – Inter group interaction involving use of derogatory verbalization

G4_Time	G5_Transcript	G5_Code	G4_Code	G4_Transcript	G4_Time
08:53.078	**P10:** Can we go now? *[looks at researcher]*	E ↘			
			↙ Pe	**P7:** No, stop being such a downing!	08:54.545
08:57.579	**P9:** Shut up! This game is crap *[glanced at P7]*	Pe ↘			
			↙ Ex	**P7:** Just cos I enjoy it!	09:00.330
09:01.949	**P10:** What, what's in your brain? *[laughs]*	E↓			
09:05.950	**P10:** *This is crap!*	Pe↘			
			↙ E	**P7:** This is good, how can you hate this? *[jumps]*	09:09.503
09:15.144	**P9:** *[points at P7]* What's wrong with you?	E			

Table 7-16: G18 (boy (13) – boy (13)) and G19 (boy (11) – boy (11)) - Inter group interactions (enquiry regarding game play)

G18_Time	G18_Transcript	G18_Code	G19_Code	G19_Transcript	G19_Time
03:23.975	**P35:** Have you completed it yet?	E ↘			
			↙ Res	**P38:** No	03:26.239
03:27.028	**P35:** We had two more left	Pe ↘			
			Res	**P38:** We have been guessing doing it loads!	03:29.431

The summary of all the behaviours reported in this section (section6.3.2) and how many times each of the behaviours were observed in each group are shown in Appendix5E

7.3.3 Events occurring within gameplay

The collaborative network approach was valuable in identifying the strategies participants adopted during game play. The video gave qualitative insights into the strategies but a quantative approach was also used to gain deeper insights into the interactions and associated performance. This approach was believed to give more information on the strategies the participants adopted during interaction.

7.3.3.1 Performance

The log files helped to understand the events that happened during gameplay and provided useful data to measure performance of the groups. Different metrics were used to measure performance and these include:

- Scores
- Death moment (number of deaths)
- Level of agreement
- Level of disagreement

7.3.3.1.1 Scores

While score is a very coarse metric, it gave some insight into the performance of the groups. During gameplay, points are generated when players successfully shoot an alien and high score infers that the two players were successfully playing the game i.e. collaborating to move and fire at the same time. Also, low score infers that the two players were not successfully plying the game. Figure 6-7 shows the scores of each group; G1 had the highest score with 2890 points, G24 had the lowest score with 1510 points and G4 had the middle score with 2355 points.

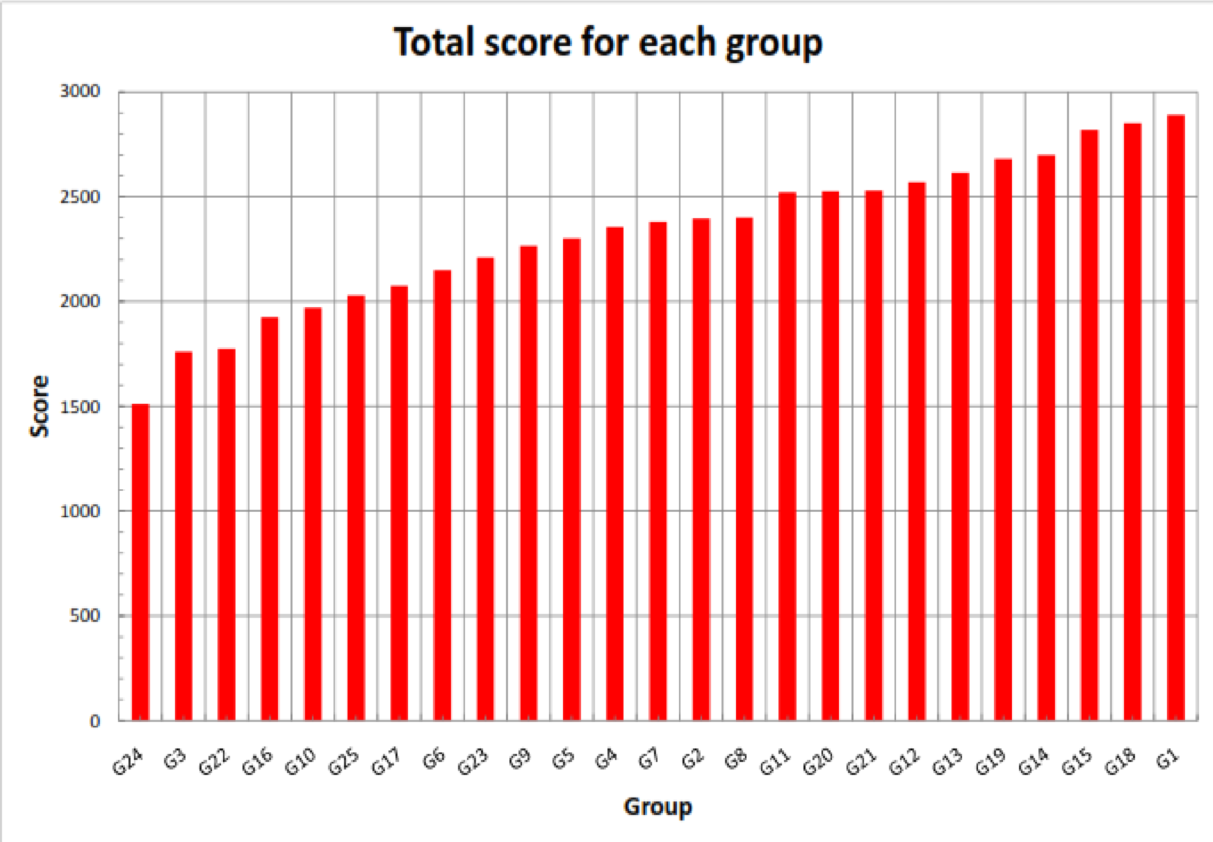

Figure 7-7: Group Scores

7.3.3.1.2 Number of Deaths

This is the number of times within game play when the player is hit by a bomb dropped by the aliens or when the aliens hit the shields and the game ends. High number of deaths during gameplay would indicate that players were not successfully playing the game i.e. not agreeing in their controller input to move and fire at the same time or had poor in-gameplay strategies. Conversely, low number of deaths means that players were successfully playing the game and had good in-gameplay strategies. As shown in Figure, G14 died the least with 10 deaths, G24 died the most with 21 deaths and G25 had the medium number of deaths with 16 deaths.

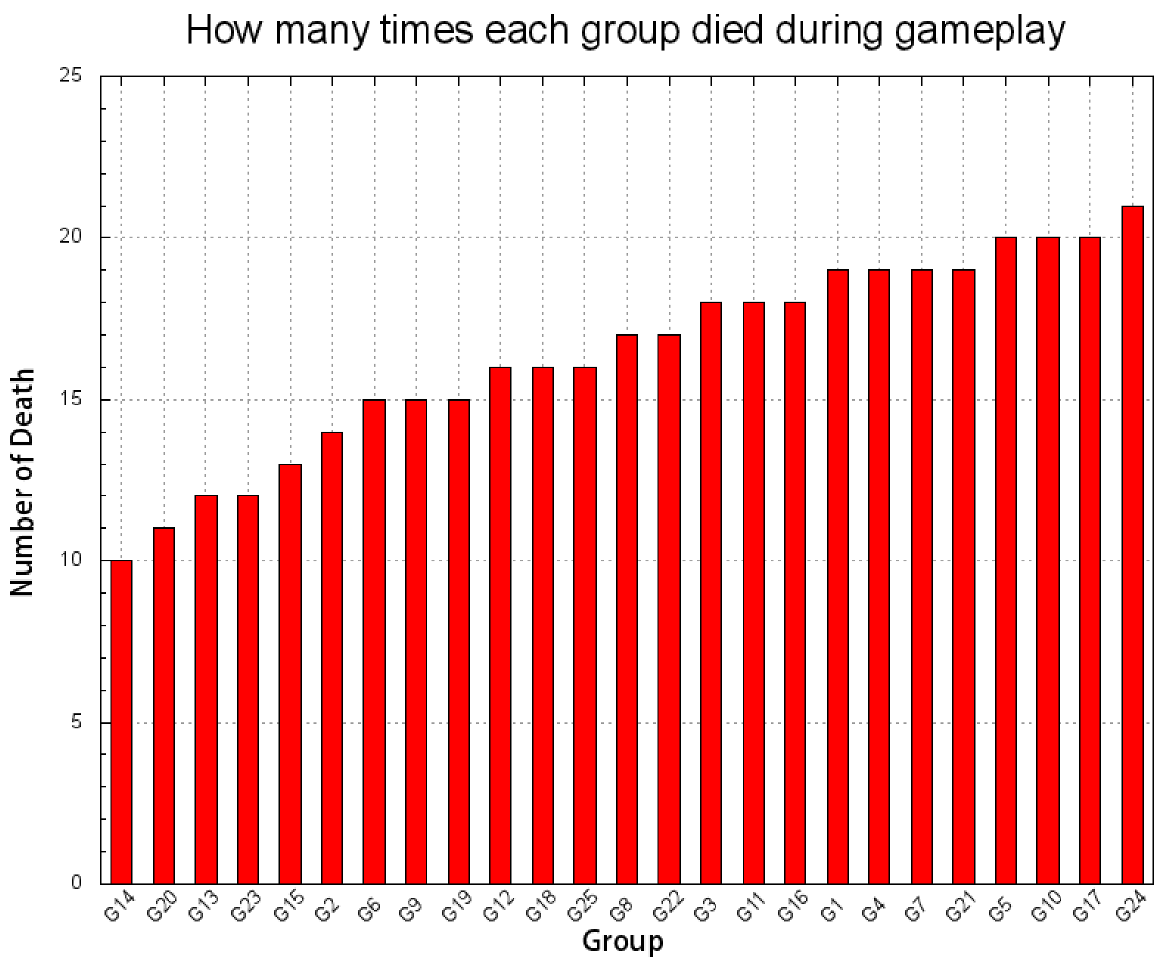

Figure 7-8: Chart showing number of deaths

7.3.3.1.3 Percentage of Agreement

The log files provided data which were useful in understanding what the participants were doing (in terms of key presses) during interaction with the game. The table in Appendix5F shows how long in seconds it took each group to reach agreement the first time. While it took 12 groups to reach agreement the first time in less than one millisecond, the other groups took longer (between 1 and 5 seconds). However, the average time it took the participants to reach agreement for the first time was 2 seconds. In order to measure how often each pair agreed in their controller input, the percentage of agreement as described in section was calculated and the values obtained for each group (Appendix 5G) were represented graphically (Figure6-9). As shown in the figure, there is a variation in the percentage agreement level of the groups of between 9.97% and 25.08% with G13 and G10 having the highest and lowest agreement levels respectively.

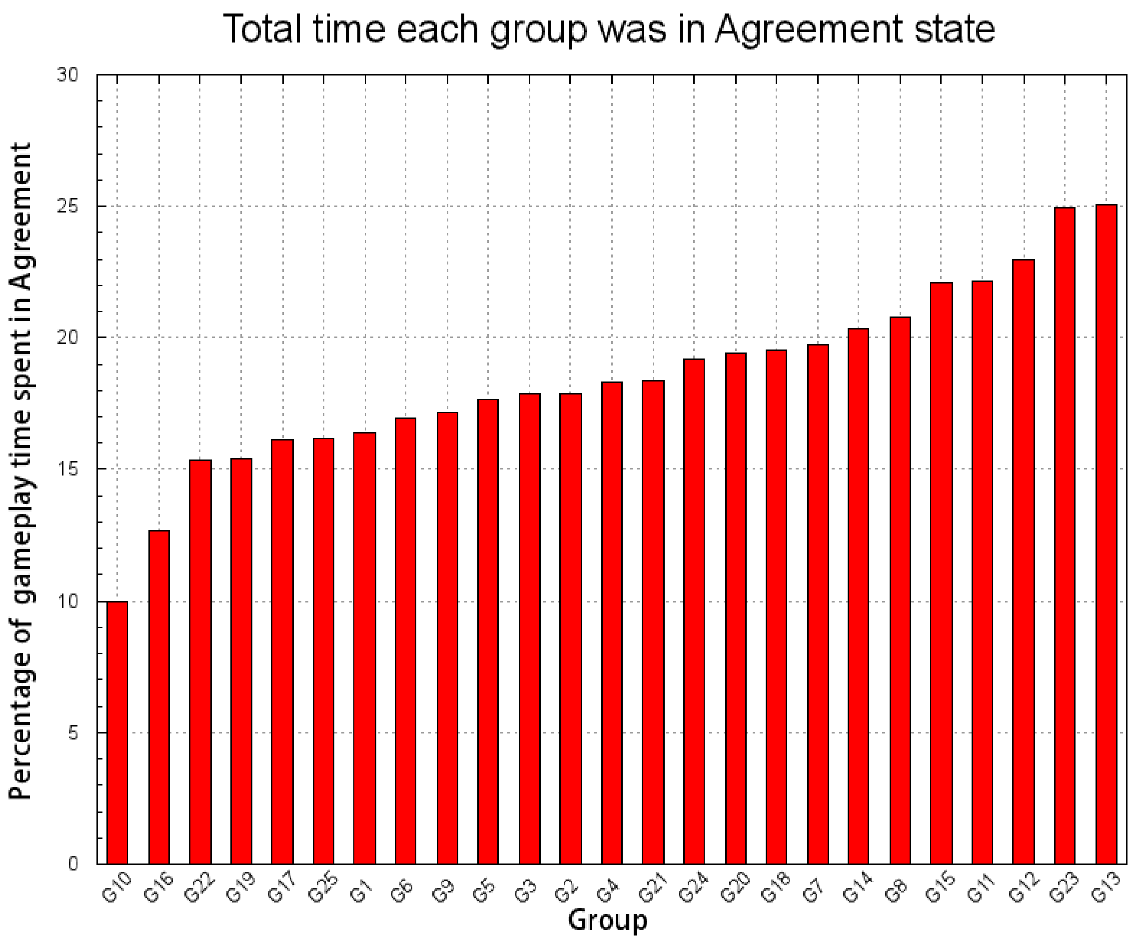

Figure 7-9: Measure of Agreement graph

7.3.3.1.4 Percentage of Disagreement

To measure how often each pair disagreed in their controller input, the percentage of agreement as described in section was calculated and the values obtained for each group (Appendix 5H) were represented graphically (Figure). As shown in the figure, there is a variation in the percentage disagreement level of the groups of between 26.83% and 59.92% with G24 and G5 having the lowest and highest disagreement levels.

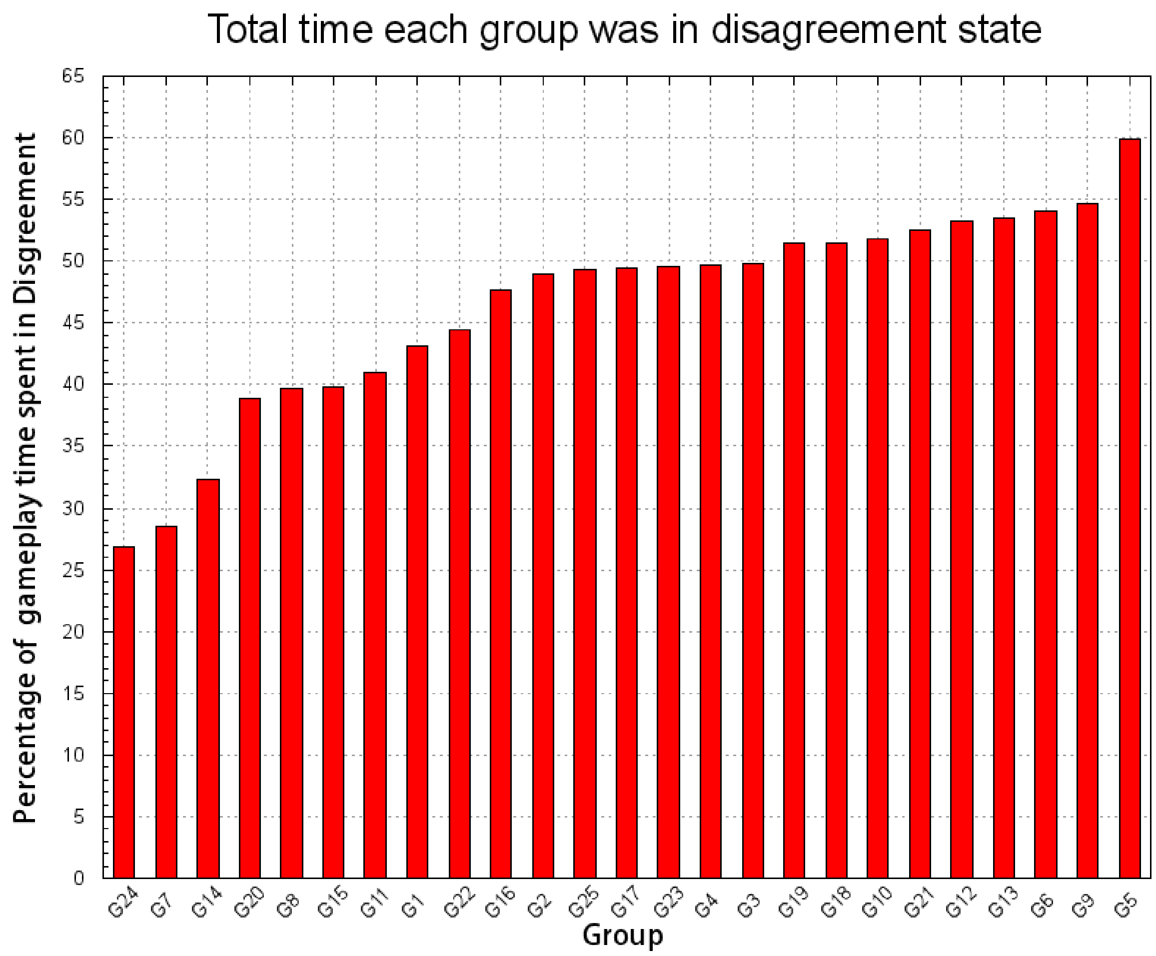

Figure 7-10: Measure of Disagreement graph

Within the context of ECA, a high performing group is expected to have the following

- highest number of scores
- least number of deaths
- highest percentage agreement
- lowest percentage disagreement

Also, a low performing group is expected to have the following

- lowest number of scores
- highest number of deaths
- Lowest percentage agreement
- Highest percentage disagreement

A medium performing group will be in between low and high performing groups with average agreement levels, score, disagreement levels and number of deaths.

To determine if the predictions are correct, a multiple regression analysis using the enter method (where all the variables were included in the regression equation) was performed on the groups performance data using the four performance metrics (i.e. score, number of deaths, agreement and disagreement levels) as summarized in Table6-17.

Table 7-17: Performance metrics

Groups	Number of deaths	Scores	Level of Agreement	Level of Disagreement
G1	19	2510	16.38	43.09
G2	14	2395	17.9	48.98
G3	18	1950	17.88	49.81
G4	19	2355	18.3	49.63
G5	20	2300	17.67	59.92
G6	15	2150	16.95	54.04
G7	19	2380	19.75	28.52
G8	17	2400	20.8	39.74
G9	15	2265	17.16	54.62
G10	20	1970	9.97	51.82
G11	18	2520	22.18	40.96
G12	16	2570	22.96	53.18
G13	12	2615	25.08	53.45
G14	10	2700	20.34	32.37
G15	13	2820	22.09	39.84
G16	18	1925	12.67	47.61
G17	20	2075	16.11	49.43
G18	16	2850	19.53	51.48
G19	15	2680	15.4	51.41
G20	11	2525	19.41	38.91
G21	19	2530	18.35	52.49
G22	17	1775	15.34	44.41
G23	12	2210	24.93	49.54
G24	21	1510	19.19	26.83
G25	16	2030	16.18	49.27

'Number of deaths' was chosen to be the dependent (or criterion) variable as it is influenced by how successful (agreeing in controller input to move or fire at the same time – level of agreement) or unsuccessful (not agreeing in controller input to move or fire at the same time – level of disagreement) groups were collaborating during gameplay. Furthermore, it was predicted that scores are influenced by the length of each gameplay session within the 10mins of game play as determined by the death moment (i.e. a time within gameplay when the player hit by the bomb dropped by the aliens or when the aliens hit the shield and the game ends). Therefore, the lower the number of deaths, the longer each gameplay session lasted for and the higher the scores. It can be seen in Appendix5L that the independent variables (level of agreement, level of disagreement and scores) together account for 33.1% of the variance in the 'number of deaths' ($F(3, 21) = 3.464$ $p<0.05$ $R^2 = 0.331$ $R^2_{adjusted} =0.235$). The coefficient table (Appendix 5L), shows which variables are individually significant predictors of the dependent variable (number of deaths). The result shows that none of the independent variables are significant predictors as their p values are greater than 0.05. (i.e. scores ($p = 0.104$; $p>0.05$), level of agreement ($p = 0.145$; $p>0.05$) and level of disagreement ($p= 0.993$; $P>0.05$). This result indicates that none of the groups satisfied the criteria for high, low or medium performance. For example while G24 had the highest number of deaths and lowest score; they had the least disagreement levels and a medium agreement level.

So, it was decided to study performance through a different lens i.e. to look at the total time (in seconds) each pair was in the three interactional states (agreement, disagreement and no interaction) for intervals of 10seconds over the 10 minute period of gameplay to gain insights into the group's performance over time. This was represented in charts for all the groups. An example of the chart is shown in Figure7-11 (the charts for the groups can be seen in Appendix5I).

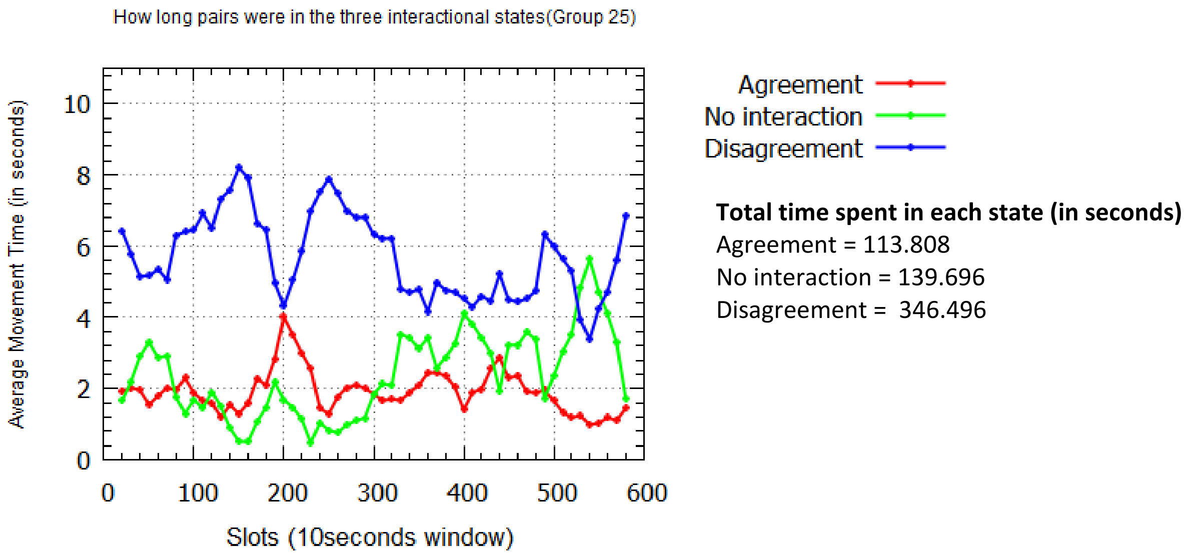

Figure 7-11: The amount of time spent in the three interaction states for every 10seonds interval (Group 25)

Comparing the performance of the groups in terms of how much they agreed on their controller input, there were periods of downward and upward trends in all groups but some groups performed generally well whereas others did not. Hence, it was decided to categorize the groups into high, medium and low performance.

The groups that fall under the high category (G24, G14, G23, G11 and G7) performed very well and had generally high levels of agreement i.e. high peak levels of agreement; G24, a mixed gender group started off with a low agreement (2 seconds) but progressively increased until between 220seconds and 400seconds where they experienced a massive peak in agreement, G14, a boy-boy group started off with a relatively low agreement (3 seconds) and peaked up until about 200seconds into gameplay where they had a downward trend until end of game. While G23 (girl-girl group) had the lowest agreement level at the beginning (0.60seconds), they progressively improved and remained consistent until towards the end of game play. G11 (girl-girl group) started with a relatively low agreement level (2 seconds) but consistently improve with their highest peaks occurring between 160seconds and 260seconds as well as between 450seconds and 520seconds of gameplay. G7 seemed to be the group with the highest initial agreement level with about 4 seconds and remained relatively high throughout gameplay though they trended quite low periodically.

The groups that were classified as low (G2, G3, G4, G5, G6, G9, G10, G12, G16, G17, G18, G19, G21, G22 and G25) appeared to perform generally poorly with consistently low agreement levels with little or no massive peaks in some groups for example G4 peaked a little bit between 320seconds and 380seconds, G6 between 300seconds and 360seconds, G9 between 60seconds and 120 seconds, G17 between 200seconds and 250 seconds and G21 between 100seconds and 160 second and 500seconds to 600 seconds. G12 started off very poorly and remained consistently low for about 500seconds before trending upward.

The groups that fall under medium category (G1, G8, G13, G15 and G20) performed moderately (neither very well nor poorly) with several medium agreement peaks i.e. they tend to have neither consistently low nor high peaks.

Summarily, at a micro level (individual level), the graphs of groups that performed very well (i.e. high category) indicate that while unfortunately they were in disagreement for most of the time, they seemed to interact quite a lot during game play and were more in agreement compared to the groups that performed poorly (this is also the case for groups in the medium category). For example, G24 spent the highest amount of time in agreement state (245 seconds) and pressed their buttons for most of the time during interaction evidenced by the small amount of time they spent in the 'no interaction' state (13 seconds). On the other hand, G10 spent the highest amount of time in the disagreement state (413 seconds), the least amount of time in the agreement state (79 seconds) and seemed to interact less often than G24 having spent more time in the 'no interaction' state (108 seconds).

It was speculated that level of agreement would start off low while the level of disagreement starts off high as participants are learning how to collaborate and creating and refining strategies to succeed in the game. However, as time progresses and the participants build a system that works for them it is expected that their performance would increase and therefore the amount of time spent in the agreement state increases while the time spent in disagreement state decreases and potentially the time spent in the no interaction state increases because the participants only interact when they need to (e.g. when they are about to be hit by a bomb, when they get to the edge of the screen and may need to move right or left, or fire an alien) and agree often when they interact. To test the hypothesis, a correlation between each interaction state (i.e. agreement, disagreement and no interaction) with time was performed and the correlation coefficients (with their accompanying p values) are shown in Appendix 5O. It could be seen that the results did not follow the hypothesized pattern within the gameplay duration (Appendix 5O). Several reasons could have been responsible for the result for example, participants individual attributes and experience with games, the study environment and the gameplay duration may not have been long enough for the participants to learn to collaborate. It is suggested to allocate more time in subsequent studies.

As seen in the individual graphs of the groups (Appendix 5I), there were several peaks and troughs in the agreement, disagreement and no-interaction scores of all the groups. To understand what behaviours that led to this observation, the video data of some selected groups from each category were compared. The criteria for selection of the groups for further analysis were based on the most interesting groups from each category (for example, the best performing group in the high category and the worst performing group in the low category) and ignoring videos which the researcher was not able to transcribe the participants' talks apart from G10 as they communicated in English within some time period.

7.3.3.2 LOW CATEGORY

In the following subsections, five examples of gameplay in the low category are now discussed. These extracts are summarized on page 150.

7.3.3.2.1 Example 1 - Group 10 (G10)

Examination of the video recording of the groups revealed several occurrences of behaviours which indicate that one child in G10 (girl-girl group) was unwilling (or reluctant) to keep playing after they died the first time as seen in the transcript: **P27**: "This is the last one I'm doing and that's it!" and "X, I don't wanna do this. Can someone come instead of me? *[This question was directed to the support staff]*". Several instances of lack of interest in playing the game also manifested in the video; the same child tilted her head to the left and kept pressing a particular key for a period of time with no form of communication with her partner. At the end of game play, the child made a sound of relief and was quick to drop her controller. Both participants in the group looked around a lot of times and communicated for short period of time during gameplay (4minutes 19seonds). There were both positive and negative affective behaviours such as signs of frustration, frown, smiles, laughs and sighs within the video data.

The key observations of G10 are summarized below:

- Looked around quite a lot (P19 = 53 times , P20 = 52)
- Short talk duration (4minutes 19seconds)
- Long periods of silent play
- One participant was disengaged and was unwilling to play with several comments about quitting game
- Positive and negative affects (laughs, smiles, frowns, frustration and sighs)
- Number of death = 20
- Scores = 1976

7.3.3.2.2 Example 2 - Group 16 (G16)

There were indications that pairs in G16 disagreed severally in their controller inputs because one child did not understand how to reach agreement as shown in the transcript below. This case occurred six times during gameplay and also includes a case where one participant (P31) held the partner's controller and attempted to play game alone with just his controller.

P31:"*It won't let me do it" [shows P32 his controller]*

P32: *[looks at P31's controller] "we could only do it the same time"*

Another observation was that one of the strategies pairs in the group adopted seemed to not work for them. As shown in the transcript below, P31 started to count but presses the button on his controller at the wrong timing.

P31: "3, 2, 1*" [four times]*

P32: *[looks at P31] "Why are you going on 2?" [Smiles]*

Other key observations of G16 are summarized below:

- Long talk duration (6minutes 37seconds)
- Short periods of silent play
- One participant gave more instructions than the other (P31 = 60, P32 =44)
- Several instances of 'non-conflict' situation (21) and 'conflicts resolved' (9) and few suggestions (2), enquiry from partner (1) and researcher (1).
- Several positive affects (laughs, smiles and giggles)
- Focused gaze on screen (looked around a few times P31= 15, P32 =14)
- Number of deaths = 18
- Score = 1925

7.3.3.2.3 Example 3 - Group 4 (G4)

Pairs in G4 (boy-boy group) was observed to be shouting and blaming each other as well as play fighting. They did not seem to like the game as there were several instances of 'this game is crap' verbalizations in their video data. There was evidence of disengagement (e.g. **P11:** *"Can I quit?" [while looking at the researcher]*), distractions from friends and loss of concentration as seen in the following transcription:

P12: *[staring at friends sitting by his right]*

P11: *"X, pay attention"*

P12: *"I am"*

P11: *"No, you are not!"*

P12: *"I could see you at the side of my eyes. I got ears in my eyes. I got eyes in my ears"*

The key behaviours of G4 are summarized below:

- Long talk duration (9minutes 48seconds)
- Short periods of silent play
- One participant gave more instructions than the other (P31 = 60, P32 =44)
- Several instances of 'non-conflict' situation (11) and a few 'conflicts resolved' (2), encouragement (1), enquiry from partner (4) and researcher (4) and aggressive behaviours (4) and inter-group interactions (8).
- Several affective behaviours (laughs, smiles, frowns, signs of frustration, shouting)
- Looked around a lot
- Number of deaths = 19
- Score = 2355

7.3.3.2.4 Example 4 - Group 5 (G5)

Pairs in G5 interacted severally with the other pairs in the group (G6) they played alongside with asking questions regarding gameplay and using derogatory verbalizations as earlier stated in **section6.3.2.** One of the pairs on severally occasions stopped interacting with the game (and complained to her partner that her finger was hurting (and shook her arm). In all the cases this behaviour was observed, the partner encouraged her to carry on playing. They were also observed to drop their controllers and walked away when pairs in G6 finished playing. They however got back to complete their game after the researcher explained they had not completed their game.

The key behaviours of pairs in G5 are highlighted below:

- Short talk duration (4minutes 16seconds)
- Long periods of silent play

- One participant gave more instructions than the other (P10= 30, P9 =11)
- Several instances of 'non-conflict' situation (5) and a few 'conflicts resolved' (2), encouragement (6), enquiry from researcher (1) and inter-group interactions.
- Few positive affective behaviours (laughs, smiles)
- Several negative affective behaviours (frowns, signs of frustration, shouting)
- Focused attention more on the screen
- Number of deaths = 20
- Score = 2300

7.3.3.2.5 Example 5 - Group 17 (G17)

The pairs in the group focussed their attention on the screen and communicated frequently during gameplay. The key behaviours observed in the group are summarized below:

- Long talk duration (6minutes 4seconds)
- Short periods of silent play
- Both participated in giving instructions to each (P33= 21, P34 =20)
- Several instances of 'non-conflict' situation (6) and a few 'conflicts resolved' (1), suggestion (1), enquiry from partner regarding gameplay (2) and researcher regarding game duration (1) and inter-group interactions (1)
- Several positive affective behaviours (laughs, smiles, raising arms up, jumping, dancing and singing)
- Focused attention more on the screen
- Number of deaths = 20
- Score = 2300

In summary, the participants in the low category groups showed lack of interest in the game, loss of concentration, disengagement, unwillingness to play as well as encouragement from partner. There was also a display of lack of understanding of how to reach agreement and adoption of poor strategy which did not work. Both positive and negative affects such as signs of frustration, frowns, sighs, smiles and laughs were observed. Additionally dominating and aggressive behaviours were observed and some groups were more communicative than the others.

7.3.3.3 HIGH CATEGORY

In the following subsections, three examples of gameplay in the high category are now discussed. These extracts are summarized on page 152.

7.3.3.3.1 Example 1 - Group 7 (G7)

Initially, pairs in the group seemed to be engaged with the game as they focused their attention on the screen and one of the participants (P13) made enquiries from partner regarding gameplay such as "*Did we get them?*" and "*What are you doing?*". However, the same participant later on displayed behaviours that indicate unwillingness to play. Pairs in the group also communicated for a short period of time.

The key behaviours of G7 are summarized below:

- One participant gave more instructions than the other (P13 = 9, P14 =3)
- Short talk duration (2 minutes 23seconds)
- Long periods of silent play
- Mostly focused attention on the screen
- Unwillingness to play by one participant who enquired severally from the partner and researcher about game duration (8), gameplay (6) and quitting (3).
- Several affective behaviours (smiling, laughing, singing, dancing, sighing, frowning, tilting head to the side)
- Number of deaths = 19
- Scores = 2380

7.3.3.3.2 Example 2 - Group 23 (G23)

The pairs in G23 seemed to be engaged with the game as they mostly focused their attention on the screen during game play and showed signs of excitement such as dancing, jumping, laughing and verbalizations such as "Yes!" when they successfully killed an alien. They talked frequently for duration of 7 minutes 11seconds in total and the content of their talks was mostly 'non-conflict' verbalizations apart from on one occasion where they disagreed but later resolved their differences. Both participants in G23 participated in giving instructions to each other at different times during gameplay. One of the participants suggested to the other how they might successfully play the game as shown in the transcript: "*Let's get everyone [aliens] in the front row*" and also made enquiry about game play e.g. "*How did we die?*"

The key observations of G23 are summarized below:

- One participant gave more instructions than the other (P45 =38 , P48 =17)
- Long talk duration (7 minutes 11seconds)
- Short periods of silent play
- Mostly focused attention on the screen

- Several instances of 'non-conflict' situation (10) and few suggestions (1), 'conflicts resolved' (3), interference (1) enquiry from partner (1) and researcher (1).
- Positive affect such as laughing, smiling, dancing and jumping up
- Number of deaths = 12
- Scores = 2210

7.3.3.3.3 Example 3- Group 24 (G24)

G24 were a mixed gender group and communicated less frequently during gameplay. The key behaviours of the pairs in the group are summarized below:

- One participant gave more instructions than the other (P47 =26 , P48 =2)
- Mostly focused attention on screen
- Two instances of 'non-conflict situation.
- Short talk duration (1 minutes 15seconds)
- Long periods of silent play
- Number of deaths = 21
- Scores = 1510

Summarily, the groups in the high category showed high levels of engagement and interest in the game as they focused their attention mostly on the screen during gameplay. There were signs of excitement (such as dancing, jumping, laughing), and partners giving instructions to each other, making enquiries from partner and making suggestions on how to successfully play the game. There were also few instances of unwillingness to play the game, dominating behaviours and some groups communicated less frequently than the others.

7.3.3.4 MEDIUM CATEGORY

In the following subsections, two examples of gameplay in the high category are now discussed. These extracts are summarized on page 153.

7.3.3.4.1 Example 1- Group1 (G1)

The pairs in G1 looked around a lot during gameplay and communicated less frequently. In the few times they communicated, one of the participants dominated the interaction as she gave more instructions to the partner.

The key behaviours of G1 are summarized below:

- Short talk duration (37seconds)

- One participant gave more instructions (P1= 1, P2 = 5)
- Mostly focused attention on screen
- Long periods of silent play
- Affective behaviours such as smiling, laughing, giggling, sighs, frowning and dropping arm down
- Number of deaths = 20
- Scores = 2510

7.3.3.4.2 Example 2- Group 20 (G20)

The pairs in G20 were mostly focussed on the screen and communicated less frequently throughout gameplay. The key observations of the pairs in the group are summarized below:

- Short talk duration (4 minutes 27seconds)
- Long periods of silent play
- Mostly focussed attention on the screen
- One participant gave more instructions (P39 = 24, P40 = 9)
- Few instances of positive affects (smiles and dancing)
- A few instances of 'non- conflict' situations (5), 'conflict resolved' (1) suggestions (4), interference (3), enquiry from partner about game play (3) and about game duration from researcher (3)
- Number of deaths = 11
- Scores = 2515
- Completed game twice

In summary, behaviours observed in the medium category were engagement with game, less communication, positive and negative affective behaviours, dominating behaviours, giving suggestions, and making enquiry from partner and researcher about gameplay and game duration respectively.

From the general observations of each group in each category (high, low and medium), there seems to be no clear differences in behaviours between groups across each category. However, it was decided to look at the interesting parts of the individual graphs for each group. For example periods where a group in the low category peaked up or where a group in the high category trended downwards.

Behaviours of groups in the high category

G7's agreement performance decreased between 160-300seconds and 500-600seconds of game play; G7 was a girl-girl group and examination of their video data showed that one of the pairs seemed to have lost interest in playing within the period. The participant looked around and at the researcher, showed signs of frustration (frowns, sighing and tilted head to the side) and made verbalizations that indicate unwillingness to continue for example, "*We have to do this for 10 minutes?*", "*Miss, can I just stop?*", "*I need to stop so bad*" and "*I so wanna give up*" etc. G23 (a girl- girl group) started off with a very low agreement score because they did not understand how to play the game but improved as soon as the researcher clarified again how the game works. They mostly interacted with the game as they were rarely in the 'no-interaction' state (as shown in Appendix). Pairs in G24 (boy-girl group) did not communicate verbally but they focussed their attention more on the screen. However, within 400seconds till the end of game play, the group's agreement performance reduced (i.e. there was an upward trend in the disagreement). The video showed the boy in the group was bored during that time evidenced by his transcript: "How long do we have? *Is it nearly finished?*" and distracted (was talking to his friends). The boy shouted "*Yeah*" when the game ended and quickly dropped his controller.

Behaviours of groups in the low category

All the groups in the low category at some points improved in their agreement performances although not so much (i.e. little peaks in agreement score) apart from G10 and G16 who had consistently low levels of agreement and thus were not further analysed. The video data of G6 and G19 revealed that during the periods they were focussed on the screen and both pairs in the groups participated in giving instructions to each other. Conflict resolution, suggestions and non-conflict situations were also observed. While G4 were mostly distracted during gameplay, within the period their chart showed a high peak in agreement level, one of the pairs encouraged the other to play and they both momentarily focused their attention on the screen as shown in the transcript:

P11: "*X, turn right! We can do this! Look, just pay attention. We can do this*"

There were also periods within game play where the disagreement levels of G17 and G5 trended upwards. Further investigations showed that within these periods one of the pairs in G5 seemed to be distracted and not engaged with the game (and complained her finger hurts which caused her not to interact with the game for 7seconds). It was observed that one of the pairs in G17 did not give a clear set of instructions to the partner as seen in the transcript below:

P33: "*move, move. We both moved our way*"[laughs]

P34: "*When you said move, I didn't get which way*"

P33: "*Ok, that way!*"

P34: "*Which way is that way?*"

P33: "*It's obvious*"[laughs]

Behaviours of groups in the medium category

In the medium category, G1 trended upward in their disagreement scores from 400seconds till the end of game play while G20 trended upward in their agreement score between 320 - 440 seconds of game play. Inspection of their video data showed that G20 was focused and not distracted while one participant in G1 was bored ("*How long do we have left?*"), distracted by the youth leader and had periods of silent play.

7.3.3.5 Death Moment

Death moment is a time within game play when the player is hit by a bomb dropped by the aliens or when the aliens hit the shields and the game ends. This is referred to in this study as when a group 'dies' or 'is dead' and can happen several times within game play duration and is identified within the video data when a particular sound plays or from the log files of participants' interactions. The first and second death moments were considered important in this study because they provided an opportunity to see if there was a change in strategy after the first time the participants died. The length of play (in seconds) for each group before the first two death moments is presented in Table7-18.

Table 7-18: Game play duration in the first and second play sessions.

Group	Length of first gameplay (in seconds)	Length of second gameplay (in seconds)
1	14	40
2	39	11
3	47	37
4	27	20
5	2	44
6	65	28
7	37	7
8	6	14
9	40	11
10	29	11
11	48	11
12	9	41
13	40	53
14	30	67
15	23	44
16	29	47
17	30	8
18	23	49
19	48	41
20	57	39
21	7	27
22	6	40
23	35	27
24	6	40
25	2	40
Mean	28	31

The mean length of first game play and second game play were calculated to be 28seconds and 31seconds respectively. This result indicates that there is a difference in the length of gameplay in the first two death moments. To check if the difference in the length of gameplay in the two death moments is significant, a paired t-test was performed on the data (Appendix 5M). The result showed no significant difference in the means ($t(24) = -0.735$; $p = 0.468$; $p > 0.05$).

Using the data in Table7-18, the participants were grouped into two categories:

Category 1: Those with improved strategy i.e. those that played for shorter duration of time in the first game play compared to the second game play as shown in Table7-19. These include participants in G1, G5, G8, G12, G13, G14, G15, G16, G18, G21, G22, G24, and G25.

Table 7-19: Game play duration in the first and second play sessions for groups in category 1

Group	Length of first gameplay (to the nearest seconds)	Length of second gameplay (to the nearest seconds)
G1	14	40
G5	2	44
G8	6	14
G12	9	41
G13	40	53
G14	30	67
G15	23	34
G16	29	47
G18	23	49
G21	7	27
G22	6	40
G24	6	40
G25	2	40
Mean	**15**	**41**

Category 2: Those with no improvement in strategy i.e. those that played for longer period of time in the first game play compared to the second game play as shown in Table7-20. These include participants in G2, G3, G4, G6, G7, G9, G10, G11, G17, G19, G20 and G23.

Table 7-20: Game play duration in the first and second play sessions for groups in category 2

Group	Length of first gameplay (to the nearest seconds)	Length of second gameplay (to the nearest seconds)
G2	39	11
G3	47	37
G4	27	20
G6	65	28
G7	37	7
G9	40	11
G10	29	11
G11	48	11
G17	30	8
G19	48	41
G20	57	39
G23	35	27
Mean	**42**	**21**

The length of play before death was used as a parameter to measure improvement in strategy since it is a product of moving around and shooting successfully during game play. Thus, the longer a group played before dying, the more successful they were at playing the game and it was considered that the group were using a successful strategy. So, pairs will play for longer duration if the strategies they adopted during game play were successful. Conversely, pairs would play for shorter periods if the strategies they adopted were not successful. It is noteworthy to mention that staying alive in the game is related to factors such as agreement and in-game play strategy (or decisions). For example during game play, participating pairs need to be in agreement (agree in their controller input) in order to shoot at the aliens, move to dodge from the bullets or collect bonuses and avoid death in the game. Nevertheless, being in agreement is not sufficient because they may agree in their controller input but might be making poor gameplay decisions which could consequently lead to death in the game. Analysis in this section was performed through the lens of agreement on controller input; although in-game play decisions are also considered important, it is beyond the scope of this study.

The mean length of first game play and second game play sessions for those in category1 were calculated to be 15seconds and 41seconds respectively. Also, the mean length of first game play and second gameplay sessions for those in category2 were calculated to be 42seconds and 21seconds respectively. These results indicate that there is a difference in the length of gameplay in the first two death moments for groups in the two categories. To check if the difference in the length of gameplay in the two death moments is statistically significant, a paired t-test was carried out (Appendix5N). The results showed a significant difference in the means in category 1 ($t(12) = 8.401$; $p<0.05$) and category 2 ($t(11) = 6.407$; $p<0.05$). These differences could be attributed to improvement in strategy in groups in category 1 and no improvement in strategy in groups in category 2.

In order to investigate how the strategies changed over time, the behaviours of the participants (including their talks, gestures, eye gazes and affective behaviours) before first game play, during first game play, during second gameplay and 5 seconds pause after first and second deaths as well as how long (in seconds) they spoke for within the first and second gameplay sessions were presented in the table in Appendix 5J. Only the groups that their talks were transcribed were analysed.

The table shows that there was a change in strategy in all groups (the strategies used in the first period differed from those used in the second gameplay period) apart from G2, G7, G16 and G20 where no change was observed (they used the same set of strategies during first and second game play). In the following subsections, the researcher draws out the general reasons for strategy improvement and discussed specifics of individual groups.

7.3.3.5.1 Behaviours of groups with improved strategy

Across all groups with improved strategy, it was evident that there was increased communication and engagement with the game as they mostly stared at the screen and had more conversation in the second game play than the other groups. Some groups are analysed in more detail and specific ways in which their strategies were improved are presented.

There were evidence of more equitable behaviours in G5, G22 and G25 during the second game play:

- In G22, there was a shift from one participant dominating the interaction in the first game play to both participants being more participatory in interacting with each other.
- In G5, there was improvement in controller manipulation by one of the participants (P10); the group died in the first game because of her inability to press the correct key. In the second game play, P10 improved to the extent that she was confident enough to show her partner (who was previously teaching her the correct key presses) what key to press. As a result the group seemed to be more interactive and enjoyed the game.
- In G25, the pairs seemed to have realized what made them to fail and an attempt was made to resolve the issue evidenced by the conversation which they had when the first game ended. In the second game play, they became more participatory by interacting more with each other.

There was evidence of tutoring behaviour in G18 during the first game play where one of the participants (P36) showed the partner how to use the controller. But this was absent in the second game play which suggests that the participant who was being taught had learned. Furthermore, there was evidence the pairs negotiated a strategy during second game play which did not happen in the first game play. Pairs in G21 seemed to realize that the strategy they used in the first gameplay did not work and before the start of the second game they negotiated a strategy for the second game. Pairs in G16 negotiated a strategy before first gameplay but the strategies adopted in the first and second gameplay did not change. It appeared they understood the strategies they adopted in the first game play worked for them and did not bother to change it. It is evidenced from Table7-18 that they played relatively longer in the first game play than any other group in this category.

7.3.3.5.2 Behaviours of groups with no improvement in strategy

In general, groups with no improvement in strategy exhibited domineering behaviours where one participant in a group gave instructions to the partner. There was aslo evidence of reduced distractions and communication for the groups as they had less conversation in the second gameplay than the first gameplay. Some groups are analysed in more detail and specific ways in which their strategies were improved are presented.

In G3, there was tutoring behaviour in the first game play displayed by one of the participants (P5) which did not occur in the second game play rather, there was evidence of encouraging behaviour by the same participant (P5) who tutored the other. This suggests that P5 may have concluded the partner had learned and switched from tutoring to encouragement (discontinued the tutoring early) which may have affected their game play. In G4, one of the participants (P7) did not know what he was doing in the first game play (did not realize they both have to control the snowman) and there is no evidence this changed in the second gameplay as he was asked the same question "What are you doing?" by P8 after each gameplay. Pairs in G2 negotiated a strategy before first gameplay. But the strategies adopted in the first and second gameplay did not change. They might have considered that the strategies they adopted in the first game play worked for them and did not bother to change it but rather encouraged each other at the end of the game. One of the participants (P4) mentioned that the controller was unresponsive but the researcher looked at the interaction map on the screen and confirmed that this was not the case. It was probably as a result of not pressing the keys at the same time. In G23, there was unresolved conflict in the first gameplay (as one of the pairs in the group did not seem to understand that they needed to collaborate in order to play the game) which was carried over to the second gameplay. Although G23 played for a shorter period in the second gameplay, they seemed to improve their strategy becoming more engaged and interactive after the researcher intervened and explained to the pairs again how to play the game. There was also evidence of that some pairs in G6, G19 and G23 were distracted during game play distraction; while the pairs in G23 and G19 occasionally looked around during gameplay, pairs in G6 were distracted by the youth leader who diverted their attention to his phone. Pairs in G17 reflected at the end of the first game play which did not seem to have worked for them.

7.3.4 Participants' Gameplay Experiences

The participants were asked through the use of questionnaire which version of the game they preferred and to state their reasons. 32 (64%) of the participants indicated that they preferred the single-player version, 17 (34%) of the participants indicated that they preferred the collaborative version while one participant (2%) did not answer the question. The participants that preferred the single-player version thought it was easy (16 (50%)), less confusing (1 (2%)), allowed more control (10 (20%)) and not distractive (1 (2%)). Three others did not give any reasons while one participant stated he did not like the game in general. Furthermore, the participants that preferred the collaborative version of the game indicated that it was fun (11), encouraged teamwork (2) and communication (1), challenging (2) and got help from their partners (2). The participants were also asked whether they enjoyed playing the single-player more than the collaborative version of the game and to state their reasons. 15 (30%) of the participants indicated that they enjoyed playing the single player version, 27 (54%) of the participants indicated that they enjoyed playing the collaborative version while the remaining 8 of the participants were undecided. Participants who indicated they enjoyed playing the single-player version stated that their reasons were because it was easy (5), allows more control (4), does not encourage communication (1) and not distractive (1). The remaining four did not state their reasons. Furthermore, those who indicated they enjoyed playing the collaborative version of the game thought it fun (11), challenging (2), cool (2), encouraged teamwork (4), communication (1) and friendship (2). Two participants had no idea why they enjoyed playing the collaborative version of the game and three others did not provide any answers. These results were also reinforced by a participant's response during the interview session as shown in the G13's transcript below:

P25: "I like it together cos it's more of a challenge"

P26: "*Yeah, it's more challenging cos you have to communicate and like say where you are actually going. It's more fun*"

Two participants who were not sure which version they enjoyed more thought that the collaborative version was fun but could also be challenging and confusing. To measure the extent to which the participants liked the ECA element of the game they were asked if they would like to turn all the single player games into ECA games. 14 (28%) of the participants indicated that they would like to turn all the single player games to ECA games, 20 (40%) of the participants indicated that they would not while 16 (32%) remaining participants were undecided. The participants were asked to rate their experience of playing the single-player and collaborative versions of the game on a five point scale from 'very easy' to 'very hard' as well as to give brief explanations to their responses. The participants' ratings were coded as 1=very easy, 2= easy, 3= ok, 4=hard, 5=very hard and represented in a bar charts as shown in Figure7-19 and Figure7-20. The modal rating for the participants' experience playing the single-player version of the game was found to be 1 with the participants rating ranging from 'very easy' (min=1) to 'very hard' (max=5). This result indicated they found the single-player version 'very easy' to play and the positive comments they mentioned were familiarity (2), more controls (17) and less confusing to play (1).

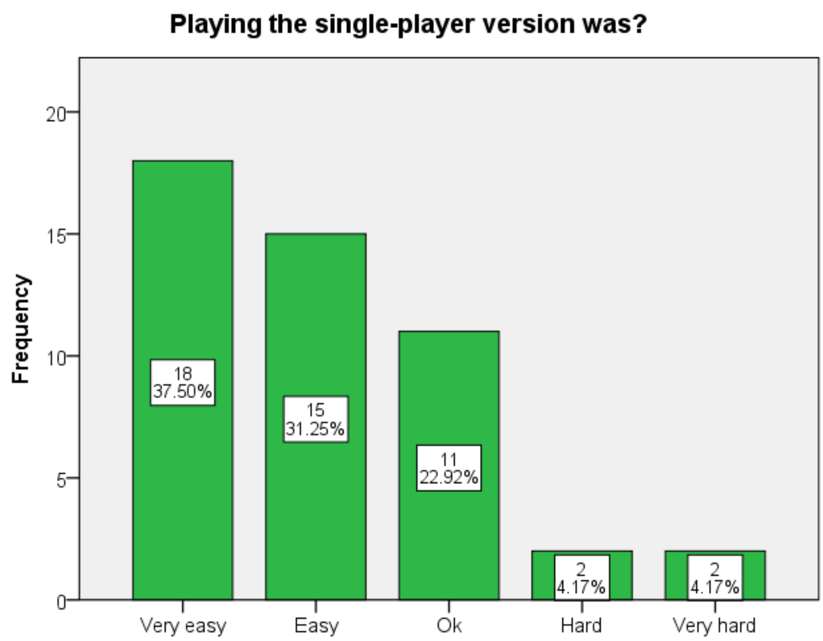

Figure 7-12: Participants' rating of their experience playing the single-player version

The modal rating for the participants' experience playing the collaborative version of the game was found to be 3 with the participants rating ranging from 'very easy' (min=1) to 'very hard' (max=5). Several reasons were provided by the participants: some of those who rated the collaborative version as 'easy' (3 participants), 'very easy' (4 participants) and 'Ok' (2 participants) attributed their response to the teamwork afforded by the collaborative version;

some of those who rated the collaborative version as ‘very hard’ and ‘hard’ stated that it provided limited control as they needed to press buttons at the same time to progress in the game (2 participants), required more communication (3 participants), and difficult to press the same button at the same time (6 participants). Furthermore, some participants that rated the collaborative version as ‘Ok’ mentioned it was fun (2 participants) and challenging (1). Other reasons why some participants rated the collaborative version as ‘very hard’ was because they disagreed a lot and one person dominated the interaction. One participant recognized that the collaborative version was hard but the teamwork if afforded helped.

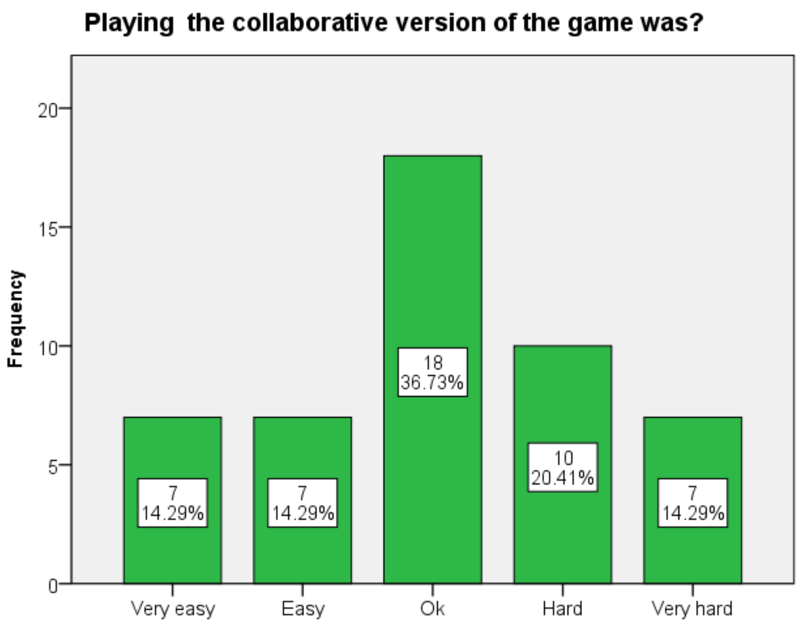

Figure 7-13: Participants’ rating of their experience playing the collaborative version of the game

Figure6-21 shows the participants’ ratings of how much fun they experienced while playing the game with the game pad (coded as 1=awful, 2= not very good, 3= good, 4=really good and 5=brilliant). The modal response was calculated to be 5 with participants’ ratings ranging from awful (min=1) to brilliant (max=5). A cross tabulation (Appendix5k) of the results of the Smileyometer and Again-again results showed that 13 (81.25%) of the participants that rated the game pad as ‘brilliant’ indicated they would like to play the game again with the game pad while all those (3 participants) who rated the game pad as ‘awful’ indicated they would not like to play the game again with the game pad.

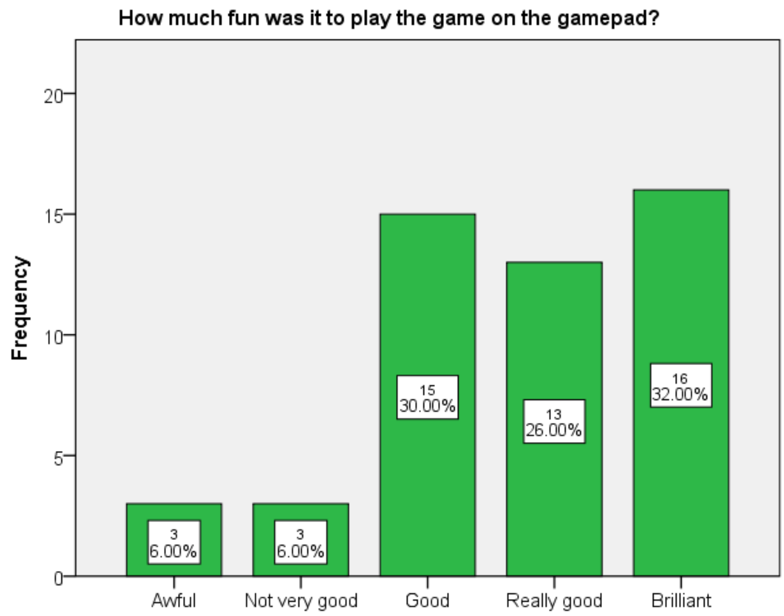

Figure 7-14: Participants' rating of the game pad

7.3.5 Issues with controller and reaching agreement

The participants were asked (using the post gameplay questionnaire) if they experienced problems with the interaction device during game play. This question was aimed at investigating whether the game controller (in this case game pad) worked well. Responses from the participants indicated that none of them experienced any difficulties with the game pad. The participants were also asked if they had problems reaching agreement with their partners and to state what the problems were if they did. This question was intended to identify potential problems that could arise whilst playing ECA enabled games. Only eight (16%) of the participants indicated they had problems reaching agreement with their partners. Four (50%) of the eight participants stated that they had issues collaborating with their partners (e.g. P35: "*One person wants one thing to happen and the other wants something else*"), two (25%) of the participants stated that they argued (e.g. P9:"*We were arguing a lot*"), one participant (12.5%) stated that his partner's poor listening skills affected the way they reached agreement (e.g. P8: "*Because his listening skills were poor*") while one participant (12.5%) stated that they were disorganized (e.g. P46: "*It was hard to know who was doing what*"). These responses are represented graphically as shown in Figure7-22.

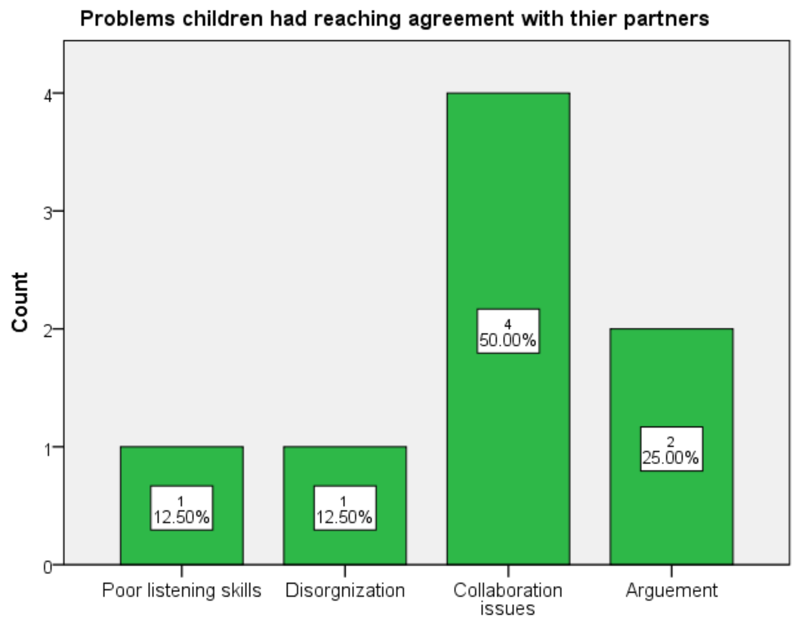

Figure 7-15: Issues reaching agreement

To further investigate what influenced the participants' interactions during game play, they were interviewed at the end of each gameplay session. Only 23 groups took part in the interview sessions; the participants in the other two groups simply walked away after completing their post-test evaluation forms. The results of the interviews are presented and discussed in the next chapter (chapter 8).

7.4 Conclusion

In this chapter, the main study of the research conducted in this thesis which involved a more varied and larger user population was reported. The study adopted a range of qualitative and quantitative data collection methods including questionnaire, interview, observation, collaborative networks, fun toolkit and logging of participants' interactions during game play. These methods had previously been tested in the first and second pilot studies (in chapters 4 and 5) for their suitability for this kind of research and were shown to be appropriate. Several interesting results were obtained which were presented in this chapter but are discussed in the subsequent chapter (Chapter 8).

8 CHAPTER EIGHT: UNDERSTANDING ECA

8.1 Introduction

In this chapter, an attempt was made to bring together and provide some explanations to findings from the three studies reported in this thesis with more focus on the main study results. It begins by modelling the key aspects within the ECA gameplay studied within this work which separates out the important aspects that influenced game play followed by the general analysis of findings and then proceeded to present design guidelines and the ECA model.

8.2 Gameplay Model

The model represented in Figure8-1 describes the way gameplay is viewed in this work by highlighting the salient aspects of ECA explored in this thesis. While ECA can be scaled up to larger numbers, this thesis focussed on pairs of participants aged 11-16 years old interacting with an ECA supported game.

As shown in the model, each participant has an independent perception of the game state (which relies on the design of the game and the player's understanding of the game) and thus individually interprets what goes on in the game for example they might notice the aliens moving, bombs dropping, the interaction map etc. Based upon their perception of the game state, they will have independent desired actions for example a player might want to move away from the bomb or shoot at the aliens. Desired actions in turn can be influenced by each player's general game play experience and their individual understanding of the game. Furthermore, the desired action is bounded and controlled by the agreement strategy which could influence the actions the participants take and in turn feeds into the game.

The model also shows the various sources of data and the methods used to collect data to explore the salient aspects of ECA (in pink bubbles). There were two versions of the ECA game, single-player and collaborative (ECA) versions; the single-player version of the game was used to help participants understand how the game worked and the researcher is not aware of any problems in how the participants perceived the game state. To understand the collaborative strategies within the context of ECA, the participants were video recorded during interaction with the game and interviewed after game play. Also, logging the participants' actions served as a means to understand what actions were taken during game play and survey methods helped to obtain information on the participants' general game play experiences.

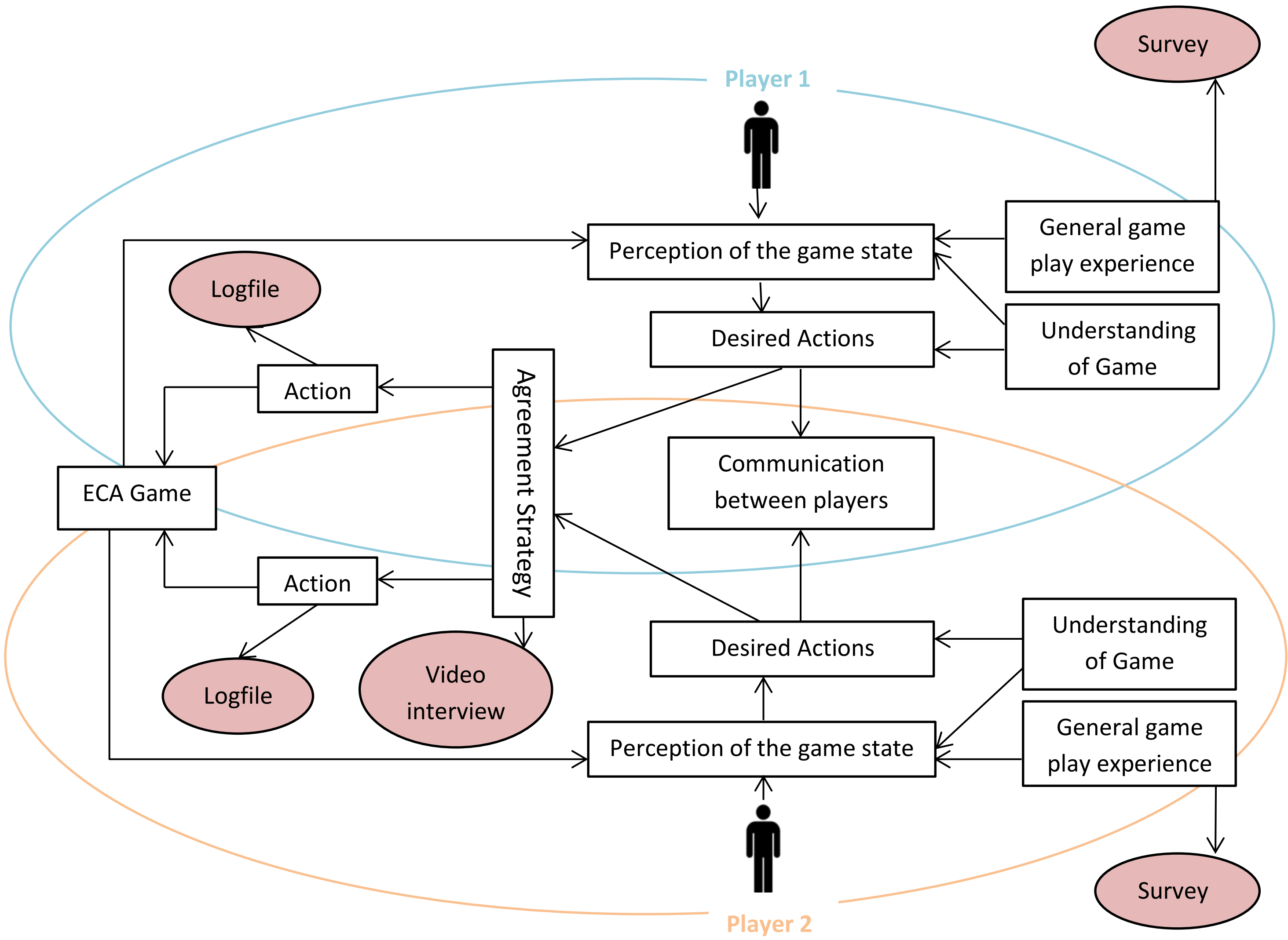

Figure 8-1 Model of key aspects of ECA studied in the thesis

To effectively analyse the large amount of data obtained from the main study, different approaches (lenses) were adopted and these provided interesting insights into the interactions. The strategy used was to firstly transcribe the video data and then using collaborative networks to reveal patterns of behaviours that occurred within the video data. Next, the log files (quantitative data) were visualized and used to study the performance across groups and consequently understand the collaboration with game play. Responses of the participants in the survey were coded and grouped into themes (semi-structured interview) and counted (questionnaire).

The following sections present the analyses of the key findings of this thesis, bringing together results of the studies carried out in the course of the PhD program but focusing more on the main study results reported in chapter 6.

8.3 Collaboration Behaviours

Observing the participants during gameplay provided a rich set of data to understand how they collaborated within an ECA game environment. The findings from the main study (chapter 6) revealed a range of different collaborative behaviours exhibited by the participants in multiple groups whilst playing the ECA game. Some of these behaviours were reinforced by the findings of the pilot studies reported in chapter 4 and chapter 5 and include: negotiations prior to game play, verbal suggestions which were not always accepted, soliciting help from partner and researcher through questioning, non-conflict situation (agreement), conflict resolution (an indicator of good collaborative interaction (Roschelle & Teasley, 1995)) and not allowing partner dominate. There was also evidence of dominating behaviours where a participant gave instructions and the other did not respond verbally but carried out the instructions. However, this dominating behaviour did not persist for the entire game play sessions and typically ended with the other player disagreeing or giving their own instructions. These observations imply that ECA could help empower people that are being dominated and encourage more equitable participation; this may be particularly desirable especially in educational settings.

In addition, several new behaviours were evident and include encouraging partners to continue playing even in difficult situations and evidence of participants assuming tutoring roles to help their partners or another group out. Peer tutoring behaviour is especially useful within educational contexts and has been shown to have both academic and non academic benefits such as enhancement of peer relations and development of social behaviours and classroom disciplines (Webb, 1989). Furthermore, some aggressive behaviour such as shouting at partner, hitting or pretending to hit partner and blaming partner were displayed when game ended. While the participants were play fighting and did not mean to harm each other, the observation could probably be attributed to the excitement or even the difficulty participants experienced during interactions with the game. It may also be that the participants found it difficult to cope with the fact that they were defeated and were quick to blame each other (this behaviour was also observed in pilot study). This indicates that it is possible for participants to feel frustrated however a mechanism to encourage them to try again could be helpful. Also, several occurrences of inter group interference where participants in one group made enquiries from another group during game play regarding game score and in some instances involved use of derogatory verbalizations (causing distractions during game play). While this was an inter-group behaviour, it demonstrates that there may be unacceptable behaviours which may be displayed in such gaming environment. Thus, children should always be supervised and never be left unattended. All groups communicated by talking but some were more communicative than others. This was as a result of verbal domination by partners or a partner being shy and not wanting to communicate. Thus, the researcher is of the view that in such situations participants should be encouraged to interact or communicate because without it they cannot be said to successfully collaborate whatever the final outcome.

8.4 Interactions

The percentage of agreement score was a useful metric to guide analysis which provided an understanding of how much each group agreed in every key press as well as their associated behaviours. The groups with the lowest scores G10 (9.98%) and G16 (12.67%) displayed behaviours that do not encourage collaboration and these include: unwillingness or reluctance to play, lack of interest, loss of concentration, no communication and disengagement. Lack of understanding of how the game works was evident as one participant in G16 held the partner's controller and attempted to play the game alone with just his controller. Another observation was that one of the strategies adopted by G16 did not seem to work for the group (one of the participants started to count (3, 2, 1) but presses the button on his controller at the wrong timing; at 2 rather than at 1). The groups with the highest collaboration scores G23 (24.93%) and G13 (25.08%) appeared to be more engaged with the game as they focused their attention on the screen and exhibited several positive affective behaviours such as laughing, smiling, dancing, jumping and stamping foot on the ground. They had mostly non-conflict verbalizations and a few verbalizations which suggested disagreement but were often times resolved amicably.

The graphs of agreement, disagreement and no-interaction states (Appendix5G) were used to gain some insights into the participants' performance over time. It was hypothesized that as the participants' progresses in the game, performance is expected to increase and thus the amount of time spent in the agreement and no-interaction states increases while the time spent in the disagreement decreases. Interestingly, the results suggest that performance did not increase over time as there was no trend in the graphs; one would have expected that the participants would improve and refine their strategies for gameplay and reaching agreement with time having played the game for a period of 10minutes. This might be that participants may require more time to arrive at a workable strategy which would improve their performance. A further examination of the individual charts showed that a decrease in performance was caused by participants losing concentration and interest (unwillingness to play) resulting to disengagement from the game which was reinforced by the data from video analysis. Additional factors were related to unclear set of instructions and conflicts among participants though they were eventually resolved. Also, in periods where participants' performance improved, they appeared to be engaged and frequently interacted with the game. In terms of the participants' verbalizations, non-conflict, suggestions and conflicts resolved were associated to periods where participants' performances improved.

In this thesis, the length of play before death was used to measure improvement in strategy. It was believed that pairs would play for longer if the strategies they adopt work for them. Results from the main study reported in Chapter 6 showed that 13 groups played for a longer period of time in the second gameplay while others played for longer period of time in the first gameplay. The video data of the groups revealed behaviours that influenced how long they played for: There were evidence of peer tutoring behaviours (Appendix5G) where a participant showed the partner buttons on the controller and what direction they represent (as observed G5 and G18) or when a participant in a group told the partner the right and left directions by gesturing with the controller (as observed in G3). This behaviour occurred in the first gameplay by the one participant (apart from in G5 where it occurred in the two gameplay sessions with each participant tutoring the other in the different gameplay sessions). This suggests that there was phase of tutoring which appeared to end and that people doing the tutoring make judgement about when the tutoring phase is complete. Other behaviours found were giving encouragement and pre-gameplay and in-gameplay strategy negotiation.

In this research, latency is defined as the time interval between one key press and agreement press and this is a part of the necessary amount of disagreement required during game play (i.e. disagreement required = pre-latency + Post-Latency + actual/complete disagreement). Agreement relies on participants pressing the same button but because the participants are users, it would be difficult to press the buttons simultaneously. While it would be useful to analyse the log files to calculate the latency (and recommend to interaction designers as a design guideline), it would be considered in future studies due to time limitations.

8.5 Gameplay Experience

To explore the effects of ECA on participants' enjoyment of the game, several approaches were adopted including use of questionnaire and fun toolkit. The questionnaire used in the main study included questions on which version of the game the participants preferred and whether they enjoyed playing alone more than with their partners. The questionnaire revealed that clearly a large number of participants (27 (54%)) enjoyed playing the collaborative version of the game more than the single player version (15 (30%)) and the positive comments they mentioned include fun, challenging, cool, encouraged teamwork, friendship and communication. However, given a choice they prefer the single-player version (32 (64%)) to the collaborative version (17 (34%)) and also mentioned some positive comments including easy, less confusing, allows more control and not distractive. This result is also supported by the participants' responses to whether they would like to turn all the single player games to ECA games (20 (40%) of the participants indicated 'No', 14 (28%) of the participants indicated 'Yes' and 16 (32%) of the participants were undecided). Furthermore, from the results of the participants' rating of the two versions of the game, the single-player version of the game seemed to be easier to play compared to the collaborative version as a large number of the participants (18 (37.5%) and 15 (31.3%)) rated the version as 'very easy' and 'easy' respectfully while a large number of participants (18 (36.7%), 10 (20.4%) and 7 (14.3%)) rated the collaborative version as 'ok', 'hard' and 'very hard' respectfully. The participants claimed that the single-player was easy because they are used to playing single player games (familiarity), have more control (i.e. they could do whatever they wanted) and is less confusing to play. On the other hand, some participants claimed that the collaborative version of the game was hard because it provided limited control as they needed to press buttons at the same time to progress in the game, required more communication, can be difficult to press the same buttons at the same time, disagreed a lot and one person dominated the interaction (this was mentioned on two occasions). Whilst the collaborative version of the game was generally difficult to play some participants found it quite easy stating that it was fun, challenging and promoted teamwork. This result reinforces those obtained in the previous studies reported in chapter 4 and chapter 5 of this thesis.

The Smileyometer and Again-Again results revealed that more than half of the participants (13 (81.25%)) found the game pad fun to use and would like to play the game again with the controller. Only 3(6%) of the participants thought the game pad was awful and would not like to play the game again using the controller. This finding supports the work of Read and her colleagues which indicated that people would like to do fun things again (Read et al., 2002) . However, this might not be the case in every situation as the results in the first and second pilot studies (reported in chapters 4 and 5) showed that while the dancemat was the most fun controller to use, the participants would not like to use it again. As stated earlier in Chapter 5, this could be attributed to lack of prior experience with the dance mat.

The results obtained in the first and second pilot studies confirmed the conclusions of previous research that the fun sorter on the construct of fun measures the same thing as the Smileyometer (Read, 2007). It was observed that the controllers the participants ranked lowest on the funsorter was rated as 'not very good' using the smileyometer (in four cases) and those ranked highest on the funsorter were rated as 'brilliant' using the smileyometer (all cases). Results from the studies also suggest that controllers that are fun or easy to use influenced some participants' decision on the controller they liked most as participants that ranked a controller highest on the 'most fun' construct ranked the same controller as highest on the 'liked the most' construct whereas those that ranked a controller highest on the 'easiest to use' construct ranked the same controller as highest on the 'liked the most' construct. Furthermore, results from the first and second pilot studies revealed that teenagers were able to reveal through the use of fun toolkit how much they enjoyed playing the game with the dancemat and expressed their doubts on whether they would like to play the game again with the dancemat. This could be attributed to the participants (aged 11-16 years old) who are more cognitively advanced with improved reasoning skills compared to the younger children (van Dijk et al., 2012).

8.6 Visualization

A very simple visual representation (a map) was used to provide a visual feedback of each participant's interaction with the game as reported in chapter 3 of this thesis. It was anticipated that the interaction map would support more effective collaboration through awareness of own and partner's actions (Bowman et al., 2012). Results from the main study (questionnaire) showed that 44 (88%) of the participants noticed the map and 33(75%) out of the 44 participants claimed to be aware of its function in the game and used it during interaction with the game as reported in chapter 6 section 6.3.2. There were also comments from some participants (gathered from video data and interview responses) about using the interaction map during game play. Similar results were also found in the first and second pilot studies reported in chapter 5 and 6 respectively. These results suggest that visualization is an important part or aspect of gameplay.

8.7 Issues that influenced collaboration

To understand what influenced the participants' interactions, a semi-structured interview method was adopted. Presented below are the themes generated from the thematic analysis (Appendix6A) of the participants' responses during the interview sessions with the quotes from the raw data indicative of each theme.

8.7.1 Strategy

All groups developed strategies to reach agreement as earlier reported in chapter 6 section 6.3.2. While six groups (G2, G4, G16, G18, G21, and G25) did this in advance the other nineteen groups developed strategies during game play. During the interview session, various participants mentioned that the strategies they adopted influenced how they collaborated and these are described below

8.7.1.1 Random pressing of controller buttons:

Five groups (G1, G2, G3, G4 and G18) indicated that they randomly pressed the controller buttons as seen in P36's transcript (G18) "*we thought of this idea where say X has his controller… Now If B is for shoot, we could pick to press shoot. If I am pressing B all the time when X wants to press B cos I am pressing B randomly, and jack presses it just once it will come up once. And the same with me, he will have to keep pressing moving so I can move anytime I like*" but participants in G1 and G4 later noticed the map and used it to collaborate as seen in P1's transcript (G1) "*we were just pressing the button and we just looked at the corner to and saw what each other was pressing*"; Participants in G17 and G22 also indicated they used the map to collaborate during game play.

8.7.1.2 Pre-play negotiations

Participants in G25 negotiated a strategy before game play as seen in P49's transcript "*what we did, err at the beginning we said when we want to shoot say shoot, when we want to move right say right, and when we want to move left say left before we started to play the game*".

8.7.1.3 Verbal Communication

Several groups (G3, G5, G6, G11, G12, G13, G14, G15, G16, G17, G19, G20, G21, G24) reported they communicated by talking to each other and telling each other what to do. One of the participants in G2, G12, G16, G22 and G25 dominated the interaction by instructing their partners on what actions to take as seen in P3's transcript (G2) "*I told him I was the leader and I told him when to move and shoot*". Conversely, participants G17 noted that they helped each other during gameplay as seen in the following transcript:

P33: "*We were talking to each other like say go right! cos if I like shout at them, they won't do it!"*

P34: *[laughs]*

P33: "*and if we did wrong, we were not shouting at them, we were just saying try to do it next time and like helping each other*".

8.7.1.4 Gameplay Judgements

One child in G15 also identified that sometimes they played the game without communicating verbally but trusted their gameplay judgements as seen in the transcript "*Err, we did it as well without talking- we both knew what to do*". While in some groups (G5, G13 and G15) their gameplay judgements seemed to work in their favour, P31 in G16 indicated that they disagreed due to their poor judgments during game play as seen in the transcript "*Erm, well cos sometimes I though the bullet was coming down and it looked like it was gonna hit me but Sam didn't think it was, so I just pressed it*". Three groups (G9, G12 and G18) identified they used the bomb positions to know what direction to move (i.e. strategized using game features) as seen in P23's transcript (G12) **"**you just see and know where the bombs were going and you know not to go there".

8.7.1.5 Copying partner's actions

One of the participants in G9 identified that imitating partner's actions helped the group to be in agreement as seen in the following transcript "*Just looking at what the other person was doing and then doing the same just to shoot properly*".

8.7.2 Accidental interaction

This refers to when players generate game control inputs not planned or intended. As shown in the transcript below, participants in G21 mentioned that they disagreed in their controller input either because they were in a 'no interaction state' or unintentionally did not press their controller buttons at the same time.

P41: **"***Somebody didn't press it or we did not press it at the same time*".

P42: "*It was an accident and we got really excited*"

8.7.3 Harmonious gameplay

This refers to the maintenance of agreement (or lack of disagreement) in the participants' actions. Only G7 identified this as shown in the transcript below:

P13: "*We both just started using the same thing at the same time without realizing how to interact with it. But then we got into it…*"

8.7.4 Collaboration

Ability to work together was reported by two groups G5 and G21 as a factor that helped them to reach agreement as seen in P42's transcript (G21): "*We worked together*". One child in G5 (P9) added that they enjoyed working together and it helped them to reach agreement as seen in the excerpt: "*It was fun how we got err both have to do the same move to make it work. Some people are used to single player controller but when you do it collaborative like we did, it kind of bring extra factor to the game"*. This is the opposite of the result found in Chapter 5 as pairs found it difficult to work together.

Additional issues were found from the results of the interview sessions conducted in the second pilot study (chapter 5) which covered a range of levels including technological, experience associated with using controller and familiarity with controller. While none of the participants experienced problems with the game pad, eight (16%) of the participants in the main study indicated they had problems reaching agreement with their partners and these were mainly human factors: difficulty collaborating with partners (identified by four participants), conflicts (identified by two of the participants), poor listening skills (identified by one participant) and disorganization (identified by one participant).

8.8 Design Guidelines

The work described in this thesis focused on one part of the ECA model (described in Chapter one), the High-Urgency-Low-effect space, where players need to interact quite rapidly with some degree of chance in the way decisions are reached. Based on the findings from this research, several considerations that need to be taken into account when designing an engaging and interactive system that supports ECA are now presented.

- **Visibility of Interaction**: Interaction map was used in this work and findings showed this was useful as 75% of the participants who reported to have noticed the map, knew its purpose and used it to interact during gameplay (Chapter6 section 6.3.2). Visibility of action was also mentioned as one of the important factors that influenced participants interaction during the interview session conducted in chapter 5 of this research (section 5.3.7.7). It is therefore suggested that designers who wish to design for ECA should consider visualization in their work.
- **Anticipate aggression:** It is important to be aware that ECA can trigger aggressive behaviours in frustrated participants especially in boy groups. In this research, some participants felt frustrated particularly at the end of game play and argued, shouted, hit and blamed their partners. For example, in the main study reported in chapter 6, one of the pairs P8 in G4 (boy-boy group) got upset when the game ended and screamed at his partner and also his partners head. The partner responded by instructing P8 to stop hitting him and also hit P8 back on the head. While this behaviour was observed in a small number of cases, it needs to be considered in design of ECA applications. It is suggested that there should be a form of distraction to prevent the participants from displaying such behaviours at the end of the game for example a demo of how agreement is reached in ECA games.
- **Unfamiliar interactions**: The study reported in chapter 5 of this thesis showed that the 63% and 75% of the participants were familiar with game pad and PS2/PS3 controller. All apart from one participant had no prior experience with the. Also, the participants found the dancemat fun to play the game with but would not like to use it again (reported in chapter4 section 4.3.3 and chapter5 section 5.3.4). In terms of performance, participants performed worst with the dancemat and best with gamepad (chapter 5, section 5.3.6). The main study result reported in chapter 6 of this thesis showed that a large number of participants were familiar with button based technologies (20(40%) and 24(48%) of participants reported always playing games by pressing buttons on PlayStation and X-box controller respectively). Also, the post gameplay questionnaire revealed that participants (81.25%) found the game pad fun to play the game with and would like to use it again.

Based on these results, it is recommended to consider technologies users are familiar with when designing ECA games. However, if using unfamiliar technologies, it is important to understand that users may find it challenging to play ECA games with unfamiliar technologies.

- **Encourage equitable collaboration:** Some 'bad' collaboration behaviours were observed during gameplay (reported in chapter 6). These include use of derogatory verbalization (between G5 and G4), aggressive behaviours (G2, G4) and domineering behaviours which occurred in all groups (especially in the only mixed group in the main study reported in chapter 6) but did not persist for the entire game play sessions. Therefore, when users interact with the ECA game/application in a setting where there may be more than one groups (e.g. in the classroom), it is important to note that there may be the presence of some unacceptable behaviours such as use of derogatory verbalizations and aggressive behaviours and users (especially children) should always be supervised and never be left unattended.
- **Appropriate interaction methods:** The research reported in this thesis explored one part of the ECA model: the high-effect/high-urgency. Also, the pilot studies (reported in chapter 4 and chapter 5) explored ECA using three interaction devices: game pad, tangible controller and dance mat. Result from the studies showed that while the dance mat was fun to play the game with (8(67%) and 6(75%) of the participants rated the dance mat as most fun in the first and second pilot studies respectively), the participants would not like to use it again because it was frustrating (i.e. it was challenging for participants to put their foot in the right place on the mat while engaged in the game). It is therefore suggested that when designing games that support ECA, the choice of controller to use should be determined by which part of the ECA model the game falls into. For example, if the game falls within the high-effect/high-urgency part of the ECA model it can be frustrating for players to play the game with the dance mat due to the way the dance mat works.
- **Ensure engagement:** In the main study reported in chapter 6 and chapter 7, groups that performed well were engaged as they focused mostly on the screen whereas the poor performing groups were disengaged because they were distracted or just bored and lacked interest to continue. In the design of ECA games, it is important to consider ways to engage users as engagement in the game would lead to better performance.

- **Reduce cognitive overload:** There were indications from the findings reported in chapter 6 that some of the participants struggled with pressing the right buttons on the input device (for example, one of the pairs in G5 accidentally pressed the wrong button following the instruction given by his partner) and this needs to be accounted for in ECA systems. Therefore, it is suggested that input devices should be highlighted with different colour or signage for easier and proper identification of the keys on the device.
- **Explain game mechanics:** There were issues with participants not understanding how the game works despite explanations for example, one of the pairs in G4 at the beginning of game play asked the partner severally "*Where am I?*" probably thinking he was supposed to control a different game character. There was no immediate feedback in the game mechanics as found with normal games but this was effectively added in through the interaction map. It is suggested that to assist the users learn to play the game (game mechanics) and to collaborate in the game (for example develop strategy to agree and understand the influence of interactions on gameplay), provision of audio visual guidelines played at the beginning of game play be incorporated into the game design. In a situation where no audio visual guidelines are played, an approach such as scaffolding would need to be used

8.9 Conclusion

This chapter presented analysis of the key findings of the studies reported in this thesis highlighting the salient aspects of ECA explored in this work. It also presented the ECA model which describes the various contexts where ECA can be applied and concludes with a set of design guidelines for interaction designers. The next chapter summarizes the work in the entire thesis by answering the research questions and stating the contributions of the work to the HCI community as well as presented the limitations and directions for future work.

9 CHAPTER NINE: CONCLUSION

9.1 Summary of Research

This research explored the concept of ECA, a type of interaction where collaborative agreement is required in order to play a digital game. It focussed on the strategies participants between the ages of 11-16 years and grouped in pairs adopt to reach decisions and control while playing an ECA game. It also explored the effects of ECA on participants' game play experience. The work reported in this thesis followed a child-centred and exploratory approach to achieve its aim and produce a set of guidelines for incorporating ECA into existing or new games/application areas.

A mixed methods approach combining several qualitative and quantitative data collection and analysis methods was adopted to explore the aims of the research. These include use of survey methods (fun toolkit, questionnaire and unstructured interview) to gather participants' demographics, their subjective opinions on ECA, game play experience and familiarity with their partners; observation methods (video and researcher observation) and Logging of participants actions during interaction with the ECA game.

The research was carried out in several phases. Firstly, the gap in knowledge was identified and several research questions were formulated to help understand the ECA. These were reported in chapter one and chapter two. Secondly, an appropriate application (a game) was selected and designed (incorporating ECA into it) to enable the study of the concept. Several early play testing studies were also carried out to ensure the game worked as intended. The choices made in the design of the game and the outcomes of the user testing studies were reported in chapter three. Thirdly, the first pilot study was carried out with the aim of testing the chosen methods to ensure their suitability for the research as well as the study materials to certify them ready for the study. The outcomes of the first pilot study were reported in chapter four. Fourthly, there was need to conduct a second pilot study because it was thought that the use of video recording as opposed to the researcher observing the participants (which was used in the first pilot study) would be more appropriate for exploring ECA. The outcomes of the second pilot study were reported in chapter five. Fifthly, the main study was carried after ensuring the methods were suitable and the study materials were ready to explore the aims of the research. The outcomes of the main study were reported in chapter six and analysed in chapter seven making references to results from the first and second pilot studies.

9.2 Research Question

The answers to the research questions formulated in this thesis to explore the concept of ECA are now discussed.

RQ1: What are the collaborative behaviours exhibited by the participants while interacting with an ECA game?

Observing the participants during gameplay was helpful in understanding the behaviours they exhibited during game play. Several behaviours were found in the three studies reported in chapters 4, 5, 6and 7 of this thesis and these include:

- **Giving directions/instructions** where a participant directs or instructs the partner
- **Making suggestions** where a participant puts forward an idea to the partner on what strategy to adopt which were not always accepted.
- **Playing silently** where were pairs played silently with no form of conversation or discussion i.e. did not communicate via talking during interaction with game.
- **Awareness of the map on the screen** where a participant points at the map on the screen and makes verbalizations
- **Asking for help from the researcher** where a participant asks for information from researcher
- **Arguing** where the participants discussed their interactions during game play with each giving their own different opinions.
- **Pointing at the screen** where a participant points at the screen
- **'Telling by showing'** where a participant shows partner what to do using the own controller while the partner watched.
- **Strategy negotiation** which includes pre-gameplay and in-gameplay strategy negotiations where pairs discussed the strategies they want to use during gameplay
- **Conflicts** which refers to disagreements between pairs which were always resolved and in some cases with explanations.
- **Non-conflict behaviours** where participant affirmed to partner's instructions without further explanations.
- **Copying partners actions** where participants glanced at their partner's controllers to copy what their partner was doing

- **Making enquiry** were participants asked the researcher or their partner's questions regarding gameplay, quitting game, scores or about the research being conducted.
- **Deictic gestures** which includes verbal and pointing instructions
- **Affective behaviours** including laughing, jumping, smiling, frowning, sighing, dancing, stamping foot on the ground, dropping arms and shouting
- **Dominating behaviours** were one of the pairs controlled the interaction through verbal instructions while the other passively obeyed. This behaviour however did not continue throughout the rest of the game play session and ended with the other player disagreeing or giving their own instructions. Dominating behaviours were observed in a mixed group where the boy in the group gave instructions severally to the partner during game play (the girl instructed the partner only twice during the entire game period)
- **'Tutoring behaviour'** where one child in a pair corrected the partner when the partner was not correctly pressing a key
- **Giving encouragement** where a participant motivated or encouraged the partner to continue playing even in difficult situation
- Not allowing partner dominate
- **Aggressive behaviours** where a child behaves in an angry way towards a partner by shouting at partner, hitting or pretending to hit partner and blaming partner at the end of game play
- **Distractions, loss of concentration and unwillingness to play** in groups which led poor performance during gameplay
- **Engagement** in groups which resulted to good performance during gameplay
- **Inter group interaction** where participants in one group tutored or enquired from the members of another group about their scores during gameplay. The interactions sometimes involved exchange of derogatory verbalizations.
- **Lack of understanding of how to collaborate** where some participants did not understand how to play the ECA game

RQ2: What factors influenced the participants' interactions during gameplay?

The unstructured interview sessions conducted after gameplay using the graphs of the participants' actions (interactions) as well as the post-test questionnaire helped to provide answers to this research question (**RQ2**). These results were reported in chapter 6 and discussed in chapter 7 of this thesis. Several factors that influenced the participants' interactions during gameplay are highlighted below:

- **Strategies adopted**: All groups developed strategies to play the game either before or during gameplay and these strategies were instrumental to how well they interacted. For example, the use of game features or copying partner's actions were helpful in knowing what actions to take whereas group that had no initial strategy struggled but then noticed the interaction map in the game which then helped them.
- **Synchronicity of response**: This relates to synchronous agreement between players interactions which occur when players press the same keys simultaneously. This is either influenced positively by a quick reaction to each other's interactions or negatively by slow response to each other's interactions. Difficulty in coordinating key presses can also make it difficult to agree on controller input.
- **Collaboration**: Ability to work together helped some groups to reach agreement while difficulty working together hindered some groups from reaching agreement.
- **Interaction issues:** This refers to the challenges posed by the controllers as the players interacted with the game. As seen in the second pilot study, one group reported that the dance mat was a "*…little bit unresponsive in places*" which resulted in a slow response during interaction. The participants may have found it challenging to put their foot in the right place on the mat while engaged in the game as more practice is required interact accurately with the dance mat. Also, the dance mat can be tiring to use, and the pace of interaction is naturally slower due to the larger body movements (gross movement of legs compare to fine movement of thumbs or wrist).
- **Familiarity with controller:** This refers to the degree of familiarity the participants felt with the controllers which can either foster or hinder collaboration. For example, one of the participants in the second pilot study mentioned that the game pad had strong single player connotations for them which could hinder collaboration. Conversely, one group

reported that they were not familiar with the tangible controller and dance mat which made them work together

- **Ease of use of controller:** This refers to the players' ability to easily interact with the controllers which in turn fosters collaboration
- **Accidental interactions:** This refers to when players generate game control inputs not planned or intended and this might hinder collaboration.
- **Awareness of actions:** This refers to how clearly a controller input can be seen by other players during interaction which can aid collaboration

RQ3: Are the behaviours identified in **RQ1** influenced by different input methods?
In the first and second pilot study reported in chapter four and five of this thesis, the participants grouped in pairs played the ECA game with three different input devices: gamepad, tangible controller and dance mat. Results from the studies indicate that there were no clear differences in the behaviours exhibited by the participants during interaction with the gamepad, dance mat and tangible controller. In the first pilot study, all the behaviours found were present in the gamepad condition, four of the behaviours in the dancemat, condition and a few (two of the behaviours) in the tangible condition. Also in the second pilot study, all the strategies were observed for various groups while playing with all the three controllers except for 'Not allowing partner dominate' and 'telling by showing' which occurred only in the gamepad condition in Groups A and C.

RQ4: What effect does ECA have on participants' gameplay experience?

Survey methods such as questionnaire and fun toolkit were used to elicit information from the participants regarding their gameplay experience during game play and were helpful in providing answers to **RQ4.** These were reported in chapters 4, 5, 6 and 7 of this thesis. The ECA game provided several gameplay experiences which are highlighted below:

- The participants displayed several positive and negative affective behaviours (such as shouting, laughing, singing, jumping, dancing, frowning, sighing, dropping arms down) during interaction with the ECA game which are normal expected behaviours during enjoyable gameplay.

- While none of the participants found any of the three controllers awful, they thought the dance mat was the most fun controller compared to the game pad and tangible controller. Also, the participants found the game pad to be easiest to play the game with compared to the dance mat and the tangible controller.
- Although the dance mat was the most fun controller for the participants, they indicated they would not like to play the ECA game again with it. This was attributed to the fact that the participants had no previous experience with the dance mat.
- The controllers the participants' ranked lowest on the funsorter was rated as 'not very good' using the smileyometer and those ranked highest on the funsorter were rated as 'brilliant' using the smileyometer.
- Some participants showed no variability in their score across the three constructs used in the funsorter ('most fun', easiest to play' and 'liked the most'). This could be as a result of some of the participants not understanding the differences between the constructs.
- The controllers that are fun or easy to use influenced some of the participants' decision on the controller they liked most.
- The participants enjoyed playing the ECA game more than the single-player version and several positive comments such as fun, challenging, cool, encouraged teamwork, friendship and communication were mentioned by the participants as the reasons. However, given a choice they prefer the single-player version to the ECA game and they mentioned some positive comments including easy, less confusing, allows more control and not distractive.

9.3 Contributions to knowledge

This research produced both major and minor contributions to knowledge and these are discussed below.

9.3.1 Major

- One of the major contributions of this research is the exploration of the concept of ECA, a type of interaction where participants aged between 11-16 years old have to synchronously generate the same control inputs in order to interact with a game using a range of existing methods for evaluating collaboration. These methods include both qualitative and quantitative data gathering and analysis approaches adapted to effectively evaluate ECA. Review of literature reported in Chapter 2 of this thesis revealed that while collaboration has been studied with children in co-located settings, most of the work focused on the design of interfaces to support co-present collaboration and on the use of technology to support children's collaborative interactions. No work has explored collaboration in the way described in this thesis. The SCOSS framework though closely related differed from ECA in that agreement is more explicit requiring children to click their individual 'we agree' button to proceed. Also, agreement and disagreement are more visually explicit providing a good resource for discussions during interactions. Additionally, ECA uses contemporary input methods and though participants have separate controllers, they can only move left, right or fire if they agree in their controller input while in SCOSS each child can control only their own task elements with their own mouse. This research also produced an ECA model which describes the various contexts where ECA can be applied i.e. the perceived effect of interaction and urgency within the context of gaming. Perceived effects of interaction refer to the degree to which an interaction influences gameplay while 'urgency' refers to how quickly players are required to react within the game environment. Four different contexts were identified including High-Urgency-Low-effect, High-Urgency-High-Effect, Low-Urgency-Low-Effect and Low-Urgency-High-Effect and these alter the way in which collaborative agreement is reached in different types of games.

- Another major contribution is the understanding of the collaborative behaviours participants adopted to reach agreement while interacting with the ECA game such as tutoring behaviours, non-conflict, conflict, inter group interactions etc. (full details of the behaviours are listed in section 8.3 of this chapter) and their associated design guidelines for designers wishing to design games/applications that incorporate ECA (highlighted in Chapter 7 section 7.4.1.).

9.3.2 Minor

- One of the minor contributions of this research is the understanding of UX within the context of ECA. In this research one dimension of UX, enjoyment, was explored and several observations were made. The studies reported in chapter 4, 5, 6 and 7 revealed various affective behaviours (such as laughing, dancing, jumping, smiling, singing, frowning, sighing and dropping arms down) displayed by the participants during interaction with the ECA game. The ECA game was more enjoyable than the single player because it is fun, challenging, encouraged teamwork, friendship and communication. However, if given a choice participants would prefer the single-player version to the ECA game because it is easy, less confusing, allows more control and not distractive. The participants reported the dance mat as most fun controller and would like to play the game again with it. While this finding supports previous research, there was evidence from first and second pilot studies that this might not always be the case as the participants reported the dancemat as the most fun controller to use and would not like to use it again due to lack of prior experience with the dance mat. This result further shows that teenagers were able to reveal through the use of fun toolkit how much they enjoyed playing the game with the dancemat and expressed their doubts on whether they would like to play the game again with the dancemat. This was attributed to the fact that those who participated in the study (11-16 years) are more cognitively advanced with improved reasoning skills compared to the younger children. Also it was found in the first and second pilot studies that the fun sorter on the construct of fun measures the same thing as the Smileyometer; this result supports previous research. Also, the controllers that are fun or easy to use influenced some of the participants' decision on the controller they liked most; participants that ranked a controller highest on the 'most fun' construct ranked the same controller as highest on the 'liked the most' construct whereas those that ranked a controller highest on the 'easiest to use' construct ranked the same controller as highest on the 'liked the most' construct..

- The second minor contribution of this research is the understanding of a range of interaction methods and how they influenced ECA. In the first and second pilot studies, participants played the ECA game using three interaction methods: gamepad, tangible controller and dance mat. The participants were unfamiliar with the dance mat and consequently it was challenging for them to interact with the controller although it was the most fun controller. On the other hand the game pad was easy to play the game as it was a familiar piece of technology for the participants. Thus, while unfamiliar technologies might be fun to use, familiar technologies are more suited for ECA games.

9.4 Research Limitations

The major limitation of this research work was gaining access to the participants intended to take part in the research. As research within ChiCI group is often carried out with school children at the time and convenience of the school, it was sometimes difficult to have access to these children such that their school activities are not disrupted. In some cases the schools were just not willing to grant access to the researcher to come into the schools to run studies. The researcher had to resort to running studies in a Mess day format but due to the nature of mess days and the nature of the research which involved use of several data collection methods and input technologies, it was again challenging for the researcher to get large numbers of participants to take part. This issue was however resolved as the researcher made contacts with several youth centres in Coventry and gained access to the children who attended the centres at their leisure times (after several failed attempts to gain access to children in schools within Coventry).

9.5 Future work

Future work will look to scale up ECA to a whole class and new application possibilities to explore what strategies the participants adopt to reach decision and control and whether they differ from those obtained using small groups. Scaling up ECA to a whole class would potentially help to turn single player games into multiplayer games so that the whole class can participate in an inclusive way. Additionally, the more general findings could be used to make ECA games for children.

While the application used to explore the concept of ECA in the research falls within the high-effective/high-urgency part of the ECA model, it would be interesting to explore applications in the other parts of the model and compare results.

Validation study will be conducted using experts such as interaction designers, teachers and social psychologist to see if the design guidelines produced in this research make sense as a piece of research in this sort of group work in the classroom context.

Findings of this research showed that while participants played for 10minutes, there was no increase in performance over time; hence ECA will be further explored using larger number of participants who will play for extended periods of time to see if the performance increases over time.

Also as mentioned in chapter7, agreement relies on participants pressing the same button simultaneously but there will always be a time lag between when a key is pressed and when agreement is reached (latency) as ECA involves human users. It would be useful to analyse the log files in future in order to calculate the latency and potentially recommend the figure to interaction designers as a design guideline.

9.6 Concluding Remarks

The work presented in this thesis provided insights into the concept of ECA, methods for evaluating ECA, the behaviours exhibited by participants while interacting with ECA enabled game and their associated design guidelines and the factors that influenced participants' interactions during game play. It is hoped that these insights presented in this thesis prove useful contribution to others working in the area and help stimulate further research.

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11 APPENDICES

The following are the appendices of the documents used for studies and data that were collected during the studies in this research. These have been presented according to the chapters where the documents are used and the relevant data is presented. Below are the lists of the appendix outline:

11.1 Appendix1: Chapter 1 Documents

Child Computer Interaction group

University of Central Lancashire

Preston PR1 2HE

www.chici.org

Dear Parent / Guardian,

Picture and Video/Audio Recording Consent form for your Ward

I am a PhD student and member of Child Computer Interaction Group at the University of Central Lancashire. I am embarking on a new piece of research exploring new ways of interacting with computers using a range of interaction techniques (such as Nintendo Wii Motes and PS1/2 dance Mats). I would like your child to take part in the evaluation sessions of this research which involve the use of video recorder to capture children's use of game controller, body positions and conversations while playing space invader game. Each evaluation session is expected to last for 30 minutes. It is very likely that your child's face would be captured during study sessions, but the video data would be safely stored on the University' network and not be used in publications/presentations. However, if there is a need to use the videos in publications/presentations, permission would be sought and your child's face distorted to prevent the issue of someone else recognizing your child.

In addition, the evaluation sessions will involve conducting an interview with your child. An audio recorder will be used during the interview sessions to record your child's responses to questions. I will not collect your child's personal information rather participant codes will be used for the purpose of anonymity. Names mentioned during the interview sessions will be changed when used in presentations or in any published document. The audio data obtained will be transcribed unabridged.

We also want to bring to your notice that pictures would be taken during the event and may be used for publicity purposes. However, adequate measures would be taken to ensure that your child's identity is protected i.e. making sure your child's names are not shown in the pictures and your child's face shown in images are distorted in any publication. The pictures and video/audio data will be stored on UCLAN's network and used strictly for my research however, all data will be destroyed after research is completed.

If you are happy for your child to be video/tape recorded and feature in photos taken while participating in the study, please fill out the consent form below and return it to yyyy. Please be assured that if you do not want your child to be photographed, video/tape recorded, I am more than happy to respect this and it will not affect their participation in the day's event.-

Name of Child...

I agree for my child (named above) to participate in the evaluation sessions on xx/xx/xxxx.

- ☐ *I understand evaluation sessions will be audio/video recorded*
- ☐ *I am happy for my child to be video/audio recorded*
- ☐ *I do not want my child to be video/audio recorded*
- ☐ *I am happy for my child to be photographed*
- ☐ *I request that my child does not appear in photographs*

Parent / Guardian signature...**Date**.................

11.2 Appendix2: Chapter 4 Documents

A. Arduino code for simulating keyboard keys (in $C^{\#}$)

```
#include <PS2X_lib.h>  //for v1.6
PS2X ps2x; // create PS2 Controller Class for the first dancemat
PS2X ps2x2; // create PS2 Controller Class for the second dancemat
//variable declaration
uint8_t keyC[8] = { 0, 0, 6, 0, 0, 0, 0 };
uint8_t keyZ[8] = { 0, 0, 29, 0, 0, 0, 0 };
uint8_t keyX[8] = { 0, 0, 27, 0, 0, 0, 0 };
uint8_t keyA[8] = { 0, 0, 4, 0, 0, 0, 0 };
uint8_t keyS[8] = { 0, 0, 22, 0, 0, 0, 0 };
uint8_t keyD[8] = { 0, 0, 7, 0, 0, 0, 0 };
uint8_t keyB[8] = { 0, 0, 5, 0, 0, 0, 0 };
uint8_t keyM[8] = { 0, 0, 16, 0, 0, 0, 0 };
uint8_t keyN[8] = { 0, 0, 17, 0, 0, 0, 0 };
uint8_t keyH[8] = { 0, 0, 11, 0, 0, 0, 0 };
uint8_t keyJ[8] = { 0, 0, 13, 0, 0, 0, 0 };
uint8_t keyK[8] = { 0, 0, 14, 0, 0, 0, 0 };

void setup(){
   Serial.begin(9600);
   ps2x.config_gamepad(13, 11, 10, 12, true, true);   // setup pins
   ps2x2.config_gamepad(3, 5, 2, 4, true, true);   // setup pins a
   delay(3000);
}

void loop(){
    ps2x.read_gamepad();  // We read entered value for the first dancemat

 if(ps2x.ButtonPressed(PSB_PAD_UP)) // if this value matches with top button;
   {
     Serial.write(keyX, 8);
     delay(100);// gives host time to read the key
   }
  else if(ps2x.ButtonReleased(PSB_PAD_UP))
   {
    Serial.write(keyS, 8);
    delay(100);
    }

  if(ps2x.ButtonPressed(PSB_PAD_LEFT)) // if this value matches with left button
   {
     Serial.write(keyZ, 8);
     delay(100);
   }
  else if(ps2x.ButtonReleased(PSB_PAD_LEFT))
   {
    Serial.write(keyA, 8);
    delay(100);
   }

  if(ps2x.ButtonPressed(PSB_PAD_RIGHT)) // if this value matches with right button
   {
    Serial.write(keyC, 8);
    delay(100);
   }
  else if(ps2x.ButtonReleased(PSB_PAD_RIGHT))
   {
    Serial.write(keyD, 8);
   delay(100);
   }
```

```
ps2x2.read_gamepad();      // We read entered value for the second dancemat

 if (ps2x2.ButtonPressed(PSB_PAD_UP))
    {
     Serial.write(keyN, 8);
     delay(100);
    }
  else if(ps2x2.ButtonReleased(PSB_PAD_UP))
    {
     Serial.write(keyJ, 8);
     delay(100);
    }

If (ps2x2.ButtonPressed(PSB_PAD_RIGHT)) // if this value matches with right button
    {
     Serial.write(keyM, 8);
     delay(100);
    }
  else if(ps2x2.ButtonReleased(PSB_PAD_RIGHT))
    {
     Serial.write(keyK, 8);
     delay(100);
    }

 if(ps2x2.ButtonPressed(PSB_PAD_LEFT)) // if this value matches with left button
    {
     Serial.write(keyB, 8);
     delay(100);
    }
   else if(ps2x2.ButtonReleased(PSB_PAD_LEFT))
    {
     Serial.write(keyH, 8);
         delay(100);
    }

   delay (100);

}
```

B. Codes for the space invaders game

The design of the game as mentioned in chapter two of this thesis followed an object oriented approach where classes were used to represent objects within the game. In total, there were 26 classes including the main class (spacegame.as). Some classes are similar and as a result, only the places where they differ would be stated. Also, the areas where the single-player version differs from the collaborative version of the game are stated. The design of the input technologies also differ: while gamepad and dance mat versions are basically the same (in ActionScript3.0) the tangible controller differ and is stated.

Single-Player Version

Alien3.as

```
package
{
	import flash.display.MovieClip;
	import flash.display.Stage;

	public class alien3 extends MovieClip
	{
		public var Level3:int = 0;
		public var Level3New:int = 0;
		public var IsInFront3:Boolean=false;
		public var alien3IsDead:Boolean=false;

		public function alien3(alienX:Number, alienY:Number)
		{
			this.x = alienX;
			this.y = alienY;

			this.scaleX = 0.7;
			this.scaleY = 0.7;

		}
	}

}
```

Aliens3.as

```
package
{
	import flash.display.MovieClip;
	import flash.display.Stage;
	import flash.utils.Timer;
	import flash.events.TimerEvent;
	import flash.display.Sprite;
	import flash.media.Sound;
	import flash.media.SoundChannel;
	import flash.sensors.Accelerometer;

	public class aliens3 extends MovieClip
	{
		public var aliensNumberX:Number = 7;
		public var aliensNumberY:Number = 5;
```

```
			public var aliensList:Array = new Array(aliensNumberX);
			private var aliensX:Number = 80;
			private var aliensY:Number = 80;
			private var left:Number = aliensX;
			private var right:Number = 0;
			private var bottom:Number = 0;
			private var top:Number = aliensY;
			public var moveX:Number = 4;
			public var moveY:Number = 9;
			private var moveH:Number = 1;
			private var moveV:Number = 0;
			private var shieldsList:Array;
			private var shieldsList1:Array;
			private var shieldsList2:Array;
			private var shieldsList3:Array;
			private var shieldsList4:Array;
			private var shieldsList5:Array;
			private var shieldsList6:Array;
			private var shieldsList7:Array;
			public var bombList:Array = new Array  ;
			public var bombList1:Array = new Array  ;
			public var bombList2:Array = new Array  ;
			public var bonus1List:Array = new Array  ;
			public var bonus2List:Array = new Array  ;
			public var bonus3List:Array = new Array  ;
			public var bombDroppingTimer:Timer = new Timer(3300);
			public var bonusDroppingTimer:Timer = new Timer(8000);
			public var nbonusDroppingTimer:Timer = new Timer(15000);
			public var mbonusDroppingTimer:Timer = new Timer(20000);
			private var moveRight:Boolean = true;
			private var moveDown:Boolean = false;
			private var collideShield:Boolean = false;
			private var mStage:Stage;
			private var mSprite:Sprite = new Sprite  ;
			private var xIncrement:Number = 95;
			private var yIncrement:Number = 75;
			public var movementTimer:Timer = new Timer(50);
			private var localShieldList:Array;
			private var localShieldList1:Array;
			private var localShieldList2:Array;
			private var localShieldList3:Array;
			private var localShieldList4:Array;
			private var localShieldList5:Array;
			private var localShieldList6:Array;
			private var localShieldList7:Array;
			private var localGameTimer:Timer;
			private var localAliens1:alien1;
			private var objGameTimer:gametimer;
			private var objBonus1:bonus1;
	public function aliens3(mainStage:Stage, mainSprite:Sprite, shieldList:Array, shieldList1:Array, shieldList2:Array,
shieldList3:Array, shieldList4:Array, shieldList5:Array, shieldList6:Array, shieldList7:Array,oGameTimer:gametimer)
		{
			mStage = mainStage;
			mSprite = mainSprite;
			localShieldList = shieldList;
			localShieldList1 = shieldList1;
			localShieldList2 = shieldList2;
			localShieldList3 = shieldList3;
			localShieldList4 = shieldList4;
			localShieldList5 = shieldList5;
			localShieldList6 = shieldList6;
			localShieldList7 = shieldList7;
			objGameTimer = oGameTimer;
```

```
createAliens();
movementTimer.addEventListener(TimerEvent.TIMER,movementTimerEventHandler);
movementTimer.start();
bombDroppingTimer.addEventListener(TimerEvent.TIMER,bombDroppingTimerEventHandler);
bombDroppingTimer.start();
bonusDroppingTimer.addEventListener(TimerEvent.TIMER,bonusDroppingTimerEventHandler);
bonusDroppingTimer.start();
nbonusDroppingTimer.addEventListener(TimerEvent.TIMER,nbonusDroppingTimerEventHandler);
nbonusDroppingTimer.start();
mbonusDroppingTimer.addEventListener(TimerEvent.TIMER,mbonusDroppingTimerEventHandler);
mbonusDroppingTimer.start();
}
private function createAliens()
{
var xPos:Number = aliensX;
var yPos:Number = aliensY;
var objAlien:alien3;
for (var i:int = 0; i < aliensNumberY; i++)
{
aliensList[i] = new Array(aliensNumberX);
for (var j:int = 0; j < aliensNumberX; j++)
{
objAlien = new alien3(xPos,yPos);
objAlien.Level3 = i;
if (i == aliensNumberY - 1){
objAlien.IsInFront3 = true;
}
aliensList[i][j] = objAlien;
mSprite.addChild(aliensList[i][j]);
xPos +=  xIncrement;
}
yPos +=  yIncrement;//Increae vertical position
xPos = aliensX;//Reset XPos to start on next line
}
}

private function movementTimerEventHandler(evt:TimerEvent)
{
if (AllDead())
{
spacegame.instance.logString2("Game over: All Alien Dead!")
movementTimer.stop();
bombDroppingTimer.stop();
bonusDroppingTimer.stop();
nbonusDroppingTimer.stop();
mbonusDroppingTimer.stop();
spacegame.instance.checkEndGame();
}
if(AlienHasCollideShield() || AlienHasCollideShield1() || AlienHasCollideShield2() || AlienHasCollideShield3()
|| AlienHasCollideShield4() || AlienHasCollideShield5() || AlienHasCollideShield6() || AlienHasCollideShield7())
{
spacegame.instance.logString2("Game over: Alien hit Shield")
movementTimer.stop();
bombDroppingTimer.stop();
bonusDroppingTimer.stop();
nbonusDroppingTimer.stop();
mbonusDroppingTimer.stop();
spacegame.instance.checkEndGame();
}
if (right >= mStage.stageWidth)
{
moveRight = false;
moveDown = true;
```

```
			right = 0;
		}
		if (left <= 24)
		{
			moveRight = true;
			moveAliensDown();
			left = 25;
		}
		if (top <= 10)
		{
			moveDown = true;
		}
		if (bottom >= mStage.stageHeight)
		{
			moveDown = false;
		}
		if (moveRight == true && moveDown == false)
		{
			moveAliensRight();
		}
		if (moveRight == false && moveDown == true)
		{
			moveAliensDown();
			moveDown = false;
		}
		if (moveRight == false && moveDown == false)
		{
			moveAliensLeft();
		}

	}
	public function moveAliensDown()
	{
		var objAlien:alien3;
		var minBottom:Number = mStage.stageHeight;
		moveV = 5;
		for (var i:int = 0; i < aliensNumberY; i++)
		{
			for (var j:int = 0; j < aliensNumberX; j++)
			{
				objAlien = aliensList[i][j];
				if (objAlien == null)
				{
					break;
				}
				objAlien.y +=  moveY * moveV;
				if ((objAlien.y + objAlien.height < minBottom) && objAlien.visible)
				{
					minBottom = objAlien.y + objAlien.height;
				}
			}
		}
		bottom = minBottom;
	}

	public function moveAliensLeft()
	{
		var objAlien:alien3;
		var minTop:Number = mStage.stageWidth;
		var minLeft:Number = mStage.stageWidth;
		moveH = -1;
		for (var i:int = 0; i < aliensNumberY; i++)
		{
```

```
                for (var j:int = 0; j < aliensNumberX; j++)
                {
                        objAlien = aliensList[i][j];
                        if (objAlien == null)
                        {
                                break;
                        }
                        objAlien.x +=  moveX * moveH;
                        if ((objAlien.x < minLeft) && objAlien.visible)
                        {
                                minLeft = objAlien.x;
                        }
                }
        }
        left = minLeft;
}
public function moveAliensRight()
{
        var objAlien:alien3;
        var maxRight:Number = 0;
        moveH = 1;
        for (var i:int = 0; i < aliensNumberY; i++)
        {
                for (var j:int = 0; j < aliensNumberX; j++)
                {
                        objAlien = aliensList[i][j];
                        if (objAlien == null)
                        {
                                break;
                        }
                        objAlien.x +=  moveX * moveH;
                        if ((objAlien.x + objAlien.width > maxRight) && objAlien.visible)
                        {
                                maxRight = objAlien.x + objAlien.width;
                        }
                }
        }
        right = maxRight;
}

public function moveAliens()
{
        var objAlien:alien3;
        var xPos:Number;
        var yPos:Number;

        for (var i:int = 0; i < aliensNumberY; i++)
        {
                for (var j:int = 0; j < aliensNumberX; j++)
                {
                        objAlien = aliensList[i][j];
                        if (objAlien == null)
                        {
                                break;
                        }
                        xPos = objAlien.x + moveX * moveH;
                        yPos = objAlien.y + moveY * moveV;

                        if (xPos > mStage.stageWidth)
                        {
                                moveH = -1;
                                objAlien.x +=  moveX * moveH;
                                objAlien.y +=  moveY;
```

```
                    }
                    else if (xPos < 10)
                    {
                        moveH = 1;
                        objAlien.x +=  moveX * moveH;
                        objAlien.y +=  moveY;
                    }
                    else
                    {
                        objAlien.x +=  moveX * moveH;
                    }
                }
            }
        }

        private function bombDroppingTimerEventHandler(evt:TimerEvent)
        {
            dropBombs();
            objGameTimer.bomb3 = bombList.length;

        }
        private function bonusDroppingTimerEventHandler (evt:TimerEvent)
        {
            dropBonus();
            objGameTimer.bonus3 = bonus1List.length;

        }
        private function nbonusDroppingTimerEventHandler (evt:TimerEvent)
        {
            dropnBonus();
            objGameTimer.nbonus3 = bonus2List.length;

        }
        private function mbonusDroppingTimerEventHandler (evt:TimerEvent)
        {
            dropmBonus();
            objGameTimer.mbonus3 = bonus3List.length;

        }
        public function dropAbomb(oAlien3:alien3)
        {
                bombList.push(new bomb3(mStage,mSprite,oAlien3,localShieldList,localShieldList1,
localShieldList2, localShieldList3, localShieldList4, localShieldList5, localShieldList6, localShieldList7));

        }
        public function dropAbonus(oAlien3:alien3)
        {
                bonus1List.push(new bonus3(mStage,mSprite,oAlien3,localShieldList,localShieldList1,
localShieldList2, localShieldList3, localShieldList4, localShieldList5, localShieldList6, localShieldList7));
        }
        public function dropAnbonus(oAlien3:alien3)
        {
                bonus2List.push(new nbonus3(mStage,mSprite,oAlien3,localShieldList,localShieldList1,
localShieldList2, localShieldList3, localShieldList4, localShieldList5, localShieldList6, localShieldList7));
        }
        public function dropAmbonus(oAlien3:alien3)
        {
                bonus3List.push(new mbonus3(mStage,mSprite,oAlien3,localShieldList, localShieldList1,
localShieldList2, localShieldList3, localShieldList4, localShieldList5, localShieldList6, localShieldList7));
        }
        public function dropBombs()
        {
            var objAlien3:alien3;
```

```
			//var objAlien:alien;
			//var objAlien1:alien1;
			for (var i:int = 0; i < aliensNumberY; i++)
			{
				for (var j:int = 0; j < aliensNumberX; j++)
				{
					objAlien3 = aliensList[i][j];
					objAlien3.Level3 = i;
					if (i == aliensNumberY - 1)
					{
						objAlien3.IsInFront3 = true;
					}
					if (objAlien3.IsInFront3 && objAlien3.visible && Math.random () <0.3)
					{
						dropAbomb(objAlien3);
						//dropAbonus1(objAlien,objAlien1,objAlien3);

					}
				}
			}
		}
		public function dropBonus()
		{
			var objAlien3:alien3;

			for (var i:int = 0; i < aliensNumberY; i++)
			{
				for (var j:int = 0; j < aliensNumberX; j++)
				{
					objAlien3 = aliensList[i][j];
					if (objAlien3.IsInFront3 && objAlien3.visible && Math.random() < 0.05)
					{
						//dropAbomb(objAlien3);
						dropAbonus(objAlien3);
					}
				}
			}
		}
		public function dropnBonus()
		{
			var objAlien3:alien3;
			var objAlien:alien;
			var objAlien1:alien1;
			for (var i:int = 0; i < aliensNumberY; i++)
			{
				for (var j:int = 0; j < aliensNumberX; j++)
				{
					objAlien3 = aliensList[i][j];
					if (objAlien3.IsInFront3 && objAlien3.visible && Math.random() < 0.05)
					{
						//dropAbomb(objAlien3);
						dropAnbonus(objAlien3);

					}
				}
			}
		}
		public function dropmBonus()
		{
			var objAlien3:alien3;

			for (var i:int = 0; i < aliensNumberY; i++)
			{
```

```
				for (var j:int = 0; j < aliensNumberX; j++)
				{
					objAlien3 = aliensList[i][j];
					if (objAlien3.IsInFront3 && objAlien3.visible && Math.random() < 0.05)
					{

						dropAmbonus(objAlien3);

					}
				}
			}
		}
		public function AllDead():Boolean
		{
			var objAlien:alien3;
			var isDead:Boolean = true;

			for (var i:int = 0; i < aliensNumberY; i++)
			{
				for (var j:int = 0; j < aliensNumberX; j++)
				{
					objAlien = aliensList[i][j];
					if (objAlien.visible)
					{
						isDead = false;
					}
				}
			}

			return isDead;

		}
		public function AlienHasCollideShield():Boolean
		{
			var objAlien:alien3;
			var hasCollide:Boolean = false;

			for (var i:int = 0; i < aliensNumberY; i++)
			{
				for (var j:int = 0; j < aliensNumberX; j++)
				{
					objAlien = aliensList[i][j];
					if (objAlien.visible)
					{
						if (AlienCollideShield(objAlien))
						{
							hasCollide = true;
							break;
						}
					}

				}
			}
			return hasCollide;
		}
		private function AlienCollideShield(al:alien3):Boolean
		{
			var objShield:shield;
			var xCollide:Boolean = false;
			var yCollide:Boolean = false;
			var hasCollide:Boolean = false;
			for (var i:int=0; i<localShieldList.length; i++)
			{
```

```
			objShield = localShieldList[i];
			xCollide = (objShield.x<=al.x+al.width) && (al.x+al.width<=(objShield.x+objShield.width));
			yCollide = (objShield.y<=al.y+al.height) && (al.y+al.height<=(objShield.y+objShield.height));
				if (xCollide && yCollide && (objShield.visible == true))
				{
					hasCollide = true;
					break;
				}
			}
			return hasCollide;
		}
public function AlienHasCollideShield1():Boolean
		{
			var objAlien:alien3;
			var hasCollide:Boolean = false;

			for (var i:int = 0; i < aliensNumberY; i++)
			{
				for (var j:int = 0; j < aliensNumberX; j++)
				{
					objAlien = aliensList[i][j];
					if (objAlien.visible)
					{
						if (AlienCollideShield1(objAlien))
						{
							hasCollide = true;
							break;
						}
					}

				}
			}
			return hasCollide;
		}
		private function AlienCollideShield1(al:alien3):Boolean
		{
			var objShield:shield1;
			var xCollide:Boolean = false;
			var yCollide:Boolean = false;
			var hasCollide:Boolean = false;
			for (var i:int=0; i<localShieldList1.length; i++)
			{
				objShield = localShieldList1[i];
				xCollide = (objShield.x<=al.x+al.width) && (al.x+al.width<=(objShield.x+objShield.width));
				yCollide = (objShield.y<=al.y+al.height) &&
(al.y+al.height<=(objShield.y+objShield.height));
				if (xCollide && yCollide &&(objShield.visible == true))
				{
					hasCollide = true;
					break;
				}
			}
			return hasCollide;
		}
public function AlienHasCollideShield2():Boolean
		{
			var objAlien:alien3;
			var hasCollide:Boolean = false;
			for (var i:int = 0; i < aliensNumberY; i++)
			{
				for (var j:int = 0; j < aliensNumberX; j++)
				{
					objAlien = aliensList[i][j];
```

```
						if (objAlien.visible)
						{
							if (AlienCollideShield2(objAlien))
							{
								hasCollide = true;
								break;
							}
						}

					}
				}
				return hasCollide;
			}
			private function AlienCollideShield2(al:alien3):Boolean
			{
				var objShield:shield2;
				var xCollide:Boolean = false;
				var yCollide:Boolean = false;
				var hasCollide:Boolean = false;

				for (var i:int=0; i<localShieldList2.length; i++)
				{
					objShield = localShieldList2[i];
					xCollide = (objShield.x<=al.x+al.width) && (al.x+al.width<=(objShield.x+objShield.width));
					yCollide = (objShield.y<=al.y+al.height) &&
(al.y+al.height<=(objShield.y+objShield.height));
					if (xCollide && yCollide && (objShield.visible == true))
					{
						hasCollide = true;
						break;
					}
				}
				return hasCollide;
			}
			public function AlienHasCollideShield3():Boolean{
				var objAlien:alien3;
				var hasCollide:Boolean = false;
				for (var i:int = 0; i < aliensNumberY; i++){
					for (var j:int = 0; j < aliensNumberX; j++){
						objAlien = aliensList[i][j];
						if (objAlien.visible){
							if (AlienCollideShield3(objAlien)){
								hasCollide = true;
								break;
							}
						}
					}
				}
				return hasCollide;
			}
			private function AlienCollideShield3(al:alien3):Boolean
			{
				var objShield:shield3;
				var xCollide:Boolean = false;
				var yCollide:Boolean = false;
				var hasCollide:Boolean = false;
				for (var i:int=0; i<localShieldList3.length; i++)
				{
					objShield = localShieldList3[i];
					xCollide = (objShield.x<=al.x+al.width) && (al.x+al.width<=(objShield.x+objShield.width));
					yCollide = (objShield.y<=al.y+al.height) &&
(al.y+al.height<=(objShield.y+objShield.height));
					if (xCollide && yCollide && (objShield.visible == true))
```

```
					{
						hasCollide = true;
						break;
					}
				}
				return hasCollide;
			}
			public function AlienHasCollideShield4():Boolean
			{
				var objAlien:alien3;
				var hasCollide:Boolean = false;

				for (var i:int = 0; i < aliensNumberY; i++)
				{
					for (var j:int = 0; j < aliensNumberX; j++)
					{
						objAlien = aliensList[i][j];
						if (objAlien.visible)
						{
							if (AlienCollideShield4(objAlien))
							{
								hasCollide = true;
								break;
							}
						}
					}
				}
				return hasCollide;
			}
			private function AlienCollideShield4(al:alien3):Boolean
			{
				var objShield:shield4;
				var xCollide:Boolean = false;
				var yCollide:Boolean = false;
				var hasCollide:Boolean = false;
				for (var i:int=0; i<localShieldList4.length; i++)
				{
					objShield = localShieldList4[i];
					xCollide = (objShield.x<=al.x+al.width) && (al.x+al.width<=(objShield.x+objShield.width));
					yCollide = (objShield.y<=al.y+al.height) &&
(al.y+al.height<=(objShield.y+objShield.height));
					if (xCollide && yCollide && (objShield.visible == true))
					{
						hasCollide = true;
						break;
					}
				}
				return hasCollide;
			}
public function AlienHasCollideShield5():Boolean
			{
				var objAlien:alien3;
				var hasCollide:Boolean = false;

				for (var i:int = 0; i < aliensNumberY; i++)
				{
					for (var j:int = 0; j < aliensNumberX; j++)
					{
						objAlien = aliensList[i][j];
						if (objAlien.visible)
						{
							if (AlienCollideShield5(objAlien))
							{
```

```
							hasCollide = true;
							break;
						}
					}
				}
			}
			return hasCollide;
		}
		private function AlienCollideShield5(al:alien3):Boolean
		{
			var objShield:shield5;
			var xCollide:Boolean = false;
			var yCollide:Boolean = false;
			var hasCollide:Boolean = false;
			for (var i:int=0; i<localShieldList5.length; i++)
			{
				objShield = localShieldList5[i];
				xCollide = (objShield.x<=al.x+al.width) && (al.x+al.width<=(objShield.x+objShield.width));
				yCollide = (objShield.y<=al.y+al.height) &&
(al.y+al.height<=(objShield.y+objShield.height));
				if (xCollide && yCollide && (objShield.visible == true))
				{
					hasCollide = true;
					break;
				}
			}
			return hasCollide;
		}
		public function AlienHasCollideShield6():Boolean
		{
			var objAlien:alien3;
			var hasCollide:Boolean = false;

			for (var i:int = 0; i < aliensNumberY; i++)
			{
				for (var j:int = 0; j < aliensNumberX; j++)
				{
					objAlien = aliensList[i][j];
					if (objAlien.visible)
					{
						if (AlienCollideShield6(objAlien))
						{
							hasCollide = true;
							break;
						}
					}
				}
			}
			return hasCollide;
		}
		private function AlienCollideShield6(al:alien3):Boolean
		{
			var objShield:shield6;
			var xCollide:Boolean = false;
			var yCollide:Boolean = false;
			var hasCollide:Boolean = false;
			for (var i:int=0; i<localShieldList6.length; i++)
			{
				objShield = localShieldList6[i];
				xCollide = (objShield.x<=al.x+al.width) && (al.x+al.width<=(objShield.x+objShield.width));
				yCollide = (objShield.y<=al.y+al.height) &&
(al.y+al.height<=(objShield.y+objShield.height));
				if (xCollide && yCollide && (objShield.visible == true))
```

```
                        {
                                hasCollide = true;
                                break;
                        }
                }
                return hasCollide;
        }

        public function AlienHasCollideShield7():Boolean
        {
                var objAlien:alien3;
                var hasCollide:Boolean = false;

                for (var i:int = 0; i < aliensNumberY; i++)
                {
                        for (var j:int = 0; j < aliensNumberX; j++)
                        {
                                objAlien = aliensList[i][j];
                                if (objAlien.visible)
                                {
                                        if (AlienCollideShield7(objAlien))
                                        {
                                                hasCollide = true;
                                                break;
                                        }
                                }
                        }
                }
                return hasCollide;
        }
        private function AlienCollideShield7(al:alien3):Boolean
        {
                var objShield:shield7;
                var xCollide:Boolean = false;
                var yCollide:Boolean = false;
                var hasCollide:Boolean = false;
                for (var i:int=0; i<localShieldList7.length; i++)
                {
                        objShield = localShieldList7[i];
                        xCollide = (objShield.x<=al.x+al.width) && (al.x+al.width<=(objShield.x+objShield.width));
                        yCollide = (objShield.y<=al.y+al.height) &&
(al.y+al.height<=(objShield.y+objShield.height));
                        if (xCollide && yCollide && (objShield.visible == true))
                        {
                                hasCollide = true;
                                break;
                        }
                }
                return hasCollide;
        }
    }//End Class
}//End Package
```

Bomb3.as

```
package
{
	import flash.display.MovieClip;
	import flash.display.Stage;
	import flash.utils.Timer;
	import flash.events.TimerEvent;
	import flash.display.Sprite;
	public class bomb3 extends MovieClip
	{
			public var bombVpos:Number = 0;
			private var bombTimer:Timer = new Timer(1);
			private var moveY:Number = 5;
			private var localShieldList:Array;
			private var localShieldList1:Array;
			private var localShieldList2:Array;
			private var localShieldList3:Array;
			private var localShieldList4:Array;
			private var localShieldList5:Array;
			private var localShieldList6:Array;
			private var localShieldList7:Array;
			private var collideShield:Boolean = false;
			private var mStage:Stage;
			private var mSprite:Sprite;
			public function bomb3(mainStage:Stage, mainSprite:Sprite, oAlien:alien3, shieldList:Array, shieldList1:Array,
shieldList2:Array, shieldList3:Array, shieldList4:Array, shieldList5:Array, shieldList6:Array, shieldList7:Array)
			{
				mStage = mainStage;
				mSprite = mainSprite;
				localShieldList = shieldList;
				localShieldList1 = shieldList1;
				localShieldList2 = shieldList2;
				localShieldList3 = shieldList3;
				localShieldList4 = shieldList4;
				localShieldList5 = shieldList5;
				localShieldList6 = shieldList6;
				localShieldList7 = shieldList7;
				bombTimer.addEventListener(TimerEvent.TIMER, bombTimerEventHandler);
				this.x = oAlien.x + oAlien.width * 1 / 2;
				this.y = oAlien.y + oAlien.height;
				mSprite.addChild(this);
				bombTimer.start();
			}
			private function bombTimerEventHandler(evt:TimerEvent)
			{
				HasCollidedShield();
				HasCollidedShield1();
				HasCollidedShield2();
				HasCollidedShield3();
				HasCollidedShield4();
				HasCollidedShield5();
				HasCollidedShield6();
				HasCollidedShield7();
				if (collideShield)
				{
					parent.removeChild(this);
					bombTimer.stop();
				}
				this.y +=  moveY;
				if (this.y >= mStage.stageHeight)
				{
					this.visible = false;
				}
```

```
}

private function HasCollidedShield()
{
	var shieldXpos:Number;
	var shieldYpos:Number;
	var objShield:shield;
	var xCollide:Boolean = false;
	var yCollide:Boolean = false;
	for (var i:int=0; i<localShieldList.length; i++)
	{
		objShield = localShieldList[i];
		shieldXpos = objShield.x;
		shieldYpos = objShield.y;
		xCollide=(shieldXpos<=this.x) && (this.x<=shieldXpos+objShield.width);
		yCollide=(shieldYpos<=this.y) && (this.y<=shieldYpos+objShield.height);
		if ((xCollide && yCollide && (objShield.visible == true)))
		{
			collideShield = true;
			objShield.visible = false;
		}
	}
}
private function HasCollidedShield1()
{
	var shieldXpos:Number;
	var shieldYpos:Number;
	var objShield:shield1;
	var xCollide:Boolean = false;
	var yCollide:Boolean = false;
	for (var i:int=0; i<localShieldList1.length; i++)
	{
		objShield = localShieldList1[i];
		shieldXpos = objShield.x;
		shieldYpos = objShield.y;
		xCollide=(shieldXpos<=this.x) && (this.x<=shieldXpos+objShield.width);
		yCollide=(shieldYpos<=this.y) && (this.y<=shieldYpos+objShield.height);
		if ((xCollide && yCollide && (objShield.visible == true)))
		{
			collideShield = true;
			objShield.visible = false;
		}
	}
}
private function HasCollidedShield2()
{
	var shieldXpos:Number;
	var shieldYpos:Number;
	var objShield:shield2;
	var xCollide:Boolean = false;
	var yCollide:Boolean = false;

	for (var i:int=0; i<localShieldList2.length; i++)
	{
		objShield = localShieldList2[i];
		shieldXpos = objShield.x;
		shieldYpos = objShield.y;
		xCollide=(shieldXpos<=this.x) && (this.x<=shieldXpos+objShield.width);
		yCollide=(shieldYpos<=this.y) && (this.y<=shieldYpos+objShield.height);
		if ((xCollide && yCollide && (objShield.visible == true)))
		{
			collideShield = true;
			objShield.visible = false;
```

```
			}
		}
	}
	private function HasCollidedShield3()
	{
		var shieldXpos:Number;
		var shieldYpos:Number;
		var objShield:shield3;
		var xCollide:Boolean = false;
		var yCollide:Boolean = false;
		for (var i:int=0; i<localShieldList3.length; i++)
		{
			objShield = localShieldList3[i];
			shieldXpos = objShield.x;
			shieldYpos = objShield.y;
			xCollide=(shieldXpos<=this.x) && (this.x<=shieldXpos+objShield.width);
			yCollide=(shieldYpos<=this.y) && (this.y<=shieldYpos+objShield.height);
			if ((xCollide && yCollide && (objShield.visible == true)))
			{
				collideShield = true;
				objShield.visible = false;
			}
		}
	}
	private function HasCollidedShield4()
	{
		var shieldXpos:Number;
		var shieldYpos:Number;
		var objShield:shield4;
		var xCollide:Boolean = false;
		var yCollide:Boolean = false;
		for (var i:int=0; i<localShieldList4.length; i++)
		{
			objShield = localShieldList4[i];
			shieldXpos = objShield.x;
			shieldYpos = objShield.y;
			xCollide=(shieldXpos<=this.x) && (this.x<=shieldXpos+objShield.width);
			yCollide=(shieldYpos<=this.y) && (this.y<=shieldYpos+objShield.height);
			if ((xCollide && yCollide && (objShield.visible == true)))
			{
				collideShield = true;
				objShield.visible = false;
			}
		}
	}
	private function HasCollidedShield5()
	{
		var shieldXpos:Number;
		var shieldYpos:Number;
		var objShield:shield5;
		var xCollide:Boolean = false;
		var yCollide:Boolean = false;
		for (var i:int=0; i<localShieldList5.length; i++)
		{
			objShield = localShieldList5[i];
			shieldXpos = objShield.x;
			shieldYpos = objShield.y;
			xCollide=(shieldXpos<=this.x) && (this.x<=shieldXpos+objShield.width);
			yCollide=(shieldYpos<=this.y) && (this.y<=shieldYpos+objShield.height);
			if ((xCollide && yCollide && (objShield.visible == true)))
			{
				collideShield = true;
				objShield.visible = false;
```

```
                }
            }
        }
        private function HasCollidedShield6()
        {
            var shieldXpos:Number;
            var shieldYpos:Number;
            var objShield:shield6;
            var xCollide:Boolean = false;
            var yCollide:Boolean = false;
            for (var i:int=0; i<localShieldList6.length; i++)
            {
                objShield = localShieldList6[i];
                shieldXpos = objShield.x;
                shieldYpos = objShield.y;
                xCollide=(shieldXpos<=this.x) && (this.x<=shieldXpos+objShield.width);
                yCollide=(shieldYpos<=this.y) && (this.y<=shieldYpos+objShield.height);
                if ((xCollide && yCollide && (objShield.visible == true)))
                {
                    collideShield = true;
                    objShield.visible = false;
                }
            }
        }
        private function HasCollidedShield7()
        {
            var shieldXpos:Number;
            var shieldYpos:Number;
            var objShield:shield7;
            var xCollide:Boolean = false;
            var yCollide:Boolean = false;
            for (var i:int=0; i<localShieldList7.length; i++)
            {
                objShield = localShieldList7[i];
                shieldXpos = objShield.x;
                shieldYpos = objShield.y;
                xCollide=(shieldXpos<=this.x) && (this.x<=shieldXpos+objShield.width);
                yCollide=(shieldYpos<=this.y) && (this.y<=shieldYpos+objShield.height);
                if ((xCollide && yCollide && (objShield.visible == true)))
                {
                    collideShield = true;
                    //spacegame.instance.logString2("Bomb hits Shield 8");
                    objShield.visible = false;
                }//left
            }//for
        }//function

    }

}
```

NOTE: bonus.as, **nbonus.as** and **mbonus.as** class are similar to bomb class except that they move downwards randomly at different times and increases the score by 5, 10 and 20 respectively when they collide with the snowman. Also **bullet.as** is similar to the bomb.as class except that it moves upwards rather than downwards, kills the birds when they collide and increases scroes by 10, and is controlled by the player.

GameTimer.as

```
package
{
	import flash.display.MovieClip;
	import flash.display.Stage;
	import flash.utils.Timer;
	import flash.events.TimerEvent;
	import flash.text.TextField;
	import flash.display.Sprite;
	import flash.text.TextFormat;
	public class gametimer
	{
		public var gTimer:Timer = new Timer(100);
		public var sTimer:Timer = new Timer(1000);
		public var scoreHitAlien:Number = 0;
		private var mStage:Stage;
		private var txtTime:TextField;
		private var txtScore:TextField;
		private var txtFrmt:TextFormat;
		public var valTime:Number = 0;
		public var bomb3:Number = 0;
		public var bonus3:Number = 0;
		public var nbonus3:Number = 0;
		public var mbonus3:Number = 0;
		public function gametimer(mainStage:Stage, mSprite:Sprite)
		{
			var txtFrmt:TextFormat = new TextFormat  ;
			txtFrmt.size = 12;
			txtFrmt.font = "verdana";
			txtTime = new TextField  ;
			txtTime.scaleX = 2;
			txtTime.scaleY = 2;
			txtTime.x = 1;
			txtTime.y = 30;
			txtTime.textColor = 0xffffff;
			txtTime.width = 200;
			txtTime.defaultTextFormat = txtFrmt;
			txtTime.text = "Time : 0";
			mSprite.addChild(txtTime);
			var txtFrmt1:TextFormat = new TextFormat  ;
			txtFrmt1.size = 14;
			txtFrmt1.font = "times new roman";
			txtFrmt.bold = true;
			txtScore = new TextField  ;
			txtScore.scaleX = 2;
			txtScore.scaleY = 2;
			txtScore.x = 350;
			txtScore.y = 30;
			txtScore.textColor = 0xffffff;
			txtScore.width = 200;
			txtScore.defaultTextFormat = txtFrmt1;
			mSprite.addChild(txtScore);
			gTimer.addEventListener(TimerEvent.TIMER,gTimerEventHandler);
			gTimer.start();
			sTimer.addEventListener(TimerEvent.TIMER,sTimerEventHandler);
			sTimer.start();
		}
		private function gTimerEventHandler(evt:TimerEvent)
		{
			txtScore.text = " " + String(scoreHitAlien);
		}
```

```
		private function sTimerEventHandler(evt:TimerEvent)
		{
			valTime +=  1;
			txtTime.text = "Time : " + String(valTime);
			spacegame.instance.aliensSpeed();
		}

	}

}
```

Player1.as

```
package
{
	import flash.display.MovieClip;
	import flash.display.Stage;
	import flash.utils.Timer;
	import flash.utils.*;
	import flash.events.TimerEvent;
	import flash.display.Sprite;
	import flash.events.*;
	import flash.text.TextField;
	import flash.text.TextFormat;
	import flash.media.Sound;
	import flash.media.SoundChannel;
	import flash.utils.Endian;
	import flash.filesystem.File;
	import flash.filesystem.FileMode;
	import flash.filesystem.FileStream;
	public class player extends MovieClip
	{
		private var xPos:Number;
		private var yPos:Number;
		private var moveX:Number = 15;
		private var localShieldList:Array;
		private var localShieldList1:Array;
		private var localShieldList2:Array;
		private var localShieldList3:Array;
		private var localShieldList4:Array;
		private var localShieldList5:Array;
		private var localShieldList6:Array;
		private var localShieldList7:Array;
		public var collideBomb3:Boolean = false;
		private var mStage:Stage;
		private var mSprite:Sprite = new Sprite  ;
		private var localAliens3:aliens3;
		private var collisionTimer:Timer = new Timer(100);
		private var playerPositionTimer:Timer = new Timer(1000);
		private var objGameTimer:gametimer;
		public var file1:File = File.desktopDirectory.resolvePath( "Single_d_p1Right.txt" );
		public var file10:File = File.desktopDirectory.resolvePath( "Single_d_p1Left.txt" );
		public var file3:File = File.desktopDirectory.resolvePath( "Single_d_p1Shoot.txt" );
		public var file11:File = File.desktopDirectory.resolvePath( "Single_d_All_in_One.txt" );
		public var stream1:FileStream = new FileStream();
		public var stream10:FileStream = new FileStream();
		public var stream3:FileStream = new FileStream();
		public var stream11:FileStream = new FileStream();
		public var leadingZeroMiliseconds:String;
		public var leadingZeroSeconds:String;
		public var leadingZeroMinutes:String;
		public var leadingZeroHours:String;
```

```
		public function logString1(s:String): void
		{
			var today = new Date();
			if (+ today.getMilliseconds()>=10 && + today.getMilliseconds()<= 99)
			{
			 leadingZeroMiliseconds = "0";
		}
			else if (+ today.getMilliseconds() < 10)
			{
		leadingZeroMiliseconds = "0" + "0";
		}
			else
			{
		leadingZeroMiliseconds = "";
			}

			if(+ today.getSeconds()<10)
			{
				leadingZeroSeconds = "0"
			}
			else
			{
		leadingZeroSeconds = "";
			}

			if(+ today.getMinutes()<10)
			{
				leadingZeroMinutes = "0"
			}
			else
			{
		leadingZeroMinutes = "";
			}
			if(+ today.getHours()<10)
			{
				leadingZeroHours = "0"
			}
			else
			{
		leadingZeroHours = "";
			}
			stream1.open(file1,FileMode.APPEND);
			stream1.writeUTFBytes(today.getDate()+"/"+(today.getMonth()+1)+"/"+today.getFullYear()+ "\t" +
leadingZeroHours + today.getHours()+":" + leadingZeroMinutes + today.getMinutes()+ ":" + leadingZeroSeconds +
today.getSeconds() +"."+ leadingZeroMiliseconds + today.getMilliseconds());
			stream1.writeUTFBytes("\t"+s+"\r\n");
			stream1.close();

		}
		public function logString3(s:String): void
		{
			var today = new Date();
			if (+ today.getMilliseconds()>=10 && + today.getMilliseconds()<= 99)
			{
			 leadingZeroMiliseconds = "0";
		}
			else if (+ today.getMilliseconds() < 10)
			{
		leadingZeroMiliseconds = "0" + "0";
		}
			else
			{
```

```
                    leadingZeroMiliseconds = "";
                              }

                              if(+ today.getSeconds()<10)
                              {
                                        leadingZeroSeconds = "0"
                              }
                              else
                              {
                    leadingZeroSeconds = "";
                              }

                              if(+ today.getMinutes()<10)
                              {
                                        leadingZeroMinutes = "0"
                              }
                              else
                              {
                    leadingZeroMinutes = "";
                              }
                              if(+ today.getHours()<10)
                              {
                                        leadingZeroHours = "0"
                              }
                              else
                              {
                    leadingZeroHours = "";
                              }
                              stream3.open(file3,FileMode.APPEND);
                              stream3.writeUTFBytes(today.getDate()+"/"+(today.getMonth()+1)+"/"+today.getFullYear()+ "\t" +
leadingZeroHours + today.getHours()+":" + leadingZeroMinutes + today.getMinutes()+ ":" + leadingZeroSeconds +
today.getSeconds() +"."+ leadingZeroMiliseconds + today.getMilliseconds());
                              stream3.writeUTFBytes("\t"+s+"\r\n");
                              stream3.close();

                    }
                    public function logString10(s:String): void
                    {

                              var today = new Date();
                              if (+ today.getMilliseconds()>=10 && + today.getMilliseconds()<= 99)
                              {
                               leadingZeroMiliseconds = "0";
                    }
                              else if (+ today.getMilliseconds() < 10)
                              {
                    leadingZeroMiliseconds = "0" + "0";
                    }
                              else
                              {
                    leadingZeroMiliseconds = "";
                              }
                              if(+ today.getSeconds()<10)
                              {
                                        leadingZeroSeconds = "0"
                              }
                              else
                              {
                    leadingZeroSeconds = "";
                              }

                              if(+ today.getMinutes()<10)
                              {
```

```
				leadingZeroMinutes = "0"
			}
			else
			{
		leadingZeroMinutes = "";
			}
			if(+ today.getHours()<10)
			{
				leadingZeroHours = "0"
			}
			else
			{
		leadingZeroHours = "";
			}
			stream10.open(file10,FileMode.APPEND);
			stream10.writeUTFBytes(today.getDate()+"/"+(today.getMonth()+1)+"/"+today.getFullYear()+ "\t"
+ leadingZeroHours + today.getHours()+":" + leadingZeroMinutes + today.getMinutes()+ ":" + leadingZeroSeconds +
today.getSeconds() +"."+ leadingZeroMiliseconds + today.getMilliseconds());
			stream10.writeUTFBytes("\t"+s+"\r\n");
			stream10.close();

		}

		public function logString11(s:String): void
		{

			var today = new Date();
			if (+ today.getMilliseconds()>=10 && + today.getMilliseconds()<= 99)
			{
			 leadingZeroMiliseconds = "0";
		}
			else if (+ today.getMilliseconds() < 10)
			{
		leadingZeroMiliseconds = "0" + "0";
		}
			else
			{
		leadingZeroMiliseconds = "";
			}
			if(+ today.getSeconds()<10)
			{
				leadingZeroSeconds = "0"
			}
			else
			{
		leadingZeroSeconds = "";
			}

			if(+ today.getMinutes()<10)
			{
				leadingZeroMinutes = "0"
			}
			else
			{
		leadingZeroMinutes = "";
			}
			if(+ today.getHours()<10)
			{
				leadingZeroHours = "0"
			}
			else
			{
		leadingZeroHours = "";
```

```
				}
				stream11.open(file11,FileMode.APPEND);
				stream11.writeUTFBytes(today.getDate()+"/"+(today.getMonth()+1)+"/"+today.getFullYear()+ "\t"
+ leadingZeroHours + today.getHours()+":" + leadingZeroMinutes + today.getMinutes()+ ":" + leadingZeroSeconds +
today.getSeconds() +"."+ leadingZeroMiliseconds + today.getMilliseconds());
				stream11.writeUTFBytes("\t"+s+"\r\n");
				stream11.close();

			}
public function player(mainStage:Stage, mainSprite:Sprite, shieldList:Array, shieldList1:Array, shieldList2:Array, shieldList3:Array,
shieldList4:Array, shieldList5:Array, shieldList6:Array, shieldList7:Array,oAliens3:aliens3,oGameTimer:gametimer)
			{
				mStage = mainStage;
				mSprite = mainSprite;
				localShieldList = shieldList;
				localShieldList1 = shieldList1;
				localShieldList2 = shieldList2;
				localShieldList3 = shieldList3;
				localShieldList4 = shieldList4;
				localShieldList5 = shieldList5;
				localShieldList6 = shieldList6;
				localShieldList7 = shieldList7;
				localAliens3 = oAliens3;
				objGameTimer = oGameTimer;
				xPos = mStage.stageWidth / 2 - 150;
				yPos = mStage.stageHeight - 120;
				this.x = xPos;
				this.y = yPos;
				this.scaleX = 1.8;
				this.scaleY = 1.4;
				mSprite.addChild(this);
				collisionTimer.addEventListener(TimerEvent.TIMER, collisionTimerEventHandler);
				collisionTimer.start();

			}
			private function collisionTimerEventHandler(evt:TimerEvent)
			{
				HasCollidedBomb3();
				HasCollidedmBonus3();
				HasCollidednBonus3();
				HasCollidedBonus3();
				if (collideBomb3 && this.visible)
				{
					this.visible = false;
					collisionTimer.stop();
					spacegame.instance.checkEndGame();
				}

			}
			private function HasCollidedBomb3()
			{
				var objBombList:Array = localAliens3.bombList;
				var objBomb:bomb3;
				var dx:Number;
				var dy:Number;
				var dist:Number;
				var minDist:Number;

				for (var i:int=0; i<objBombList.length; i++)
				{
					objBomb = objBombList[i];
					dx = this.x - objBomb.x;
					dy = this.y - objBomb.y;
```

```
				dist = Math.sqrt(dx*dx+dy*dy);
				minDist = this.width / 2 + objBomb.width / 2;
				if ((dist<=minDist)&& objBomb.visible)
				{
					collideBomb3 = true;
					spacegame.instance.logString2("Gameover - Bomb hit player");
					spacegame.instance.channel.stop();
					objBomb.visible = false;

				}
			}
		}

		private function HasCollidedBonus3()
		{
			var objBonusList3:Array = localAliens3.bonus1List;
			var objBonus3:bonus3;
			var dx:Number;
			var dy:Number;
			var dist:Number;
			var minDist:Number;
			for (var i:int=0; i<objBonusList3.length; i++)
			{
				objBonus3 = objBonusList3[i];
				dx = this.x -objBonus3.x;;
				dy = this.y - objBonus3.y;
				dist = Math.sqrt(dx*dx+dy*dy);
				minDist = this.height / 2 + objBonus3.height / 2;
				if ((dist<=minDist)&& objBonus3.visible)
				{
					objBonus3.visible = false;
					objGameTimer.scoreHitAlien +=  10;
spacegame.instance.logString2("Player collects bonus 1 and score changes to" + "\t" + objGameTimer.scoreHitAlien);
				}
			}
		}
		private function HasCollidednBonus3()
		{
			var objnBonusList3:Array = localAliens3.bonus2List;
			var objnBonus3:nbonus3;
			var dx:Number;
			var dy:Number;
			var dist:Number;
			var minDist:Number;
			for (var i:int=0; i<objnBonusList3.length; i++)
			{
				objnBonus3 = objnBonusList3[i];
				dx = this.x -objnBonus3.x;;
				dy = this.y - objnBonus3.y;
				dist = Math.sqrt(dx*dx+dy*dy);
				minDist = this.height / 2 + objnBonus3.height / 2;
				if ((dist<=minDist)&& objnBonus3.visible)
				{
					objnBonus3.visible = false;
					 objGameTimer.scoreHitAlien +=5;
 spacegame.instance.logString2("Player collects bonus 2 and score changes to" + "\t" + objGameTimer.scoreHitAlien)

				}
			}
		}
		private function HasCollidedmBonus3()
		{
```

```
				var objmBonusList3:Array = localAliens3.bonus3List;
				var objmBonus3:mbonus3;
				var dx:Number;
				var dy:Number;
				var dist:Number;
				var minDist:Number;
				for (var i:int=0; i<objmBonusList3.length; i++)
				{
					objmBonus3 = objmBonusList3[i];
					dx = this.x -objmBonus3.x;;
					dy = this.y - objmBonus3.y;
					dist = Math.sqrt(dx*dx+dy*dy);
					minDist = this.height / 2 + objmBonus3.height / 2;
					if ((dist<=minDist)&& objmBonus3.visible)
					{
						objmBonus3.visible = false;
						objGameTimer.scoreHitAlien +=20;
		spacegame.instance.logString2("Player collects bonus 3 and score changes to" + "\t" + objGameTimer.scoreHitAlien)

					}
				}
			}
		}
}
```

Shield.as

```
package
{
		import flash.display.Stage;
		import flash.display.Sprite;
		public class shields1
		{
			public var shieldList1:Array=new Array();
			private var mStage:Stage;
			private var mSprite:Sprite;
			private var objShield:shield1;
			private var shieldsNumber:int = 8;
			public function shields1(mainStage:Stage, mSprite:Sprite)
			{
				for (var i:int=0; i<shieldsNumber; i++)
				{
					objShield = new shield1 ;
					objShield.y = mainStage.stageHeight-170;
					objShield.x = 420+(13*i);
					shieldList1.push(objShield);
					mSprite.addChild(objShield);
				}
			}
		}
}
```

Spacegame.as

```
	package
	{
		import flash.display.MovieClip;
		import flash.events.KeyboardEvent;
		import flash.ui.Keyboard;
```

```
import flash.display.Stage;
import flash.display.Sprite;
import flash.text.engine.TabAlignment;
import flash.text.TextField;
import flash.text.TextFormat;
import flash.events.MouseEvent;
import flash.media.Sound;
import flash.media.SoundChannel;
import fl.motion.easing.Circular;
import flash.filesystem.File;
import flash.filesystem.FileMode;
import flash.filesystem.FileStream;
import flash.utils.Timer;
import flash.events.TimerEvent;
import flash.events.Event;
public class spacegame extends MovieClip
{
		private var objAliens3:aliens3;
		private var objShields:shields;
		private var objShields1:shields1;
		private var objShields2:shields2;
		private var objShields3:shields3;
		private var objShields4:shields4;
		private var objShields5:shields5;
		private var objShields6:shields6;
		private var objShields7:shields7;
		private var objPlayer:player;
		private var objPlayer1:player1;
		private var objGameTimer:gametimer;
		public var valTime1:Number = 0;
		public var scoring:Number;
		public var nTimer:Timer = new Timer(1000);
		private var mStage:Stage;
		private var mSprite:Sprite;

		public var can1Fire:Boolean = true;
		public var can2Fire:Boolean = true;
		private var movementTimer:Timer = new Timer(1500)
		private var playerPositionTimer:Timer = new Timer(1000);
		private var objBomb:bomb;
		private var objBullet:bullet;
		private var objBullet1:bullet1;
		public var rightCircle:circle2 = new circle2  ;
		public var leftCircle:circle2 = new circle2  ;
		public var centerCircle:circle2 = new circle2  ;
		public var rightCircleNew:circle = new circle  ;
		public var leftCircleNew:circle = new circle  ;
		public var centerCircleNew:circle = new circle  ;
		public var point5:bonus5 = new bonus5;
		public var point10:bonus10 = new bonus10;
		public var point20:bonus20 = new bonus20;
		public var bombTo:bombSC = new bombSC;
		private var keyz:Boolean = false;
		private var keyc:Boolean = false;
		private var keyx:Boolean = false;
		private var keyb:Boolean = false;
		private var keyh:Boolean = false;
		private var keyg:Boolean = false;
		private var p1RightState:int;
		private var p1LeftState:int;
		private var p1ShootState:int;
		private var p2RightState:int;
		private var p2LeftState:int;
```

```
private var p2ShootState:int;
private var p1RightNewState:int;
private var p1LeftNewState:int;
private var p1ShootNewState:int;
private var p2RightNewState: int;
private var p2LeftNewState: int;
private var p2ShootNewState: int;
private var rightStage:int = 0;
private var newRightStage: int;
private var aRightState:int;
private var aRightNewState:int;
private var aLeftState:int;
private var aLeftNewState:int;
private var aShootState:int;
private var aShootNewState:int;
public var score1:playerScore = new playerScore  ;
public var score2:playerScore1 = new playerScore1  ;
private var gameScore:Number = 0;
private var scoreDisplay:TextField;
public var startSound:TitleMusic = new TitleMusic();
public var channel:SoundChannel;
public var startSoundIsPlaying:Boolean = false;
public var mainSound:Start = new Start();//second way of creating sound
public var channel4:SoundChannel;
public var mainSoundIsPlaying:Boolean = false;
public var endSound:ending = new ending();
public var channel3:SoundChannel;
public var endSoundIsPlaying:Boolean = false;
public var gameOverSound:playerHit = new playerHit();
public var channel5:SoundChannel;
public var gameOverSoundIsPlaying:Boolean = false;
public var bulletUpSound:BulletUp = new BulletUp();//third way of doing it
public var channel1:SoundChannel = new SoundChannel  ;
public var txtWin1:TextField = new TextField();
public var txtWin2:TextField = new TextField();
public var txtWin3:TextField = new TextField();
public var file2:File = File.desktopDirectory.resolvePath( "SINGLE_Dancemat_In_Game.txt" );
public var file12:File = File.desktopDirectory.resolvePath( "Single_d_Gameover.txt" );
public var stream2:FileStream = new FileStream();
public var stream12:FileStream = new FileStream();
private static var _instance:spacegame;
public var leadingZeroMiliseconds:String;
public var leadingZeroSeconds:String;
public var leadingZeroMinutes:String;
public var leadingZeroHours:String;
public function logString2(s:String): void
{
        var today = new Date();
        if (+ today.getMilliseconds()>=10 && + today.getMilliseconds()<= 99)
        {
         leadingZeroMiliseconds = "0";
        }
        else if (+ today.getMilliseconds() < 10)
        {
        leadingZeroMiliseconds = "0" + "0";
        }

        else
        {
        leadingZeroMiliseconds = "";
        }

        if(+ today.getSeconds()<10)
```

```
{
        leadingZeroSeconds = "0"
}
else
{
leadingZeroSeconds = "";
}

if(+ today.getMinutes()<10)
{
        leadingZeroMinutes = "0"
}
else
{
leadingZeroMinutes = "";
}
if(+ today.getHours()<10)
{
        leadingZeroHours = "0"
}
else
{
leadingZeroHours = "";
}
stream2.open(file2,FileMode.APPEND);
stream2.writeUTFBytes(today.getDate()+"/"+(today.getMonth()+1)+"/"+today.getFullYear()+ "\t" +
leadingZeroHours + today.getHours()+":" + leadingZeroMinutes + today.getMinutes()+ ":" + leadingZeroSeconds +
today.getSeconds() +"."+ leadingZeroMiliseconds + today.getMilliseconds());
stream2.writeUTFBytes("\t"+s+"\r\n");
stream2.close();

}

public function logString12(s:String): void
{
        var today = new Date();
        if (+ today.getMilliseconds()>=10 && + today.getMilliseconds()<= 99)
        {
         leadingZeroMiliseconds = "0";
        }
        else if (+ today.getMilliseconds() < 10)
        {
        leadingZeroMiliseconds = "0" + "0";
        }

        else
        {
        leadingZeroMiliseconds = "";
        }

        if(+ today.getSeconds()<10)
        {
        leadingZeroSeconds = "0"
        }
        else
        {
        leadingZeroSeconds = "";
        }

        if(+ today.getMinutes()<10)
        {
        leadingZeroMinutes = "0"
        }
```

```
			else
			{
			leadingZeroMinutes = "";
			}
			if(+ today.getHours()<10)
			{
			leadingZeroHours = "0"
			}
			else
			{
			leadingZeroHours = "";
			}
			stream12.open(file12,FileMode.APPEND);
			stream12.writeUTFBytes(today.getDate()+"/"+(today.getMonth()+1)+"/"+today.getFullYear()+ "\t"
+ leadingZeroHours + today.getHours()+":" + leadingZeroMinutes + today.getMinutes()+ ":" + leadingZeroSeconds +
today.getSeconds() +"."+ leadingZeroMiliseconds + today.getMilliseconds());
			stream12.writeUTFBytes("\t"+s+"\r\n");
			stream12.close();

		}

		public static function get instance():spacegame
		{
			return _instance;
		}

		public function spacegame()
		{
			_instance = this;
			mStage = this.stage;
			p1RightState = 0;//none state
			p1LeftState = 0;
			p1ShootState = 0;

			p2RightState = 0;//none state
			p2LeftState = 0;
			p2ShootState = 0;
			aRightState = 0;
			aLeftState = 0;
			aShootState = 0;
			mStage.addEventListener(KeyboardEvent.KEY_DOWN, onKeyPress);
			mStage.addEventListener(KeyboardEvent.KEY_UP, onKeyRelease);
			mStage.addEventListener(Event.ENTER_FRAME, movePlayer);
			initializeGame();
			playStartSound(startSound);

		}

		private function playStartSound(soundObject:Object)
		{
			if (startSoundIsPlaying == false)
			{
				channel = soundObject.play();
				startSoundIsPlaying = true;
			}

		}
		private function stopStartSound(soundObject:Object)
		{
			if (startSoundIsPlaying == true)
			{
				channel.stop();
				startSoundIsPlaying = false;
```

```
			}

		}
		private function playMainSound(soundObject:Object)
		{
			if (mainSoundIsPlaying == false)
			{
				channel4 = soundObject.play();
				mainSoundIsPlaying = true;
			}

		}
		private function stopMainSound(soundObject:Object)
		{
			if (mainSoundIsPlaying == true)
			{
				channel4.stop();
				mainSoundIsPlaying = false;
			}

		}
		private function playEndSound(soundObject:Object)
		{
			if (endSoundIsPlaying == false)
			{
				channel3 = soundObject.play(0,99999);
				endSoundIsPlaying = true;
			}

		}
		private function playGameOverSound(soundObject:Object)
		{
			if (gameOverSoundIsPlaying == false)
			{
				channel5 = soundObject.play();
				gameOverSoundIsPlaying = true;
			}

		}
		private function stopEndSound(soundObject:Object)
		{
			if (endSoundIsPlaying == true)
			{
				channel3.stop();
				endSoundIsPlaying = false;
			}

		}
		public function playBulletUpSound(soundObject:Object)
		{
			channel1 = soundObject.play(0,1);
		}
		public function fireABullet1()
		{

			if (objPlayer.visible && can1Fire)
			{
new bullet(mStage,mSprite,objPlayer,objAliens3,objShields.shieldList,objShields1.shieldList1,objShields2.shieldList2,
objShields3.shieldList3,objShields4.shieldList4, objShields5.shieldList5,
objShields6.shieldList6,objShields7.shieldList7,objGameTimer);
				spacegame.instance.logString2(" Player shoots bullet");
				bulletUpSound.play();
				can1Fire = false;
```

```
				movementTimer.start();
			}
		}

		public function timeDelay(evt:TimerEvent)
		{
			can1Fire = true;
			can2Fire = true;
		}
		private function initializeGame()
		{
			mSprite = new Sprite  ;
			mStage.addChild(mSprite);
			movementTimer.addEventListener(TimerEvent.TIMER, timeDelay);
			movementTimer.start();
			nTimer.addEventListener(TimerEvent.TIMER,nTimerEventHandler);
			nTimer.start();
			playerPositionTimer.addEventListener(TimerEvent.TIMER, playerPositionEventHandler);
			playerPositionTimer.start();
			objGameTimer = new gametimer(mStage,mSprite);
			objShields = new shields(mStage,mSprite);
			objShields1 = new shields1(mStage,mSprite);
			objShields2 = new shields2(mStage,mSprite);
			objShields3 = new shields3(mStage,mSprite);
			objShields4 = new shields4(mStage,mSprite);
			objShields5 = new shields5(mStage,mSprite);
			objShields6 = new shields6(mStage,mSprite);
			objShields7 = new shields7(mStage,mSprite);
			objAliens3 = new aliens3(mStage,mSprite,objShields.shieldList, objShields1.shieldList1,
objShields2.shieldList2, objShields3.shieldList3, objShields4.shieldList4, objShields5.shieldList5, objShields6.shieldList6,
objShields7.shieldList7,objGameTimer);
			objPlayer = new player(mStage,mSprite,objShields.shieldList, objShields1.shieldList1,
objShields2.shieldList2, objShields3.shieldList3,objShields4.shieldList4, objShields5.shieldList5, objShields6.shieldList6,
objShields7.shieldList7,objAliens3,objGameTimer);
			var gp:Sprite = new Sprite  ;
			gp.graphics.beginFill(0x008500);
			gp.graphics.lineStyle(2,0x000000);
			gp.graphics.moveTo(1000,10);
			gp.graphics.lineTo(1000, 80);
			gp.graphics.lineTo(900,45);
			gp.graphics.lineTo(1000,10);
			mSprite.addChild(gp);
			gp.graphics.moveTo(1100,10);
			gp.graphics.lineTo(1100,80);
			gp.graphics.lineTo(1200,45);
			gp.graphics.lineTo(1100,10);
			gp.graphics.endFill();
			mSprite.addChild(gp);
			gp.graphics.beginFill(0xff0000);
			gp.graphics.drawCircle(1050,45,40);
			mSprite.addChild(gp);
			rightCircle.x = 1119;
			rightCircle.y = 42;
			mSprite.addChild(rightCircle);
			rightCircle.visible = false;
			leftCircle.x = 980;
			leftCircle.y = 42;
			mSprite.addChild(leftCircle);
			leftCircle.visible = false;
			centerCircle.x = 1051;
			centerCircle.y = 40;
			mSprite.addChild(centerCircle);
			centerCircle.visible = false;
```

```
rightCircleNew.x = 1119;
rightCircleNew.y = 60;
mSprite.addChild(rightCircleNew);
rightCircleNew.visible = false;
leftCircleNew.x = 980;
leftCircleNew.y = 60;
mSprite.addChild(leftCircleNew);
leftCircleNew.visible = false;
centerCircleNew.x = 1051;
centerCircleNew.y = 57;
mSprite.addChild(centerCircleNew);
centerCircleNew.visible = false;
score1.x = 400;
score1.y = 10;
mSprite.addChild(score1);
score2.x = 410;
score2.y = 10;
point5.x = 500;
point5.y = 5;
mSprite.addChild(point5);
var txtPoint5:TextField = new TextField();
var txtFrmt5:TextFormat = new TextFormat  ;
txtFrmt5.size = 13;
txtFrmt5.bold = true;
txtFrmt5.font = "verdana";
txtPoint5.width = 150;
txtPoint5.x = 530;
txtPoint5.y = 12;
txtPoint5.textColor = 0xffffff;
txtPoint5.defaultTextFormat = txtFrmt5;
txtPoint5.text = "5 points ";
mSprite.addChild(txtPoint5);
point10.x = 650;
point10.y = 5;
mSprite.addChild(point10);
var txtPoint10:TextField = new TextField();
txtPoint10.width = 150;
txtPoint10.x = 690;
txtPoint10.y = 12;
txtPoint10.textColor = 0xffffff;
txtPoint10.defaultTextFormat = txtFrmt5;
txtPoint10.text = "10 points ";
mSprite.addChild(txtPoint10);
point20.x = 500;
point20.y = 52;
mSprite.addChild(point20);
var txtPoint20:TextField = new TextField();
txtPoint20.width = 150;
txtPoint20.x = 540;
txtPoint20.y = 52;
txtPoint20.textColor = 0xffffff;
txtPoint20.defaultTextFormat = txtFrmt5;
txtPoint20.text = "20 points ";
mSprite.addChild(txtPoint20);
bombTo.x = 660;
bombTo.y = 52;
mSprite.addChild(bombTo);
var txtb:TextField = new TextField();
txtb.width = 150;
txtb.x = 690;
txtb.y = 52;
txtb.textColor = 0xffffff;
txtb.defaultTextFormat = txtFrmt5;
```

```
			txtb.text = "bomb ";
			mSprite.addChild(txtb);

		}
		private function onKeyPress(evt:KeyboardEvent)
		{
			 //player one's key presses
			if (evt.keyCode == 67)
			{
			keyc = true;
			rightCircle.visible = true;
			p1RightNewState = 1;
			if(p1RightState != p1RightNewState)
			{
			objPlayer.logString1("Player1_rightKeyPress_Start"  + "\t" +"1" + "\t" +"P1Right");
			objPlayer.logString11("Player1_rightKeyPress_Start"  + "\t" +"1" + "\t" +"P1Right");
			p1RightState = p1RightNewState;
			}
			}
			else if (evt.keyCode == 90 )
			{
			keyz = true;
			leftCircle.visible = true;
			p1LeftNewState = 2;
			if(p1LeftState != p1LeftNewState)
			{
			objPlayer.logString10("Player1_leftKeyPress_Start" + "\t" +"2" + "\t"+ "P1Left");
			objPlayer.logString11("Player1_leftKeyPress_Start" + "\t" +"2" + "\t"+ "P1Left");
			p1LeftState = p1LeftNewState;
			}
		}
			else if (evt.keyCode == 88)
			{
			keyx = true;
			centerCircle.visible = true;
			p1ShootNewState = 3;
			if(p1ShootState != p1ShootNewState)
			{
			fireABullet1();
			objPlayer.logString3("Player1_shootKeyPress_Start" + "\t" +"3" + "\t"+ "P1Shoot" );
			objPlayer.logString11("Player1_shootKeyPress_Start" + "\t" +"3" + "\t"+ "P1Shoot" );
			p1ShootState = p1ShootNewState;
			}
			}
		}
		private function onKeyRelease(evt:KeyboardEvent)
		{
			//player one's key releases
			if (evt.keyCode == 67)
			{
			keyc = false;
			rightCircle.visible = false;
			p1RightNewState = 0;
			if(p1RightState != p1RightNewState )
			{
			objPlayer.logString1("Player1_rightKeyPress_Stop" + "\t" + "1" + "\t"+ "P1Right");
			objPlayer.logString1("Player1_rightKeyPress_Stop" + "\t" + "" + "\t"+ "P1Right");
			objPlayer.logString11("Player1_rightKeyPress_Stop" + "\t" + "1" + "\t"+ "P1Right");
			objPlayer.logString11("Player1_rightKeyPress_Stop" + "\t" + "" + "\t"+ "P1Right");
			p1RightState = p1RightNewState;
			}
			}
			else if (evt.keyCode == 90 )
```

```
			{
			keyz = false;
			leftCircle.visible = false;
			p1LeftNewState = 0;
			if(p1LeftState != p1LeftNewState )
			{
			objPlayer.logString10("Player1_leftKeyPress_Stop" + "\t" + "2" + "\t"+ "P1Left");
			objPlayer.logString10("Player1_leftKeyPress_Stop" + "\t" + "" + "\t" +"P1Left");
			objPlayer.logString11("Player1_leftKeyPress_Stop" + "\t" + "2" + "\t"+ "P1Left");
			objPlayer.logString11("Player1_leftKeyPress_Stop" + "\t" + "" + "\t" +"P1Left");
			p1LeftState = p1LeftNewState;
			}
			}
			else if (evt.keyCode == 88)
			{
			keyx = false;
			centerCircle.visible = false;
			p1ShootNewState = 0;
			if(p1ShootState != p1ShootNewState )
			{
			objPlayer.logString3("Player1_shootKeyPress_Stop" + "\t" + "3" + "\t"+ "P1Shoot" );
			objPlayer.logString3("Player1_shootKeyPress_Stop" + "\t" + "" + "\t" +"P1Shoot");
			objPlayer.logString11("Player1_shootKeyPress_Stop" + "\t" + "3" + "\t"+ "P1Shoot" );
			objPlayer.logString11("Player1_shootKeyPress_Stop" + "\t" + "" + "\t" +"P1Shoot");
			p1ShootState = p1ShootNewState;
			}
			}
		}
		public function playerPositionEventHandler(evt:TimerEvent)
		{
			if(keyc == true && keyg == true)
			{
				logString2("Player move right")

			}
			if (keyb == true && keyz == true)
			{
				logString2("Player move left")

			}
			if (objPlayer.x < objPlayer.width / 2)
			{

				spacegame.instance.logString2("Player hit left base");
			}
			if (objPlayer.x + objPlayer.width> mStage.stageWidth)
			{

				spacegame.instance.logString2("Player hit right base");
			}

		}
		public function movePlayer(event:Event)
		{
			if (keyc == true)
			{
				objPlayer.x +=  10;

				if (objPlayer.x > mStage.stageWidth - objPlayer.width / 2)
				{
					objPlayer.x = mStage.stageWidth - objPlayer.width / 2;
				}
			}
```

```
        if (keyz == true)
        {
                objPlayer.x -=  10;
                if (objPlayer.x < objPlayer.width / 2)
                {
                        objPlayer.x = objPlayer.width / 2;
                }
        }
}
private function checkScoring()
{
        scoring = objGameTimer.scoreHitAlien;
}
private function nTimerEventHandler(evt:TimerEvent)
{
        valTime1 +=  1;
        checkVal();
        checkScoring();
}

private function checkVal()
{
        if(valTime1 == 60)
        {
                logString2("Gameover - Stipulated game duration elapsed");
                objPlayer.logString11("Gameover");
                endGame();
        }
}

public function checkEndGame()
{
        if(valTime1<=60)
        {
                stopStartSound(startSound);
                mStage.removeChild(mSprite);
                can1Fire = false;
                can2Fire = false;
                objAliens3.bombDroppingTimer.stop();
                objAliens3.bonusDroppingTimer.stop();
                objAliens3.nbonusDroppingTimer.stop();
                objAliens3.mbonusDroppingTimer.stop();
                objAliens3.movementTimer.stop();
                objGameTimer.gTimer.stop();
                objGameTimer.sTimer.stop();
                movementTimer.stop();
                mStage.addEventListener(KeyboardEvent.KEY_DOWN, onKeyPress);
                mStage.addEventListener(KeyboardEvent.KEY_UP, onKeyRelease);
                mStage.addEventListener(Event.ENTER_FRAME, movePlayer);
                initializeGame();
                playStartSound(startSound);
                fireABullet1();
        }
}
public function endGame()
{
        mStage.removeChild(mSprite);
        mSprite = new Sprite  ;
        mStage.addChild(mSprite);
        mStage.removeEventListener(KeyboardEvent.KEY_DOWN, onKeyPress);
        mStage.removeEventListener(KeyboardEvent.KEY_UP, onKeyRelease);
        stopStartSound(startSound);
        playEndSound(endSound);
```

```
nTimer.stop();
can1Fire = false;
can2Fire = false;
objAliens3.bombDroppingTimer.stop();
objAliens3.movementTimer.stop();
objAliens3.bombDroppingTimer.stop();
objAliens3.bonusDroppingTimer.stop();
objAliens3.nbonusDroppingTimer.stop();
objAliens3.mbonusDroppingTimer.stop();
objAliens3.movementTimer.stop();
objGameTimer.gTimer.stop();
objGameTimer.sTimer.stop();
movementTimer.stop();
nTimer.stop();
var txtEnd:TextField = new TextField();
var txtFrmt4:TextFormat = new TextFormat  ;
txtFrmt4.size = 42;
txtFrmt4.font = "Berlin Sans FB Demi";
txtEnd.width = 400;
txtEnd.x = 510;
txtEnd.y = 100;
txtEnd.textColor = 0xffffff;
txtEnd.defaultTextFormat = txtFrmt4;
txtEnd.text = "Game Over";
mSprite.addChild(txtEnd);
var txtScore:TextField = new TextField();
var txtFrmt5:TextFormat = new TextFormat  ;
txtFrmt5.size = 28;
txtFrmt5.bold = true;
txtFrmt5.font = "verdana";
txtScore.width = 200;
txtScore.x = 580;
txtScore.y = 310;
txtScore.textColor = 0xffffff;
txtScore.defaultTextFormat = txtFrmt5;
logString2("total score  : " + String(scoring));
mSprite.addChild(txtScore);
var txtScore7:TextField = new TextField();
txtScore7.width = 200;
txtScore7.x = 530;
txtScore7.y = 390;
txtScore7.textColor = 0xffffff;
txtScore7.defaultTextFormat = txtFrmt5;
mSprite.addChild(txtScore7);
var txtScorePlayer1:TextField = new TextField();
txtScorePlayer1.width = 200;
txtScorePlayer1.x = 350;
txtScorePlayer1.y = 390;
txtScorePlayer1.textColor = 0xffffff;
txtScorePlayer1.defaultTextFormat = txtFrmt5;
mSprite.addChild(txtScorePlayer1);
var txtScorePlayer2:TextField = new TextField();
txtScorePlayer2.width = 200;
txtScorePlayer2.x = 670;
txtScorePlayer2.y = 390;
txtScorePlayer2.textColor = 0xffffff;//0x00951f;
txtScorePlayer2.defaultTextFormat = txtFrmt5;
mSprite.addChild(txtScorePlayer2);
var txtScore6:TextField = new TextField();
txtScore6.width = 200;
txtScore6.x = 840;
txtScore6.y = 390;
txtScore6.textColor = 0xffffff;
```

```
                    txtScore6.defaultTextFormat = txtFrmt5;
                    mSprite.addChild(txtScore6);
                    var txtTime:TextField = new TextField();
                    var txtFrmt6:TextFormat = new TextFormat  ;
                    txtFrmt6.size = 28;
                    txtFrmt6.bold = true;
                    txtFrmt6.font = "verdana";
                    txtTime.width = 800;
                    txtTime.x = 450;
                    txtTime.y = 200;
                    txtTime.textColor = 0xffffff;
                    txtTime.defaultTextFormat = txtFrmt6;
                    txtTime.text = "Time (in seconds) :  " + String(valTime1);
                    mSprite.addChild(txtTime);

            }


    }

}
```

NOTE: The major difference between the single-player and collaborative version of the game is that two players controlled the snowman in the collaborative version while only one person controlled the snowman in the single-player version. Consequently, agreement, disagreement were logged in the collaboratve verson as shown in the excerpt of the **spacegame.as** below:

Excerpt from collaborative version of game (spaceame.as)

```
private function onKeyPress(evt:KeyboardEvent)
            {
                     //player one's key presses
                    if (evt.keyCode == 67)
                    {
                    keyc = true;
                    rightCircle.visible = true;
                    p1RightNewState = 1;
                    if(p1RightState != p1RightNewState)
                    {
                    objPlayer1.logString1("Player1_rightKeyPress_Start"  + "\t" +"1" + "\t" +"P1Right");
                    objPlayer1.logString11("Player1_rightKeyPress_Start"  + "\t" +"1" + "\t" +"P1Right");
                    p1RightState = p1RightNewState;
                    }
                    }
                    else if (evt.keyCode == 90 )
                    {
                    keyz = true;
                    leftCircle.visible = true;
                    p1LeftNewState = 2;
                    if(p1LeftState != p1LeftNewState)
                    {
                    objPlayer1.logString10("Player1_leftKeyPress_Start" + "\t" +"7" + "\t"+ "P1Left");
                    objPlayer1.logString11("Player1_leftKeyPress_Start" + "\t" +"7" + "\t"+ "P1Left");
                    p1LeftState = p1LeftNewState;
                    }
                    }
                    else if (evt.keyCode == 88)
                    {
```

```
            keyx = true;
            centerCircle.visible = true;
            p1ShootNewState = 3;
            if(p1ShootState != p1ShootNewState)
            {
            objPlayer1.logString3("Player1_shootKeyPress_Start" + "\t" +"4" + "\t"+ "P1Shoot" );
            objPlayer1.logString11("Player1_shootKeyPress_Start" + "\t" +"4" + "\t"+ "P1Shoot" );
            p1ShootState = p1ShootNewState;
            }
            }
            //player two's Key presses
            else if (evt.keyCode == 77)
            {
            keyg = true;
            rightCircleNew.visible = true;
            p2RightNewState = 1;
            if(p2RightState != p2RightNewState)
            {
            objPlayer1.logString7("Player2_rightKeyPress_Start" + "\t" + "2" + "\t" +"P2Right");
            objPlayer1.logString11("Player2_rightKeyPress_Start" + "\t" + "2" + "\t" +"P2Right");
            p2RightState = p2RightNewState;
            }
            }
            else if (evt.keyCode == 66)
            {
          keyb = true;
            leftCircleNew.visible = true;
            p2LeftNewState = 2;
            if(p2LeftState != p2LeftNewState)
            {
            objPlayer1.logString8("Player2_leftKeyPress_Start" + "\t" + "8" + "\t" +"P2Left");
            objPlayer1.logString11("Player2_leftKeyPress_Start" + "\t" + "8" + "\t" +"P2Left");
            p2LeftState = p2LeftNewState;
            }
            }
            else if (evt.keyCode == 78)
            {
            keyh = true;
            centerCircleNew.visible = true;
            p2ShootNewState = 3;
            if(p2ShootState != p2ShootNewState)
            {
            objPlayer1.logString9("Player2_shootKeyPress_Start" + "\t" + "5"+ "\t"+ "P2Shoot");
            objPlayer1.logString11("Player2_shootKeyPress_Start" + "\t" + "5"+ "\t"+ "P2Shoot");
            p2ShootState = p2ShootNewState;
            }
            }
            startAgreement();
}
private function onKeyRelease(evt:KeyboardEvent)
{
            //player one's key releases
            if (evt.keyCode == 67)
            {
            keyc = false;
            rightCircle.visible = false;
            p1RightNewState = 0;
            if(p1RightState != p1RightNewState )
            {
            objPlayer1.logString1("Player1_rightKeyPress_Stop" + "\t" + "1" + "\t"+ "P1Right");
            objPlayer1.logString11("Player1_rightKeyPress_Stop" + "\t" + "1" + "\t"+ "P1Right");
            objPlayer1.logString1("Player1_rightKeyPress_Stop" + "\t" + "" + "\t"+ "P1Right");
```

```
objPlayer1.logString11("Player1_rightKeyPress_Stop" + "\t" + "" + "\t"+ "P1Right");
p1RightState = p1RightNewState;
}
}
else if (evt.keyCode == 90 )
{
keyz = false;
leftCircle.visible = false;
p1LeftNewState = 0;
if(p1LeftState != p1LeftNewState )
{
objPlayer1.logString10("Player1_leftKeyPress_Stop" + "\t" + "7" + "\t"+ "P1Left");
objPlayer1.logString11("Player1_leftKeyPress_Stop" + "\t" + "7" + "\t"+ "P1Left");
objPlayer1.logString10("Player1_leftKeyPress_Stop" + "\t" + "" + "\t" +"P1Left");
objPlayer1.logString11("Player1_leftKeyPress_Stop" + "\t" + "" + "\t" +"P1Left");
p1LeftState = p1LeftNewState;
}
}
else if (evt.keyCode == 88)
{
keyx = false;
centerCircle.visible = false;
p1ShootNewState = 0;
if(p1ShootState != p1ShootNewState )
{
objPlayer1.logString3("Player1_shootKeyPress_Stop" + "\t" + "4" + "\t"+ "P1Shoot" );
objPlayer1.logString11("Player1_shootKeyPress_Stop" + "\t" + "4" + "\t"+ "P1Shoot" );
objPlayer1.logString3("Player1_shootKeyPress_Stop" + "\t" + "" + "\t" +"P1Shoot");
objPlayer1.logString11("Player1_shootKeyPress_Stop" + "\t" + "" + "\t" +"P1Shoot");
p1ShootState = p1ShootNewState;
}
}
//player two's keyreleases
else if (evt.keyCode == 77)
{
keyg = false;
rightCircleNew.visible = false;
p2RightNewState = 0;
if(p2RightState != p2RightNewState )
{
objPlayer1.logString7("Player2_rightKeyPress_Stop" + "\t" + "2" + "\t"+ "P2Right");
objPlayer1.logString11("Player2_rightKeyPress_Stop" + "\t" + "2" + "\t"+ "P2Right");
objPlayer1.logString7("Player2_rightKeyPress_Stop" + "\t" + "" + "\t" +"P2Right");
objPlayer1.logString11("Player2_rightKeyPress_Stop" + "\t" + "" + "\t" +"P2Right");
p2RightState = p2RightNewState;
}
}
else if (evt.keyCode == 66)
{
keyb = false;
leftCircleNew.visible = false;
p2LeftNewState = 0;
if(p2LeftState != p2LeftNewState )
{
objPlayer1.logString8("Player2_leftKeyPress_Stop" + "\t" + "8" + "\t" +"P2Left");
objPlayer1.logString11("Player2_leftKeyPress_Stop" + "\t" + "8" + "\t" +"P2Left");
objPlayer1.logString8("Player2_leftKeyPress_Stop" + "\t" + ""  + "\t"+ "P2Left");
objPlayer1.logString11("Player2_leftKeyPress_Stop" + "\t" + ""  + "\t"+ "P2Left");
p2LeftState = p2LeftNewState;
}
}
else if (evt.keyCode == 78)
{
```

```
                keyh = false;
                centerCircleNew.visible = false;
                p2ShootNewState = 0;
                if(p2ShootState != p2ShootNewState )
                {
                objPlayer1.logString9("Player2_shootKeyPress_Stop" + "\t" + "5" + "\t"+ "P2Shoot");
                objPlayer1.logString11("Player2_shootKeyPress_Stop" + "\t" + "5" + "\t"+ "P2Shoot");
                objPlayer1.logString9("Player2_shootKeyPress_Stop" + "\t" + "" + "\t" +"P2Shoot");
                objPlayer1.logString11("Player2_shootKeyPress_Stop" + "\t" + "" + "\t" +"P2Shoot");
                p2ShootState = p2ShootNewState;
                }
                }

                stopAgreement();

        }
        public function startAgreement()
        {
                if(p1RightNewState == 1 && p2RightNewState == 1 )
                {
                aRightNewState =1;
                if(aRightState != aRightNewState)
                {
                objPlayer1.logString4("right_KeyPress_Agreement_Start" + "\t" + "3" + "\t"+ "RightAgreement");
                objPlayer1.logString11("right_KeyPress_Agreement_Start" + "\t" + "3" + "\t"+ "RightAgreement");
                aRightState = aRightNewState;
                }
                }
                if(p1LeftNewState == 2 && p2LeftNewState == 2)
                {
                //objPlayer1.x -=  20;
                aLeftNewState =2;
                if(aLeftState != aLeftNewState)
                {
                objPlayer1.logString5("left_KeyPress_Agreement_Start" + "\t" + "9" + "\t"+ "LeftAgreement");
                objPlayer1.logString11("left_KeyPress_Agreement_Start" + "\t" + "9" + "\t"+ "LeftAgreement");
                aLeftState = aLeftNewState;
                }
                }
                if(p1ShootNewState == 3 && p2ShootNewState == 3)
                {
                aShootNewState =3;
                if(aShootState != aShootNewState)
                {
                fireABullet();
                objPlayer1.logString6("shoot_KeyPress_Agreement_Start" + "\t" + "6" + "\t"+ "ShootAgreement");
        objPlayer1.logString11("shoot_KeyPress_Agreement_Start" + "\t" + "6" + "\t"+ "ShootAgreement");
                aShootState = aShootNewState;
                }
                }
        }
        public function stopAgreement()
        {
          if((p1RightNewState == 1 && p2RightNewState ==0 )|| (p1RightNewState == 0 && p2RightNewState == 1 )
|| (p1RightNewState == 0 && p2RightNewState == 0 ))
        {
        aRightNewState =0;
        if(aRightState != aRightNewState)
        {
        objPlayer1.logString4("right_KeyPress_Agreement_Stop" + "\t" + "3" + "\t"+ "RightAgreement");
        objPlayer1.logString11("right_KeyPress_Agreement_Stop" + "\t" + "3" + "\t"+ "RightAgreement");
        objPlayer1.logString4("right_KeyPress_Agreement_Stop" + "\t" + "" + "\t"+ "RightAgreement");
```

```
objPlayer1.logString11("right_KeyPress_Agreement_Stop" + "\t" + "" + "\t"+ "RightAgreement");
aRightState = aRightNewState;
}
}
if((p1LeftNewState == 2 && p2LeftNewState == 0)|| (p1LeftNewState == 0 && p2LeftNewState == 2) ||
(p1LeftNewState == 0 && p2LeftNewState == 0))
{
aLeftNewState =0;
if(aLeftState != aLeftNewState)
{
objPlayer1.logString5("left_KeyPress_Agreement_Stop" + "\t" + "9" + "\t"+ "LeftAgreement");
objPlayer1.logString11("left_KeyPress_Agreement_Stop" + "\t" + "9" + "\t"+ "LeftAgreement");
objPlayer1.logString5("left_KeyPress_Agreement_Stop" + "\t" + "" + "\t"+ "LeftAgreement");
objPlayer1.logString11("left_KeyPress_Agreement_Stop" + "\t" + "" + "\t"+ "LeftAgreement");
aLeftState = aLeftNewState;
}
}
if ((p1ShootNewState == 3 && p2ShootNewState == 0) || (p1ShootNewState == 0 && p2ShootNewState == 3) ||
(p1ShootNewState == 0 && p2ShootNewState == 0))
{
aShootNewState =0;
if(aShootState != aShootNewState)
{
objPlayer1.logString6("shoot_KeyPress_Agreement_Stop" + "\t" + "6" + "\t"+ "ShootAgreement");
objPlayer1.logString11("shoot_KeyPress_Agreement_Stop" + "\t" + "6" + "\t"+ "ShootAgreement");
objPlayer1.logString6("shoot_KeyPress_Agreement_Stop" + "\t" + "" + "\t"+ "ShootAgreement");
objPlayer1.logString11("shoot_KeyPress_Agreement_Stop" + "\t" + "" + "\t"+ "ShootAgreement");
aShootState = aShootNewState;
}
}

}
public function playerPositionEventHandler(evt:TimerEvent)
{
if(keyc == true && keyg == true)
{
logString2("Player move right")
}
if (keyb == true && keyz == true)
{
logString2("Player move left");
}
if (objPlayer1.x < objPlayer1.width / 2)
{
spacegame.instance.logString2("Player hit left base");
}
if (objPlayer1.x > mStage.stageWidth - objPlayer1.width / 2)
{
spacegame.instance.logString2("Player hit right base");
}
}
public function movePlayer(event:Event)
{
if (keyc == true && keyg == true)
{
objPlayer1.x +=  10;
if (objPlayer1.x > mStage.stageWidth - objPlayer1.width / 2)
{
objPlayer1.x = mStage.stageWidth - objPlayer1.width / 2;
}
}
if (keyb == true && keyz == true)
{
```

```
objPlayer1.x -=  10;
if (objPlayer1.x < objPlayer1.width / 2)
	{
	objPlayer1.x = objPlayer1.width / 2;
	}
}

			}
```

Note: the code for connecting the tangible controller to the game is shown below

```
//connecting wiimote in flash
			public function createWiimoteConnection()
			{
				wiimote1 = new Wiimote();
				wiimote1.addEventListener(Event.CONNECT, onWiimoteConnect);
				wiimote1.connect();
				wiimote2 = new Wiimote();
				wiimote2.addEventListener(Event.CONNECT, onWiimoteConnect);
				wiimote2.connect();
			}
			public function onWiimoteConnect(pEvent: Event):void
			{
				wiimote1.addEventListener(ButtonEvent.TWO_PRESS, shoot1);
				wiimote1.addEventListener(ButtonEvent.TWO_RELEASE, onARelease1);
				wiimote2.addEventListener(ButtonEvent.TWO_PRESS, shoot2);
				wiimote2.addEventListener(ButtonEvent.TWO_RELEASE, onARelease2);
				wiimote sensor eventlistener
				wiimote1.addEventListener(WiimoteEvent.UPDATE, updateWiimote1);
				wiimote2.addEventListener(WiimoteEvent.UPDATE, updateWiimote2);
			}

			// all the event listener functions for wiimote1
			public function onARelease1(pEvent:ButtonEvent):void
			{
				//player one's shoot release
				centerCircle.visible = false;
				can1LogShoot = false;
				p1ShootNewState = 0;
				if(p1ShootState != p1ShootNewState)
					{
						logString3("Player1_shootKeyPress_Stop" + "\t" + "4" + "\t"+ "P1Shoot" );
						logString11("Player1_shootKeyPress_Stop" + "\t" + "4" + "\t"+ "P1Shoot" );
						logString3("Player1_shootKeyPress_Stop" + "\t" + "" + "\t" +"P1Shoot");
						logString11("Player1_shootKeyPress_Stop" + "\t" + "" + "\t" +"P1Shoot");
						stopAgreement();
						p1ShootState = p1ShootNewState;
					}

			}
			public function onARelease2(pEvent:ButtonEvent):void
			{
				//Player two's shoot key release
				centerCircleNew.visible = false;
				can2LogShoot = false;
				p2ShootNewState = 0;
				if(p2ShootState != p2ShootNewState)
					{
						can2LogShoot = false;
						logString9("Player2_shootKeyPress_Stop" + "\t" + "5" + "\t"+ "P2Shoot");
```

```
				logString11("Player2_shootKeyPress_Stop" + "\t" + "5" + "\t"+ "P2Shoot");
				logString9("Player2_shootKeyPress_Stop" + "\t" + "" + "\t" +"P2Shoot");
				logString11("Player2_shootKeyPress_Stop" + "\t" + "" + "\t" +"P2Shoot");
				//trace(p2ShootState);
				//trace(p2ShootNewState);
				stopAgreement();
				p2ShootState = p2ShootNewState;
			}

	}
	public function shoot1(e:ButtonEvent)
	{
		//player one's shoot key press
		checkShoot();
		centerCircle.visible = true;
		p1ShootNewState = 3;
		if (p1ShootState != p1ShootNewState)
		{
			can1LogShoot = true;
			logString3("Player1_shootKeyPress_Start" + "\t" +"4" + "\t"+ "P1Shoot" );
			logString11("Player1_shootKeyPress_Start" + "\t" +"4" + "\t"+ "P1Shoot" );
			startAgreement();
			p1ShootState = p1ShootNewState;
		}

	}
	public function shoot2(e:ButtonEvent)
	{
		//Player two's shoot key press
		centerCircleNew.visible = true;
		checkShoot();
		p2ShootNewState = 3;
		shootRelease1 = true;
		if (p2ShootState != p2ShootNewState)
		{
			can2LogShoot = true;
			logString9("Player2_shootKeyPress_Start" + "\t" + "5"+ "\t"+ "P2Shoot");
			logString11("Player2_shootKeyPress_Start" + "\t" + "5"+ "\t"+ "P2Shoot");
			startAgreement();
			p2ShootState = p2ShootNewState;
		}

	}
	public function updateWiimote1(pEvent:WiimoteEvent):void
	{
		var _X:Number;
		var _Y:Number;
		var _Z:Number;
		_X = wiimote1.sensorX;
		_Y = wiimote1.sensorY;
		_Z = wiimote1.sensorZ;

	 if (_Y >0.4 )
		{
			//player one's left tilt
			leftCircle.visible = true;
			player1Wiimote.visible = false;
			L1.visible = true;
			L1t.visible = true;
			checkLeftMovement()
			left1 = true;
			leftRelease1 = true;
```

```
p1LeftNewState = 2; //left
if (p1LeftState != p1LeftNewState)
{
	can1LogLeft = true;
	logString10("Player1_leftKeyPress_Start" + "\t" +"7" + "\t"+ "P1Left");
	logString11("Player1_leftKeyPress_Start" + "\t" +"7" + "\t"+ "P1Left");
	startAgreement();
	p1LeftState = p1LeftNewState;

}
}
else if (_Y <-0.4)
{
	//player one's right tilt
	rightCircle.visible = true;
	player1Wiimote.visible = false;
	R1.visible = true;
	R1t.visible = true;
	checkRightMovement();
	right1 = true;
	p1RightNewState = 1; //left
	if (p1RightState != p1RightNewState)
	{
		can1LogRight = true;
		logString1("Player1_rightKeyPress_Start"  + "\t" +"1" + "\t" +"P1Right");
		logString11("Player1_rightKeyPress_Start"  + "\t" +"1" + "\t" +"P1Right");
		startAgreement();
		p1RightState = p1RightNewState;
	}

}
else
{
leftCircle.visible = false;
rightCircle.visible = false;
player1Wiimote.visible = true;
R1.visible = false;
R1t.visible = false;
L1.visible = false;
L1t.visible = false;
right1 = false;
left1 = false;
p1RightNewState = 0;
if (p1RightState != p1RightNewState)
{
	//player one right tilt stop
	can1LogRight = false;
	logString1("Player1_rightKeyPress_Stop" + "\t" + "1" + "\t"+ "P1Right");
	logString11("Player1_rightKeyPress_Stop" + "\t" + "1" + "\t"+ "P1Right");
	logString1("Player1_rightKeyPress_Stop" + "\t" + "" + "\t"+ "P1Right");
	logString11("Player1_rightKeyPress_Stop" + "\t" + "" + "\t"+ "P1Right");
	stopAgreement();
	p1RightState = p1RightNewState;
}

p1LeftNewState = 0;
if (p1LeftState != p1LeftNewState)
{
	//player one's left tilt stop
	can1LogLeft = false;
	logString10("Player1_leftKeyPress_Stop" + "\t" + "7" + "\t"+ "P1Left");
	logString11("Player1_leftKeyPress_Stop" + "\t" + "7" + "\t"+ "P1Left");
	logString10("Player1_leftKeyPress_Stop" + "\t" + "" + "\t" +"P1Left");
```

```
				logString11("Player1_leftKeyPress_Stop" + "\t" + "" + "\t" +"P1Left");
				stopAgreement();
				p1LeftState = p1LeftNewState;
			}
			}

		}
		public function updateWiimote2(pEvent:WiimoteEvent):void
		{

			var _X:Number;
			var _Y:Number;
			var _Z:Number;
			_X = wiimote2.sensorX;
			_Y = wiimote2.sensorY;
			_Z = wiimote2.sensorZ;
			 if (_Y >0.4 )
			{
				//Player two left tilt
				leftCircleNew.visible = true;
				player2Wiimote.visible = false;
				L2.visible = true;
				L2t.visible = true;
				checkLeftMovement();
				left2 = true;
				leftRelease2 = true;
				p2LeftNewState = 2; //left
				if (p2LeftState != p2LeftNewState)
				{
					can2LogLeft = true;
					logString8("Player2_leftKeyPress_Start" + "\t" + "8" + "\t" +"P2Left");
					logString11("Player2_leftKeyPress_Start" + "\t" + "8" + "\t" +"P2Left");
					startAgreement();
					p2LeftState = p2LeftNewState;
				}
			}
		else if (_Y <-0.4)
			{
				//Player two right tilt
				rightCircleNew.visible = true;
				player2Wiimote.visible = false;
				R2.visible = true;
				R2t.visible = true;
				checkRightMovement();
				right2 = true;
				rightRelease2 = true;
				p2RightNewState = 1; //left
				if (p2RightState != p2RightNewState)
				{
					can2LogRight = true;
					logString7("Player2_rightKeyPress_Start" + "\t" + "2" + "\t" +"P2Right");
					logString11("Player2_rightKeyPress_Start" + "\t" + "2" + "\t" +"P2Right");
					startAgreement();
					p2RightState = p2RightNewState;
				}
			}

		else
			{
			leftCircleNew.visible = false;
			rightCircleNew.visible = false;
			player2Wiimote.visible = true;
			R2.visible = false;
```

```
				R2t.visible = false;
				L2.visible = false;
				L2t.visible = false;
				right2 = false;
				left2 = false;
				p2RightNewState = 0;
				if (p2RightState != p2RightNewState)
				{
					//player two stops right tilt
					can2LogRight = false;
					logString7("Player2_rightKeyPress_Stop" + "\t" + "2" + "\t"+ "P2Right");
					logString11("Player2_rightKeyPress_Stop" + "\t" + "2" + "\t"+ "P2Right");
					logString7("Player2_rightKeyPress_Stop" + "\t" + "" + "\t" +"P2Right");
					logString11("Player2_rightKeyPress_Stop" + "\t" + "" + "\t" +"P2Right");
					stopAgreement();
					p2RightState = p2RightNewState;
				}

				p2LeftNewState = 0;
				if (p2LeftState != p2LeftNewState)
				{
					//player two stops left tilt
					can2LogLeft = false;
					logString8("Player2_leftKeyPress_Stop" + "\t" + "8" + "\t" +"P2Left");
					logString11("Player2_leftKeyPress_Stop" + "\t" + "8" + "\t" +"P2Left");
					logString8("Player2_leftKeyPress_Stop" + "\t" + ""  + "\t"+ "P2Left");
					logString11("Player2_leftKeyPress_Stop" + "\t" + ""  + "\t"+ "P2Left");
					stopAgreement();
					p2LeftState = p2LeftNewState;
				}
				stopAgreement();
			}


		}
```

C. Children's Responses on initial game testing

Gender	Age	Q1	Q2	Q3	Q4	Q5	Q6
Girl	8	Its good	Good cos they shoot straight up	The speed is Ok. You have the chance to run away	Its Ok	yes	No
Girl	7	Hard to kill, move maybe slower	Really good cos it goes quite fast and gets there in time	Its OK. I like it	Really ok	yes	No
Boy	7	Maybe move fast but not so fast	Don't really know	It's ok	Ok	yes	Yes
Boy	7	I think it slow make it faster	Really good cos its fast enough	Really good cos its fast enough	Fast enough to get all the aliens	yes	Yes
Girl	7	They are hard to get cos they keep moving	I think it's fast and it can be slower	It could be slower	Not quite sure	yes	No
Boy	7	Its slow	I think its ok	Ok. They seem powerful	Its quite fast	yes	Yes
Boy	8	I think it should be a little faster	I like the colour and it was quick enough	It was quite slow so it couldn't get me	Its quite fast and I like it	yes	Yes
Girl	8	Its slow, could be little faster	Its good and ok the way it is	Don't know	Ok	yes	No
Girl	8	Aliens need to go a bit faster	Its ok	It was quite fast	Its ok I like it	yes	No
Girl	7	I think its ok	Its fast and I like it	Its Ok	Ok	yes	No
Girl	7	It's a bit slow	They are quite good	It's slow. It will be good if they release more. It will make it harder and more interesting	Its ok	yes	No
Boy	8	Its slow, could be faster	It's ok. I like the speed	Its OK. I like the speed	Its good	yes	No
Boy	8	I think it is good	Its ok	Its ok	Its ok	yes	No
Girl	7	Slow maybe make it move faster	Its ok	They are ok	ok	yes	No
Girl	7	Its slow	I think its ok	I think its OK	I think its ok	yes	No

Q1 = what do you think about the alien movement?
Q2 = what do you think about the bullet speed?
Q3 = what do you think about the speed of the bomb?
Q4 = what do you think about the player movement?
Q5 = do you like the sounds used in the game?
Q6 = did you notice the map on the right corner of the screen?

D. Children's comments on the new features to be added to the game

COMMENTS	NUMBER OF CHILDREN
Different bullet shot by player	2
Adding different weapons	2
Add background	6
Speed up aliens as time progresses	7
Ability to fire faster	6
Arrows that show you what you use	1
Improve alien faces	2
More aliens as you keep killing the aliens	1
Extra levels	3
Better sound assets	1
Spacing between the aliens closer	1
Add bonus	8
Make aliens more active	2
Better graphics	8
Harder levels	6
WASD controls for second player	1
Bullet kill more than 1 alien	1
Shoot partner	1
Easier shooting	1
Smoother and faster movement	7
Quicker bullet movement	6
Special bullets to shoot	1
Flying and jetpacks	1
More things trying to kill you	1
Quicker bombs	6
More colours to make it attractive	1
More attackers from the bottom	1

11.3 Appendix 3: Chapter 5 Documents

A. Pre-Test Questionnaire

Group: Code:

I am a Boy ☐ / Girl ☐ I am ___years old

How often do you play computer games on the following platforms? Tick in the box.

	Everyday	A few times a week	Once a week	Never
Xbox 360				
Nintendo Wii				
Desktop PC				
Touch Screen(e.g. iPads, androids ,iPod, iPhone)				
PlayStation				

What type of games do you play? Tick in the box

Shooting games e.g. danger planet	
Racing games e.g. street racing	
Physical fitness games e.g. wii fit	
Adventure games e.g. role playing games	
Others	

What game(s) do you play most?

Circle the controllers you have used in playing games?

Wiimote   **Nunchunk**

PS2/PS3 controller  **Keyboard** 

Balance board  **Gamepad** 

B. Post-Test Questionnaire

Group: Code: _________ Playing with: ______________

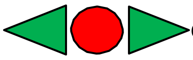
1) Do you spend time together with yellow inside school? Yes ☐ No ☐

2) How often do you play with **YELLOW** at school?

Everyday ☐ A few times a week ☐ once a week ☐ never ☐

3) How long have you Known **YELLOW?**

Before Primary School ☐ Since Starting Primary school ☐ since starting High school ☐

4) Did you notice this picture  on the top right corner of the screen? Yes ☐ No ☐

5) What do you think was the purpose of the picture? (Please go to number 7 if you ticked No in question 5)

6) Would you prefer to play the game alone? Yes ☐ No ☐

7) Did you enjoy playing alone more than playing with **YELLOW**?

Yes ☐ No ☐ maybe ☐

Give a brief explanation to your answer, please.

____

8) How much fun was it to play the game with each controller? Tick off a smiley in the table.

With Game-Pad 	Awful	Not very Good	Good	Really good	Brilliant
With Plastic Handle 	Awful	Not very Good	Good	Really good	Brilliant
With Dance mat 	Awful	Not very Good	Good	Really good	Brilliant

9) Would you like to play the game Again? Tick in the box

	YES	**MAYBE**	**NO**
With Game-Pad 			
With Plastic Handle 			
With Dance mat 			

C. Game types, specific examples and controllers

Table: Game types, specific examples and controllers

Groups	Participants	Types of game	Specific example of most played games	Controllers
A	1	Racing, Physical fitness , Adventure	Temple run	PS2/PS3 controller. Keyboard, game pad, wiimote
	2	Shooting	Call of duty, Black Ops	PS2/PS3 controller. Keyboard, game pad, Nunchunk
B	3	Physical fitness	Wii sports	wiimote, Nunchunk
	4	Don't play games	Don't play games	None
C	5	Racing, Adventure, Others -Mine Craft	Temple run	PS2/PS3 controller. Keyboard, game pad, Nunchunk, balance board
	6	Physical fitness , Adventure	Wii fit, Just dance, Sims	wiimote, Nunchunk, balance board
D	7	Shooting, Physical fitness Adventure, Others – not specified	FIFA	PS2/PS3 controller, gamepad
	8	Shooting, Adventure Others – guitar hero	Gears of War, Guitar Hero Halo, Hitman	PS2/PS3 controller, keyboard, game pad
E	9	Others- sport games	FIFA 13	PS2/PS3 controller. Keyboard, wiimote, Nunchunk, balance board, gamepad
	10	Shooting Others- puzzle games	Angry Birds, James Bond Cut the Rope	Wiimote, Nunchunk, game pad
F	11	Adventure	Mario Bros	PS2/PS3 controller. Keyboard, game pad, balance board
	12	Shooting, Racing, Adventure Physical fitness Others- league of	League of legend	PS2/PS3 controller. Keyboard, game pad, wiimote, Nunchunk, balance board

D. Familiarity with Partners

Table: Familiarity with Partners

Groups	Participants	Age	Q2	Q3	Q4	No. of Years
A	1	14	yes	everyday	Since starting high school	3
	2	15	yes	everyday	Since starting high school	3
B	3	14	yes	Once a week	Since starting high school	3
	4	14	yes		Since starting high school	3
C	5	15	yes	everyday	Since starting high school	3
	6	14	yes	everyday	Since starting high school	3
D	7	14	yes	A few times a week	Since starting high school	3
	8	15	yes	Once a week	Since starting high school	3
E	9	14	yes	A few times a week	Since starting high school	3
	10	15	yes	Once a week	Since starting high school	3
F	11	14	no	never	Since starting high school	3
	12	16	no	never	Since starting high school	4

Q2 = Do you spend time with Blue/Yellow inside school?

Q3 = How often do you play with blue/Yellow at school?

Q4 = How long have you known Blue/Yellow?

The number of years the children had known each other was calculated by subtracting their current age from how old they were when they started high school. For example a child that is 14 years old now started high school when the child was 11 years old. Hence we have 14 -11 = 3. Similarly, a child that is 15 years old started high school at the age of 12 years old. Hence we have 15-13 = 3.

E. Thematic Analysis of Observational Data from Pilot Study

Controllers			First Level Coding	Examples
Tangible	**Dance mat**	**Game pad**		
B, D, E, F	C	A, B, C, D	Dominating	**A**$_{\textbf{gamepad}}$ *"Left, right, shoot"* **B**$_{\textbf{gamepad}}$ *"I will shout you follow"*, *"Shoot like your life depends on it"* **B**$_{\textbf{tangible}}$ *"Left, right, left, left, shoot…"* **C**$_{\textbf{dancemat}}$ *"Go back left, shoot"*, *"Go all the way to the right"* C$_{\text{gamepad}}$ *"Right, go right."* **D**$_{\textbf{gamepad}}$ *"Move to the left"* **D**$_{\textbf{tangible}}$ *"I count one and you tilt left, two right, three shoot"* **E**$_{\textbf{tangible}}$ *"Shoot, left"* **F**$_{\textbf{tangible}}$ *"Shoot"*
		C	Suggestion	**C**$_{\textbf{gamepad}}$ *"Ok, maybe I shout and you press shoot "*
	C	D	Arguing	**C**$_{\textbf{dancemat}}$ *"I asked you to press…"*, *"No you were supposed to press…"*
A	A , D, C, B	D, C, F	Looking at each other's Controllers	
	A	D	Ask help from researcher	
		E	Noticed Map	
		C	Not Talking (Played silently for 10seconds)	
		F	Telling by showing	
		B	Pointing at screen	

F. PeriodS when collaborative behaviours were observed.

Before Game play	During Game play			After Game Play
$D_{Dom}T$	$B_{Dom}T$	$C_{Dom}D$	$A_{Dom}G$	$C_{Arg}D$ $D_{Arg}G$
	$D_{Dom}T$		$B_{Dom}G$	
	$E_{Dom}T$		$D_{Dom}G$	
	$F_{Dom}T$			
			$C_{Sug}G$	
	$A_{LC}W$	$A_{LC}D$	$C_{LC}G$	
		$B_{LC}D$	$D_{LC}G$	
		$C_{LC}D$	$F_{LC}G$	
		$D_{LC}D$		
		$A_{AHR}D$	$D_{AHR}G$	
			$E_{NM}G$	
			$C_{NT}G$	
			$F_{TBS}G$	
			$B_{P}G$	

KEY
Dom = Dominating
Arg = Arguing
Sug = Suggestion
LC = Looking at each other's controllers
AHR = Ask Help from Researcher
NM = Noticed Map
NT = Not Talking
TBS = Telling by showing
P = Pointing at screen

For Illustration, $D_{Dom}T$ means Group D dominated while plying with the tangible controller

G. Purpose of map responses

Table - What do you think was the purpose of the picture?

Groups	Participants	Noticed map?	Participants' Comments
A	P1	Yes	*"Don't know"*
	P2	Yes	*"To show what the other player was doing"*
B	P3	Yes	*"To show us where we were shooting"*
	P4	Yes	*"Don't have a clue"*
C	P5	Yes	*"Not sure"*
	P6	No	-
D	P7	No	-
	P8	Yes	*"To show who was trying to move or fire"*
E	C9	Yes	*"To show which person was pressing which"*
	P10	Yes	*"To help do it in time"*
F	P11	Yes	*"So you knew which way you go"*
	P12	Yes	*"More clear, intuition"*

H. Participants' responses during informal discussion with researcher

Table: Children's responses during informal discussion with researcher

Group	Responses
A	*"He organized it"*
B	*"He told me what to do and I listened"*
C	*"It was a leadership role…I kind of followed what he was doing"*
D	*"By counting"*
E	*"We knew which way we wanted to go… because we knew where the birds were more on the screen". "Bossed him around at some point"*
F	*"We communicated"*

I. Smileyometer, Again-Again and Funsorter results

TableA: Participants' ratings of their experience playing with the three controllers and responses to whether they would like to play the game again using the three controllers (Game pad, Dance mat and Tangible)

	Ratings of Fun (Smileyometer scale, 1 = worst, 5 = best)			Play Again? (Again-Again scale , 1=No, 2 = Maybe, 3 = Yes)		
	Game pad	Tangible	Dance mat	Game pad	Tangible	Dance mat
P1	3	5	5	3	3	2
P2	4	5	3	3	3	2
P3	5	3	5	3	1	1
P4	4	2	5	2	1	1
P5	3	5	2	2	3	1
P6	3	3	4	2	3	3
P7	3	4	2	2	3	2
P8	3	5	2	3	3	1
C9	4	4	2	3	3	1
P10	4	5	5	3	3	2
P11	5	3	5	3	2	2
P12	4	4	5	2	3	2

TableB: Participants' ranking of the three controllers (GP = gamepad, DM = Dance mat, T = Tangible. Scale: 1=Worst, 3 = Best)

	Easiest to Play			Most Fun			Liked the most		
	GP	T	DM	GP	T	DM	GP	T	DM
P1	3	2	1	1	2	3	2	3	1
P2	2	3	1	1	2	3	3	2	1
P3	3	1	2	2	1	3	3	2	1
P4	3	1	2	2	1	3	2	1	3
P5	2	3	1	2	3	1	2	3	1
P6	3	2	1	1	2	3	1	2	3
P7	2	3	1	2	3	1	2	3	1
P8	2	3	1	2	3	1	2	3	1
C9	3	2	1	3	2	1	3	2	1
P10	3	2	1	1	2	3	1	3	2
P11	3	2	1	2	1	3	3	2	1
P12	2	3	1	1	2	3	3	2	1

J. Preference and enjoyment of collaborative game

Table: Participants' responses to which version of game was enjoyed and preferred

Groups	**Participants**	Q6	**Q7**	**Q7b**
A	1	No	No	*"Its better playing with a partner because it's more of a challenge"*
	2	No	No	*"It was more competitive against each but was good working with yellow"*
B	3	No	No	*"It was more fun with blue and we got a higher score together"*
	4	No	No	*"It was fun shouting"*
C	5	Yes	Yes	*"Because it was easier and we got to play independently without having to do it at the same time"*
	6	Yes	Yes	*"It was easier to control and I could play it how I wanted to"*
D	7	No	No	*"It's more fun with two people"*
	8	No	No	*"Because it is more of a challenge with blue so I like it better"*
E	9	No	No	*"I preferred using teamwork in the game"*
	10	Yes	Yes	*"It was easier"*
F	11	Yes	Yes	*"We did not know which way to go, so it was easier on your own"*
	12	Maybe	Maybe	*"It is fun but can be difficult"*

Q6: Would you prefer to play the game alone?
Q7: Did you enjoy playing alone more than playing with your partner?
Q7b: Give a brief explanation to your answer, please.

11.4 Appendix 4: Chapter 6 Documents

A. Narrative Description of Video Data

For each game play session, the researcher introduced the game and instructed the children on how to play it. This was not included in the recount of what the children did or said during interaction with the game. Furthermore, the children were paired in groups A-D designated in this study as Player1 and Player2 but each group had different pairs.

Playing with Game Pad

Group A

Before the start of the game, the pairs took positions in front of the screen, standing side by side with Player1 on the left and Player2 on the right. It was observed that Player2 initiated a conversation with Player1 but the content of their discussion was not audible. However, their body language tends to suggest that they was discussing about how to play the game as both players looked at each other, looked at Player1's game pad and looked at the screen during the discussion. The researcher further suggests that since this happened before the start of the game, the children may have been talking about the strategy to play the game. Six seconds into game play, Player2 gazing at the screen instructed Player1 on what action to take by saying "*Right, right, right, yeah right, right, right, right shoot, shoot, shoot, left, left, left, left, shoot, shoot, shoot, shoot, left, left, left, shoot, shoot, shoot, left, left, left, left, shoot, shoot, shoot, shoot, right, right, right.*" Player1 did not utter a word but focussed his gaze on the screen. Player2 continued to instruct Player1 on the action to take by saying "*Just spam it! Just spam it!*" and Player1 affirmed by saying "*I know, I know.*" At 00:04:54, Player2 said "*Just spray it, just spray it*" but Player1 gave a counter instruction by saying "*The right bit, the right bit*" and Player2 affirmed to what was said by Player1 by saying "*Alright.*" Player2 continued to instruct Player1 on what to do by saying "*Alright, shoot, shoot, shoot*" with Player1 not uttering a word but with his gaze glued to the screen. Four seconds of both players playing in silence and focusing their gazes on the screen Player2 said to Player1 "*No, no, no same. Left, left, left, shoot, shoot, shoot*" but Player1 again was silent with gaze on the screen. After a second had passed, Player2 instructed Player1 on what action to take by saying "*Left, left, right, oh no same, same, same. Right, right, just keep going right. Shoot, shoot, shoot, shoot. Left to the middle*" but Player1 gave a counter instruction by saying "*Left.*" Player2 affirmed to what Player1 said and continued giving Player1 instructions as seen in the transcript "*Alright, same, same, same. Left, left, left, shoot, shoot, shoot.*" Player1, on the other hand affirmed to Player2's instruction by saying "*Yeah.*" Next, Player2 instructed Player1 to shoot by saying "*Shoot, shoot, shoot.*" Again Player1 did not utter a word but stared at the screen. At 00:05:50, Player2 pointed at the screen with his game pad while talking to Player1 but the content of his talk was inaudible. Once more, Player2 instructed Player1 to shoot by saying "*Shoot*" but Player1 argued about what action to take "*Right, move to the right bit.*" Player2 pointing at screen maintained his stance by saying "*No, no, no, we got them.*" Player2 continued to direct Player1 on what direction to go until the end of game play by saying "*left, left, left, shoot, shoot, shoot, shoot. We got them*" while Player1 silently played and focussed his gaze on the screen.

Group B

Similarly, pairs took positions in front of the screen, standing side by side with Player1 on the left and Player2 on the right. At 00:32:34, Player1 turned his head in the right direction and glancing at Player2's game pad instructed "*So left*". While Player2's gaze was fixed on the screen he responded "*Left*". With his gaze fixed on the screen, Player1 said "*Left*" again and Player2 responded "*Oh, I forgot really.*" While both players gazed at the screen, Player1 asked Player2 to shoot by saying "*Shoot, shoot, shoot.*" However, Player2 gave a counter instruction by saying "*Right*" and almost at the same time, Player1 repeated the same instruction given by Player2 "Right, right". Two seconds later (00:32:43), Player2 turned his head to the left, glanced at Player1's game pad while Player1's gaze was fixed on the screen and then stared at the screen without uttering a word. Also at 00:32:44, Player1 was observed to glance at Player2's game pad without uttering a word while Player2 fixed his gaze on the screen. Staring at the screen, Player2 instructed Player1 on what direction to move by saying "*Right, left.*" Player1 gave a counter instruction "*Left*" almost at the same time as Player2 said "*Left, yeah*." At 00:32:48 (fourteen seconds into the start of the game), Player1 noticed the map on the screen and said to Player2 while pointing at the screen with gaze fixed on the screen "Y*ou can see err… if you look at the top right you can see when we are pushing the button at the same time."* While Player1 was talking, Player2 stared at the screen, glanced at his game pad and affirmatively said "*Yeah*". As both players stared at the screen, Player1 continued "*So I can see when you are pushing left, pushing right.*" Player2 suggested to Player1 on how they could play the game differently "*What we could do is just one person… one person does what they want to do and the other person comes through*". But Player1 rejected the suggestions and gave reasons why he thinks the suggestions would not work "*No, that's not a good idea cos one person would not come through very well".* Player2 tried to provide explanation to his earlier suggestion but was cut short by Player1 who continued by saying "*And two it would be boring for the other person…"* Player2 giggled while Player1 carried on *"…who did what they wanted to do and I'm guessing [glanced at Player2] you'll be the person doing what you want to do.*" With both players gazes fixed on the screen, Player1 pointed at the screen and said "*Ok, we get that at the corner.*" Player2 did not utter a word but looked steadily at the screen. One second later, Player2 instructed "*Get the star, get the star, get the star*" and Player1 responded "*Yeah.*" After seven seconds of play with both players not uttering a word and with gazes fixed on the screen Player2 asked "*What do you wanna do?*" and then screamed "*No!*" Player1 responded "*No, Oh come on! We shot the strawberry out of the way.*" Five seconds later Player1 said quietly "*Here we go. Worked! "* At 00:33:43 Player2 started to hum the game background sound and Player1 joined in after four seconds. Player2 instructed Player1 "*Oh, no! Don't go for the big gap. Go right, left*" but Player1 did not utter a word. Both players played silently with gazes focussed on the screen but nine seconds later, Player1 instructed "*Left, left. Let's go back to the left thing. Let's trap it, yeah.*" Again, Player2 did not utter a word but continued playing with eyes fixed on the screen. After 24 seconds of play with gazes on screen and not talking to each other, Player1 broke the silence by saying "*Left, left, left, the star!*" but Player2 did not still utter a word and continued to gaze at the screen. Twelve seconds later, Player2 started to hum the game background sound while Player1 glanced at Player2's game pad and then joined in after two seconds. Player2 asked Player1 "*Should we get the ball?*" and Player1 responded "*Yeah, we can get it! We can get it.*" Both Players made an exclamation of not succeeding in achieving what they set to do. Player2 asked again, "*Should we turn right?*" Player1 responded affirmatively by saying "*Yeah.*" Player2 then said to Player1 "*We have to wait for it*" and Player1 responded by saying "*Just time that one, by the time it gets there*". Excitedly, Player2 raised his left arm up to mid-air and said "*Oh, perfect timing, perfect timing.*" Both players made a sound of excitement with Player1 raising both arms in mid-air before at the end of game play.

Group C

Pair took positions in front of the screen, standing side by side with Player1 on the right and Player2 on the left. Player1 instructed Player2 to shoot by saying “One, two s*hoot*” but player1 giggling leaned forward and gave a counter instruction “*Move that way*”. Looking at the screen, the researcher observed that both players shot at the aliens but missed. Player1 again instructed Player2 to shoot by saying “*Shoot*”. Player2 did not utter a word for 4seconds but turned her head towards Player1’s direction to the right, stared at Player1’s game pad for about 4seconds, touched Player1’s game pad and giggled. Whilst Player2 touched Player1’s game pad, Player1’s gaze was focused on her own game pad. Then Player2 instructed Player1 on what direction to go “*Move, that way, move that way, move that way*” but Player1 gave a counter instruction by saying “*Shoot*”. Both players carried on playing for about 17seconds not talking but with their gazes fixed on the screen. At 00:45:30 Player1 glanced at Player2’s game pad without saying a word, glanced at the screen, glanced at Player2’s game pad again and touched Player2’s game pad. However, Player2 pulled her game pad out of Player1’s reach and said to Player2 “*Get off*”. Player1 reacted by hitting Player2 with her elbow. Both players continued playing without uttering a word to each other but stared at the screen until the end of the session.

Group D

Pairs stood side by side in front of the screen with Player1 on the left and Player2 on the right. Only Player2’s head position could be seen in the footage and his gaze was mostly fixed on the screen apart from one time (01:00:58) when he glanced at his own game pad after his game pad nearly slipped off his hands. Also, both players communicated by talking during gameplay but the content of their talk was inaudible. Towards the end of game play (01:10:12) Player1 was observed pointing at the screen. It was not clear what message Player1 passed across to Player2 through his gesture but obviously, the researcher suggests that it is related to game play.

Playing with Wiimote

Group A

Both players stood in front of the screen in the same position as they were while playing with the game pad i.e. side by side with Player2 on the right and Player1 on the left. Player2 was observed to initiate a conversation with Player1 before the start of the session but the content of their discussion was not audible. However, their body language tends to suggest that they was discussing about how to play the game as both players stared each other, looked at their own wiimotes and each other's wiimote, and even moved their wiimotes side to side during their discussion. At 00:16:10 Player2 instructed Player1 on what action to take by saying "*Left, left*" and tilted his wiimote to the left. Player1 tilted his wiimote to the left without uttering a word and with gaze fixed on the screen whilst Player2 was giving him instructions. Again Player2 staring at the screen instructed "S*hoot, shoot*" and pressed the shoot button while Player1 followed suit in silence and with eyes fixed on the screen. Pairs continued playing in silence with their gazes fixed on the screen and eight seconds later, both players made an "*Aww*" sound simultaneously and started to tilt their wiimote to the left. Looking at the screen, the researcher observed that both players attempted to get a 'cupcake', one of the bonuses in the game but failed. Pairs continued pressing on the shoot button and at 00:16:30 Player1 pointed at the screen and said "*Oh, oh strawberries*" to bring Player2's attention to the strawberry, a bonus in the game. While both players pressed the shoot button, Player2 responded by saying "*Yeah, strawberries*" At 00:16:39, Player2 glanced at Player1's wiimote and instructed "*No, no don't shoot at it*" and tilted his wiimote to the left. Player1 tilting his wiimote to the left said "*The stars*" but Player2 quickly tilted his wiimote to the right and then to the left and said to Player1 "*No, no, no, no. Don't shoot, don't shoot.*" Player2 did not utter a word but tilted in the same directions as Player1 i.e. to the right and then to the left. Player1 and Player2 tilted their wiimotes to the left, to the right and pressed the shoot buttons while playing silently for 22seconds with their gazes fixed on the screen. However, at 00:16:57 while both players pressed the shoot buttons, Player2 glanced at his wiimote and then continued staring at the screen. At 00:17:06, Player2 said "*Here we are*" and Player1 responded "*We got them.*" Player2 continued giving instructions to Player1 by saying "*Left a bit, left a bit, right, right. No, no stay there for a… Stay there cos they are coming back. Shoot, shoot, shoot [pointing at screen].*" Player1 and Player2 were observed to move in the direction as instructed by Player1. Furthermore, both players continued playing without uttering a word to each other but stared at the screen and pressed the shoot button until the end of the session.

Group B

Both players stood side by side in front of the screen with Player1 on the right and Player2 on the left. Player1 initiated a conversation with Player2 on how to play the game which resulted in an argument between the players as seen in the following excerpt:

Player1: "*Alright, so do you want to go from left [tilts left] to right [tilts right] and like sort of err… almost like a routine really*"

Player2: "*I will go to the right*"

Player1: "*No, you have to go at the same time*"

Player1: "*Alright*"

Player2: "*Cos it's just one little thing and we have to move both hands at the same time to get it to move.*"

Player1: "OK"

Both players head positions were not caught in the camera for thirty nine seconds into the start of the game. However, their conversations were transcribed. In their conversation, both Player1 and Player2 showed leadership qualities as they were seen giving instructions to each other on the actions to take. Player1 started by instructing Player2 on what direction to go and Player2 affirming to what Player1 said in the following excerpt:

Player1: "*So, let's go left [tilting left]*"

Player2: "*Ok [tilting left]*"

Player1: "*Press 2 at the same time, come on*"

Player2: "*Aww [tilting right]*"

Player1: "*Just spam 2. Ok we just move left [tilts right] and right [tilts right] with that. Ok, just keep it and tilt it as fast as you can*"

Player2: "*Right [tilts right and left as instructed]*"

Playe1 was observed saying something to Player2 which was not audible and started to tilt to the right while Player2 tilting in the left direction made an exclamation of disappointment after realizing he was tilting in the opposite direction and then started to tilt to the right. Player1 continued to give instructions to Player2 "*That one hanging up. Ok it's fine. Ok let's stay where we are. These are the stars. It disappears if it gets shot. To the left*" while tilting to the right. Player2 tilting right said "*Right, right, right.*" Player1 affirmed to what Player2 said and carried on giving more instructions to Player2 "*Yeah, when I'm about to go further to the right [inaudible]. Just turn around the corner. Just spam 2 as much as you can [shooting].*" Player2 glanced at Player1's wiimote and started shooting with gaze focussed on the screen. Next, Player2 instructed Player1 to go left by saying "*Go left a bit, go left a bit*" while tilting his wiimote to the left. Player1 tilted his wiimote to the left for two seconds and said to Player2 "*Ok, don't move [not tilting his wiimote]. Yeah just stay where we are for now. Once anything comes out...*" But Player2 tilted to the left and while pointing at the screen explained to Player1 why he thought they should go left "*Trying to get the ones at the bottom left.*" Player1 glanced at Player2's wiimote but seemed to ignore Player2's explanation and continued directing Player1 on what to do by saying "*just keep hitting it, keep hitting it"*. However Player1 soon realized what Player2 meant but there was no difference in his response as he was observed giving same instructions: "*Yeah, alright I see what you mean. Just keep hitting it [glancing at Player2's wiimote].*" Player2 affirmed to what Player1 said "*Alright*" and immediately made an exclamation of disappointment "*Aww…*" Player1 quickly instructed Player2 to move to the right by saying "*To the right bit, to the right bit*" but as both players started moving to the right, Player2 gave a counter instruction "*Oh, no. Left, left, left*" and both players started tilting to the left. Player1 continued to instruct Player2 on what to do "*Oh, Ok. Just keep hitting it*" and Player2 pressed the shoot button without uttering a word. Two seconds later, Player1 instructed Player2 on what direction to move by saying "*Ok, Move that way*" and then both players tilted to the right. Then, Player2 suggested "*I think we need to press two. Right, we move to the star*" and Player1 agreed to Player2's suggestion "*Ok, we'll move to the star."* While both players tilted to the left, Player1 said "*Oh we both moved too much."* Player1 glanced at Player2's wiimote and instructed him to move to the right "*Just a little bit to the right [tilting his wiimote to the right]*" Player2 tilted his wiimote to the left but suddenly realized he was tilting in the wrong direction and said "*Oh right, right*" then started to tilt to the right. Both players pressed the shoot button continuously without uttering a word to each and with their gazes fixed on the screen for about 10seconds but at 00:22:47, Player1 glanced at Player2's wiimote and continued to stare at the screen. Player2 broke the silence by instructing Player1 "*Aww let's go back a bit*" and started tilting to the left. On the other hand, Player1 affirmed to Player2's instruction by saying "*I know" and started tilting in the same direction as Player2. Next,* Player1 instructed "*Spam 2, spam 2, spam 2*" while pressing the shoot button but Player2 tilting left explained "*I was too busy trying to get the last few.*" Player1 responded "*Yeah, I know you [inaudible]"* and asked "*Is that is that*" before giving instructions to Player2 "*Right, oh right a bit*" and started tilting his wiimote to the right. Player2 also tilted his wiimote to the right but without uttering a word and with his gaze focussed on the screen. Two seconds later Player1 instructed Player2 "*Go to the left side*" and Player1 responded by moving his body to his right while making a sound. Player2 also moved his body to his right almost at the same time as Player1. Next, Player1 tilted to the left and Player2 said "*Oh, no. Don't go to the left again. Ok, we just get these three in [pointing at the screen]. This is catchy, isn't it?*" and hummed the game background sound. Player1 made an exclamation of excitement "*Spraghhh*" and Player2 joined in by saying "*Sproogh.*" Both players started tilting to the left and Player1 said "*By the time we move that way*" but Player2 cuts in "*If we go that way.*" Player1 continued "*Yeah, I was gonna say, by the time we move that way…"* But before Player1 could complete the statement, both players reacted on impulse by saying "*Oh, oh, yeah!*" and started tilting their wiimote to the right. Player1 excitedly said "*High five*" and both players raised their right hands in mid-air, clapped them together and laughed. Player1 glanced at his wiimote and continued to stare at the screen while Player2 said "*I'll look good in the camera.*" Player1 giggled in response and said "*Ok, just keep hitting it.*" Three seconds later, Player1 instructed Player2 "*Just spam it, by the time they get there [pointing at screen] they will get hit.*" While both players tilted to the right, Player2 directed Player1 on what action to take by saying "*Err, right again, No, no left*" and tilted left while Player1 followed suit. At the end of the game play, both players screamed "*O, yeah!*" and then Player2 excitedly jumped up with his hands in mid-air while Player1 raised his hands in mid-air at the end of the game.

Group C

Before the start of the game, the pairs took positions in front of the screen, standing side by side with Player1 on the right and Player2 on the left. It was observed that Player1 initiated a conversation with Player2 but the content of their discussion was not audible. However, their body language tends to suggest that they was discussing about how to play the game as Player1 looked at Player2 and tilts her wiimote to the left and then right during their discussion. Player2 was also observed to tilt her wiimote in the same direction almost at the same time with Player2 while looking at Player1. At 00:51:48 Player1 was observed tilting her wiimote to the right and four seconds later instructed Player2 on what direction to go by saying "*Go that way*" and then started to tilt her wiimote in the left direction. In response, Player2 tilted her wiimote to the right and screamed "*Aouch!*" Player2 immediately instructed Player1 to shoot by saying "*Shoot*" and started pressing the shoot button of her wiimote. Also, Player2 pressed the shoot button of her wiimote in silence and with her gaze on the screen. Three seconds later, Player2 looked at Player1's wiimote and instructed Player1 to shoot by saying "*Shoot.*" Player1 responded by saying "*We have to do it at the same time.*" Then Player2 started to count "*One, two, three, four, five, six*" and Player1 joined in the counting. Two seconds later, Player2 suggested to Player1 "*Let's move this way*" and started tilting her wiimote to the left. Player1 tilted her wiimote to the left as she continued counting "*One, two, three.*" While Player1 pressed the shoot button of her wiimote, Player2 tilted her wiimote to the right and to the left then giggling looked at Player1's wiimote and said "*Alright stop*" and started to tilt in the left direction. But Player1 carried on pressing on the shoot button for five seconds before tilting left. Few seconds later, Player2 shook her wiimote and giggled and then started to tilt in the right direction as Player1. Next both players tilted their wiimotes in the right direction and then pressed the shoot buttons but at 00:52:26, Player2 made an exclamation of disappointment, dropped her arms downwards and tilted her wiimote to the left, then to the right before continuing to press the shoot button as Player1. At 00:52:49 while Player2 pressed the shoot button, Player1 tilted to the left, right, left again and then started to press the shoot button. Finally, both players tilted to the left for three seconds before pressing shoot button until the end of game play.

Group D

Both players stood side by side in front of the screen with Player1 on the left and Player2 on the right. Before the game started, Player2 looked at Player1 and initiated a conversation with Player1 about the study environment "*It's cold in here*" he said and turned his gaze back to the screen. Player1 responded by saying "*Let's do it.*" Player2 glanced at Player1, at his own wiimote, at the screen, stared at own wiimote and then said "*We can do it*" before turning his gaze back to the screen. Player1 staring at Player2 said "*Just hope we do it at the same time*" and Player2 giggled, looked at Player1 and said "*We will do it at the same time. We will have to press the buttons at the same time, yeah.*" Player1 came up with a strategy to play the game "*Just continuously press the buttons. Just hope I'm pressing it as well.*" Player2 did not utter a word but glanced at his own wiimote and stared at the screen. During game play, both players were engaged in a conversation but the content of their conversation was not audible. However, their gazes were fixed on the screen for majority of the time apart from time (00:56:36) when Player1 pointed at the screen and time (00:55:59) when he glanced at Player2's wiimote. Also, at time (00:55:22) Player2 glanced at Player1's wiimote, glanced at his own wiimote and continued looking at the screen.

Playing with Dance Mat

Group A

Pairs stood side by side in front of the screen with Player1 on the right and Player2 on the left. At the start of gameplay (00:09:56), it was observed that Player2 glanced at his dance mat for less than a second, then stared at screen without saying a word while stepping on the left button of his dance mat. Almost at the same time, Player1 was also observed to do the same thing as Player2 i.e. glanced at his dance mat for less than a second, stared at the screen without saying a word while stepping on the left button of his dance mat. At 00:10:01, Player2 glanced at his dance mat, instructed Player1 to "*fire*" and started stepping on the shoot button of his dance mat while staring at the screen. Player1 responded by stepping on the shoot button of his dance mat without uttering a word, glanced at his dance mat and at the screen. It is worth noting the both players continued to step on the shoot button of their respective dance mats until nearly the end of game play at 00:11:44. While Player1 glanced at his own dance mat, Player2 stared at the screen. At 00:10:03, Player2 glanced at his own dance mat almost at the same time as Player1 glanced at Player2's dance mat, and then glanced at Player1's dance mat. While Player1 stared at the screen, Player2 turned towards the researcher and pointing at his own dance mat asked "*Is that err, shooting?*" and immediately turned his gaze back to the screen. At 00:10:06, Player2 glanced at his own dance mat while Player1 glanced at Player2's dance mat. Next, Player1 stared at his own dance mat, instructed Player2 to "*Keep going*" and continued staring at the screen. Player2 on the other hand, glanced at Player1's dance mat about the same time as Player1 was staring at his own dance mat, then stared at his own dance mat and at the screen. Glancing at Player1's dance mat, Player2 said "*It's not…*" and continued staring at the screen. However, Player1 did not utter a word but glanced at his own dance mat and stared at the screen. At 00:10:12, while Player1 stared at the screen, Player2 glanced at his own dance mat and then stared at the screen. Next, while Player2 stared at the screen, Player1 glanced at Player2's dance mat. At 00:10:13, Player2 glanced at his own dance mat and stared at Player1's dance mat while Player1 stared at the screen. Then, Player2 instructed Player1 "*Get in bit, tata, tata*" while still staring at Player1's dance mat but Player1 responded by glancing at Player2's dance mat and then at his own dance mat. At 00:10:17, Player2 stared at the screen while Player1 glanced at Player2's dance mat and then stared at the screen. Still staring at the screen, Player2 asked "*Is it not working?*" however, Player1 did not utter a word but continued staring at the screen. At 00:10:21, Player2 glanced at his own dance mat while Player1 glanced at Player2's dance mat. About one second later, both players' eye gazes changed as Player1 was observed to glance at his own dance mat while Player2 stared at Player1's dance mat. As both players continued playing with their gazes fixed on the screen, Player2 smiled and said "*We'll get this.*" But Player1 stared at his own dance mat while Player2 glanced at his own dance mat and then stared at Player1's dance mat. While both players stared at the screen, Player2 said "*It's almost frustrating*" but Player1 remained silent with gaze focused on the screen. At 00:10:41, Player1 glanced at Player2's dance mat about the same time as Player2 glanced at his own dance mat, glanced at his own dance mat and then stared at the screen. In addition, Player2 instructed Player1 "*Go on*" while staring at the screen but Player1 remained silent with gaze focused on the screen. Next, Player1 stared at the screen whereas Player2 glanced at his own dance mat and at 00:10:45 both players simultaneously glanced at each other's dance mats. While both players stared at the screen, Player2 suggested "*Let's see how it goes if we stand on it*" and Player1 responded "*Yeah.*" Immediately, Player2 staring at Player1 with both arms raised to the sides said "*Perfect!*" and turned his gaze back to the screen. Both players stared at the screen without uttering a word to each other and at 00:11:01, Player2 broke the silence by instructing Player1 on what action to take "*Oh stand on it. Go on.*" Player1 still did not say a word rather he glanced at Player1's dance mat, at his own dance mat and stared at the screen. While Player1 stared at the screen, Player2 glanced at Player1's dance mat, stared at the screen, glanced at his own dance mat, stared at the screen and said "*Go on!*" Player1 responded by staring at his dance mat and the then at the screen. Player2 also glanced at Player1's dance mat whilst Player1 stared at his own dance mat. Both Players were silent and stared at the screen but at 00:11:33, Player2 glanced at his own dance mat, at Player1's dance mat and continued staring at the screen. Still staring at the screen, Player1 said "*We can't get there*" and then glanced at his dance mat but Player2, pointing at the screen instructed Player1 to go left by saying "*Left, left*" and then stepped on the left button of his dance mat. However, Player1 had already started to step on the left button before the instruction came but carried on stepping on the left button, stared at the screen, glanced at Player2's dance mat and stared at the screen. At 00:11:57, Player1 was observed to glance at Player2's dance mat at the same time as Player2 glanced at his own dance mat before staring at the screen. While staring at the screen, Player2 instructed Player1 to move right by saying "*Go right*" but Player1 was silent with his gaze focussed on the screen. Next, while Player1 stared at Player2's dance mat, Player2 glanced at Player1's dance mat and at his own dance mat in quick successions. Both players then stared at the screen and at 00:11:51 Player2 said to Player1 "*Come on! Hold it down, hold it down. Just fire!* " and stepped on the shoot button of his dance mat. Player1 did not utter a word but glanced at his own controller, stared at the screen before stepping on the shoot button of his dance mat. While Player1 stared at the screen, Player2 glanced at Player1's dance mat, at the screen, at Playe1's dance mat again, at his own dance mat and then stared at the screen. Furthermore, Player1 glanced at his own dance mat, glanced at Player2's dance mat and then stared at the screen till the end of game play. On the other hand, Player2 glanced at Player1's dance mat, glanced at his own dance mat and glanced at the screen. It is worth noting that whilst Player1 glanced at his own dance mat, Player2 glanced at Player1's dance mat almost at the same time. Also, whilst Player2 glanced at his own dance mat, Player1 glanced at Player2's dance mat almost at the same time. In addition, Player2 stared at the screen for six seconds, glanced at his own controller and stared at the screen until the end of game play.

Group B

Before the start of the game, the pairs took positions in front of the screen, standing side by side with Player1 on the right and Player2 on the left. Player1 started off stepping on the shoot button but then glanced at Player2's dance mat and started stepping on the right while Player2 started off stepping on the right button, glanced at his own dance mat and then ordered Player1 to shoot by saying "*Fire.*" Both Players stepped on the fire button and then Player1 glanced at his own dance mat and instructed "*Just slow it down a bit.*" Still stepping on the fire button and staring at the screen, Player2 suggested "*Let's fire it for a bit." While b*oth players stood still on the fire button, Player1 affirmed by saying "*Yeah"* and then instructed Player2 to "*Hold on there.*" Still standing on the fire button, Player2 glanced at his own dance mat and then stared at the screen. Player1 continued by saying "*I should have…*" but was interrupted by Player2 who instructed him to go left by saying "*Left, left, left*" whilst stepping on the left button. Affirming to Player2's instruction, Player1 said "*Yeah, left, left, left*" and followed suit i.e. stepping on the left button as well. While Player1 continued staring at the screen, Player2 glanced at his own dance mat and then stared at the screen. Pairs silently played for 9seconds with both players stepping on the shoot button and intermittently glancing at their individual dance mats whilst staring at the screen although at one point (00:39:32), Player2 glanced at Player1's dance mat whilst Player1's gaze was fixed on the screen. Still staring at the screen, Player1 exclaimed "*The star!*" glanced at his dance mat and then stepped on the right button to move towards the star. But Player2 still stepping on the shoot button responded "*Just leave it. It's only ten points anyway*" and then glanced at his dance mat and continued staring at the screen while Player1 glanced at his dance mat, withdrew his steps and started to step on the shoot button while staring at the screen. Then both players glanced at their respective dance mats, and stepped on the shoot button while staring at the screen. At 00:39:49 Player2 while glancing at his own dance mat and stepping on the right button said "*Oh, oh, right, right, right, right.*" But Player1 glanced at his own dance mat, and gave a counter instruction "*Left, left, left*" and stepped on the left button of his dance mat. Ignoring Player1's counter instruction, Player2 said "*Oh I want to go right cos I want to get the bomb*" whilst stepping on the right button. Player1 said "*Ok*" but continued stepping on the left button. Almost immediately, Player1 instructed Player2 to shoot by saying "*Ok, shoot, shoot, shoot*" and then pointing at the screen explained "*Keep shooting cos the left bit[inaudible]*" Player2 responded by glancing at his dance mat and stepping on the shoot button while staring at the screen. After 4 seconds of play, Player2 glanced at his own dance mat then stepped on the left button and said "*Left slightly, then we move away from the bomb.*" Player1 responded "*Yeah*" and then stepped on the left button of his dance mat. After one second, Player1 instructed "*Just keep shooting*" while stepping on the shoot button. Player2 responded "Oh yeah" and started to step on the shoot button as well. Immediately, Player1 said "*Oh oh, left a bit faster*" then glanced at his dance mat and started to step on the left button of his dance mat. While simultaneously stepping on the left button and staring at the screen, Player2 asked "*Did we get it?*" Player1 answered "*I'm not sure*", glanced at his own dance mat and started to step on the shoot button. Player2 glanced at Player1's dance mat and started to step on the shoot button of his dance mat.Player2 immediately glanced instructed "*Oh, oh, left, left, left*" and stepped on the left button of his dance mat with his gaze fixed on the screen while Player1 staring at the screen responded "*Ok, ok*" and started stepping on the left button. Next, Player2 glanced at his own dance mat and said "*The dance mat is not flat on the ground*" while stepping harder on the left button. Player1 glanced at his own dance mat and commented "*Come on! I got my foot on it but it's not registering it*" while still stepping on the left button and then staring at the screen. On the other hand, Player2 glanced at his dance mat, stared at the screen, glanced at his dance mat again and while staring at the screen asked "*Can we go to the right?*" and then started stepping on the right button. But Player1 did not utter a word but stepped on the right button while staring at the screen. After five seconds, Player2 instructed "*Fire*" while stepping on the shoot button but Player1 responded "*It's a little bit jerky, isn't it?*" while stepping on the shoot button. Player2 immediately instructed Player1 to fire again by saying "*Fire.*" This time, Player1 did not utter a word but stared at his dance mat whilst stepping on the shoot button. Next, Player2 whilst stepping on the right button said to Player1 "Right, oh, oh. It's alright we got at the bomb" and continued stepping on the shoot button. Meanwhile, Player1 continued stepping on the shoot button despite Player2's initial instruction to move right. Player1 then instructed Player2 to shoot by saying "*Shoot it"* but glancing at his own dance mat Player2 gave a counter instruction saying "*Left"* and started stepping on the left button with gaze focused on the screen. Player1 responded "*Go on*" whilst stepping on the left button as instructed. For seventeen seconds, pairs played without uttering a word to each other but both players were observed to stare at their respective dance mats and then stared at the screen on two consecutive occasions. Also, within the seventeen seconds, both players stepped on the left button for seven seconds and whilst Player1 stepped on the shoot button, Player2 moved from shoot button to left button and back to shoot button. Then both Players again stepped on the right buttons of their respective dance mats. At 00:40:55, Player2 instructed "*Fire*" and started stepping on the shoot button. Player1 did not utter a word but glanced at the screen, his dance mat and stared at the screen while stepping on the shoot button as instructed by Player2. Whilst both players were stepping on the shoot button Player2 said "*Stamp on the floor and see how it goes*" but Player1 responded after three seconds saying "*You can see it on the top bit*" while pointing at the screen. Player2 glanced at his own dance mat and said "*Keep firing*" and Player1 responded "*Ok.*" Next, Player1 glanced at his dance mat, stepped on the right button, stared at the screen, started stepping on the shoot button and while he glanced at his dance mat he said "*Put down on it*" and then continued to stare at the screen. As Player2 continued to step on the shoot button with gaze fixed on the screen he said "*You can see it at the top bit*" while he glanced at his own dance mat. Player1 pointing at the screen responded "*Yeah, you can see it just [inaudible]*" and then carried on to suggest "*Maybe we should just hold it all the way down.*" But Player2 did not utter a word but stepped on the right button of his dance mat. Player1 soon realized that Player2 ignored his suggestion and then started to step on the right button of his dance mat as well. Pairs played in silence for nine seconds with Player1 glancing at his own dance mat, staring at the screen and stepping on the shoot button. Player2 was also observed to glance at his own dance mat, stare at the screen and stepped on the shoot button as Player1 but later started to step on the right button with eye gaze changing from his dance mat to the screen. Next, Player1 said "*Ok, this is not moving*" and then glanced at Player2's dance mat and continued to step on the shoot button while Player1 stepped on the left button, then on the shoot button and responded "*If you stand on it, I think it will do it*" then glanced at his dance mat and continued to stare at the screen. Player2 glanced at Player2's dance mat and said "*I've been doing it and it's like...*" and continued staring at the screen and Player2 pointing and staring at Player2's dance mat responded "*Maybe because you are pressing two. Think about it because you are pressing that one as well*" During the explanation, Player1's eye gaze was fixed on his dance mat and afterwards both players continued to stare at the screen. For thirty five seconds pairs played without uttering a word and their eye gazes moved from their respective dance mats and the screen at irregular intervals. In addition, the two players stepped on the shoot button and then the right button at about the same time. At 00:42:19 Player2 turned to the researcher and said "*It's stopped working!*" then stared at his own dance mat and the screen but Player1 encouraged Player2 by saying "*Come on!*" While staring at the screen, Player2 said quickly "*Fire, fire, fire, fire!*" and both players started stepping on the shoot button. Pair then continued playing without uttering a word to each other until the end of game play but moved their gazes in different directions: own dance mat, partner's dance mat and the screen at intermittent times. Both players also stepped on the left and then shoot buttons of their dance mats at the same times.

Group C

Pairs stood side by side in front of the screen with Player1 on the right and Player2 on the left. At the start of the game (00:47:47), Player2 stepping on the right button of her dance mat instructed "*Go that way, that way, that way*" and glanced at Player1's dance mat. In response, Player1 stepped on her own dance mat as instructed by Player2 while staring at the screen. Next, Player2 stepping on the shoot button instructed "*Shoot, shoot*" with her gaze focused on the screen then two seconds later stared at Player1's dance mat and said "*Put your foot on it. Just put your foot on it.*" Player1 on the other hand stepped on the shoot button with her gaze still fixed on the screen and two seconds later, glanced at her own dance mat and continued staring at the screen and stepping on the shoot button. At 00:48:01 whilst stepping on the shoot button, Player1 said "*We need to do it at the same time*" but Player2 again instructed "*Go that way, go that way*" and started to step on the left button. Player1 on the other hand, glanced at Player1's dance mat and started stepping on the left button as instructed. Both players stared at the screen and continued to step on the left button but at 00:48:07, Player2 staring at Player1's dance mat held Player1 by her arm and started to count "*One, two*" and then both players stepped on the left button at the same time. Whilst Player1 played silently but still stepping on the left button and staring at the screen, Player2 glanced at the screen, at her dance mat, stared at the screen, glanced at her dance mat again and continued to stare at the screen. Next, both players started to step on the shoot button but at 00:48:16, Player1 started to step on the left button and Player2 said "*We are doing it differently*". Pairs glanced at each other's dance mats and Player2 started to step on the left button. One second later, Player1 staring at the screen stepped on the shoot button whereas Player2 was stepping on the left button but Player1 glanced at Player2's dance mat and immediately started to step on the left button as Player1. At 00:48:29, Player2 touched Player1's left arm and pointed at her own dance mat while staring at her dance mat and then started to step on the right button. Player1 on the other hand, stared at Player2's dance mat and then followed suit. Both players continued stepping on the right button and with gazes fixed on the screen but at 00:48:37 Player2 giggled and said "*It doesn't work!*" Furthermore, Player2 pulled Player1's left arm to make Player1 step on the right button at the same time. Both players continued to step on the right button of their respective dance mats for seventeen seconds and then Player2 started to step on the shoot button but Player1 stepped on the left button but glanced at

Player2's dance mat and started stepping on the shoot button. Whilst pairs continued stepping on the shot button, Player1 started counting "*One, two, three!*" and Player2 giggled. Player1 continued "*On every three you step on it*" but Player2 responded "*It's not working really.*" For twenty four seconds, pairs stepped continuously on the shoot button. Within the period, Player1 stared at the screen whilst Player2 glanced at his dance mat and stared at the screen on two consecutive occasions, glanced at Player1's dance mat and stared at the screen also on two consecutive occasions then glanced at Player1's dance mat, his dance mat and stared at the screen. Furthermore, Players stepped on the left button and then on the shoot button with gazes moving from the screen and their respective dance mats until the end of game play.

Group D

Pairs stood side by side in front of the screen with Player2 on the left and Player1 on the right. Before the game started, Player2 looking at Player1 asked "*How are we gonna do this?* " Player1 looking at Player2 responded "*You'll be the one who decides where to go and I'll just follow.*" At the start of game play, Player2 instructed Player1 to go left by saying "*Go left*" while stepping on the left button of his dance mat and Player1 not uttering a word followed suit. Next, both players glanced at their respective dance mats and Player2 said "*Left, left.*" Player1 giggling asked "*Left?*" and Player2 quickly said "*Up*" and glancing at Player1's dance mat started to step on the shoot button while Player1 glanced at his dance mat and followed suit. While pairs were stepping on the shoot button of their respective dance mats, both players glanced at each other's dance mats and then Player2 said "*Fire! It's not firing.*" Player1 looked up at the screen and started stepping on the right button while Player2 also looked at the screen but continued to step on the shoot button. At 00:57:59 glanced at Player2's dance mat and started to step on the right button of his dance mat then Player2 instructed "*Fire*" and Player1 responded "*Oh*" and started to step on the shoot button. Both players glanced at Player1's dance mat and continued to step on the shoot button in silence for seven seconds with their gazes focussed on the screen. However, at 00:57:58 Player1 glanced at own dance mat, the screen, Player2's dance mat then stepped on the left button for one second and continued to step on the shoot button. Next, Player2 with gaze still on the screen instructed "*Right*" and stepped on the right button of his dance mat. Player1 on the other hand glanced at his dance mat and started stepping on the left button but looked up at the screen, glanced at his dance mat again and then stepped on the right button as instructed. Next, Player2 glanced at his dance mat and at Player1's dance mat and then instructed "*Up*" while stepping on the shoot button. Player1 without uttering a word stepped on the shoot button as instructed. Five seconds later, Player2 glanced at his dance mat and instructed "*Left, oh left*" Again Player1 did not utter a word but stepped on the left button as instructed. At 00:58:32, Player1 glanced at his dance mat and continued stepping on the left key with gaze fixed on the screen. Then Player2 glanced at his dance mat and said "*Oh*" and then started to step on the shoot button and Player1 glanced at his dance mat and followed suit without any instruction from Player2. Player2 glanced at his dance mat and at Player1's dance mat and said "*Come on! It's not doing it*" while Player1 glanced at Player2's dance mat, stared at his dance mat and responded "*You have to lift it up*" Next, Player1 glanced at Player2's dance mat and started to step on the right button while Player2 continued to step on the shoot button with eyes fixed on the screen. While Player2's gaze was on the screen, Player1 gaze moved intermittently from his dance mat to the screen on two consecutive occasions. Then at 00:58:44, Player2 still stepping on the shoot button of his dance mat glanced at Player1's dance mat and said "*keep firing*" while Player1 without uttering a word glanced at his dance mat and Player2's dance mat and continued stepping on the shoot button of his dance mat with gaze on the screen. Player2 glanced at his dance mat, at the screen and while staring at Player1's dance mat said "*Come on*" while stepping on the shoot button of his dance mat. On the other hand, Player1 glanced at Player2's dance mat and continued to step on the shoot button while staring at the screen. At 00:58:55, Player1 glanced at Player2's dance mat and started stepping on the left button of his dance mat while Player2 was still stepping on the shoot button and had his gaze on the screen. Two seconds later, Player1 simultaneously glanced at Player2's dance mat and pointed at the screen and then instructed "*Left, left*" but Player2 while stepping on the shoot button gave a counter instruction "*Up.*" Player1 asked "*You want it all up?*" and then started stepping on the shoot button. Both players stepped on the shoot button of their respective dance mats until the end of game play with their gazes moving intermittently from the screen, each other's dance mats and their own dance mats.

B. Collaborative Network

Group A (Game pad)
Before Game play

P1_ Eye_Gaze Code	**P1Eye_Gaze**	**P1 Gesture**	**P1_Transcript**	**P1 Transcript Code**	**P2 Transcript Code**	**P2_Transcript**	**P2Eye_Gaze**	**P2 Gesture**	**P2_ Eye_Gaze Code**
	Looks at P2 Looks at p1's controller Looking at screen		Conversation inaudible	Co_{inaud}	Co_{inaud}	Conversation inaudible	looks at P1 Looks at own controller Looking at the screen		
During Game Play									
PAT1	Looking at screen				Gi	Right, right. right	Looking at screen		PAT1
					C^+	Yeah			
					Gi	Right, right. right, right			
					Gi	Shoot, shoot, shoot			
					Gi	Left , left, left, left			
					Gi	Shoot, shoot, shoot, shoot			
					Gi	Left , left, left			
					Gi	Shoot, shoot, shoot			
					Gi	Left , left, left, left			
					Gi	Shoot, shoot, shoot, shoot			
					Gi	Right, right, right			
					Gi	Just spam it! Just spam it!			
			I know! I know!	Ag					
					Gi	Just spray it! Just spray it!			
			The right bit, the right bit	D					
					Ag	Alright			
					Gi	Shoot, shoot, shoot			

	Played silently	NT	NT	Played silently	
			↓ C^-	No, No, No, same	
			↓ Gi	Left , left, left	
			↓ Gi	Shoot, shoot, shoot	
			↓ Gi	Left , left	
			↓ Gi	Right	
			↓ **D**	Oh, no	
			↓ Gi	Same, same, same	
			↓ Gi	Right, right	
			↓ Gi	Just keep going right	
			↓ Gi	Shoot, shoot, shoot, shoot	
			↙ Gi	Left to the middle	
	Left	Ag ↘			
			↓ C^+	Alright	
			↓ Gi	Same, same, same	
			↓ Gi	Left , left, left	
			↙ Gi	Shoot, shoot, shoot	
	Yeah	Ag ↘			
			↓ Gi	Shoot, shoot, shoot	
				[inaudible]	Shows P1 own game pad
			↙ Gi	Shoot	
	Right, move to the right bit	D ↓			
	No, no, no	C^- ↓			
	We got them	Pe ↘			
Pointing at screen			↓ Di	Left ,left, left	
			↓ Di	Shoot, shoot, shoot	
			Pe	We got them	

Group B (Game pad)
During Game play

P3 Eye_Gaze Code	P3Eye_Gaze	P3 Gesture	P3_Transcript	P3 Transcript Code	P4 Transcript Code	P4_Transcript	P4Eye_Gaze	P4 Gesture	P4 Eye_Gaze Code
PAT3	Glanced at P2's controller		So, Left	Gi ↘					
					↙ Ag	Left	Looks at screen		PAT1
PAT1	Looking at screen		Left	Gi ↘					
					↙	Oh, I really forgot			
			Shoot, shoot, shoot	Gi ↘					
					↙ D	Right			
			Right	Ag ↓					
			Played silently	NT	NT	Played silently	Glanced at P1's controller		PAT3
							Looking at screen		PAT1
PAT3	Glanced at P2's controller								
					↓ Gi	Right			
PAT1	Looking at screen								
					↙ Gi	Left			
			Left	Ag ↓					
		Pointing at screen	You can see err, if you look at the top right you can see when we are pushing the button at the same time	Nm ↘	↙ C^+	Yeah	Glanced at own controller		PAT2
							Looking at screen		PAT1

			So I can see when you are pushing left, pushing right	Nm↘		
					↙ Su	What we could do is just one person …one person does what they want to do and the other person comes through
			No	D↓		
			That’s not a good idea cos one person would not come through very well	**X**↘		
					↓D	No
					↙ **X**	They’ll be like…
			And two, it would be boring for the other person…	**X**↓	**X**	[laughs]
PAT4 PAT1	Glanced at P2 Looking at screen		…who did what they wanted and I’m guessing, you’ll be the person doing what you want to do	**X**↓		
			Ok	C^+↓		
		Points at screen	We get that at the corner	Gi↓		

				↓Pe	Get the star! Get the star
		Played silently	NT	NT	Played silently
				↓E	What do you wanna do?
				↙ C^-	No
		No	C^-↓		
		Oh come on! We shot the strawberry out of the way	Pe↓		
		Here we go. Worked!	Pe↓		
		[hums game background sound]			[hums game background sound]
				↓C^-	Oh, no!
				↓Gi	Don't go for the big gap
		Played silently	NT	NT	Played silently
		Left, left. Let's go back to the left thing	Gi↓		
		Let's trap it	Gi↓		
		Yeah	C^+↓		
		Played silently	NT	NT	Played silently
		Left, left, left	Gi↓		
		The star!	Pe↓		
		Played silently	NT	NT	Played silently
PAT3	Glanced at P2's controller	[hums game background sound]			[hums game background sound]
				↙ Su	Should we get the ball?
		Yeah	C^+↓		
PAT1	Looking at screen	We can get it. We can get it			

Yeah	Gi		
		Su	Should we turn right?
	Ag		
Just time that one, by the time it gets there		Gi	We have to wait for it
	Gi		
		Pe	Oh, perfect timing [lift arms up to mid-air]

Group C (Game pad)
During Game play

P5 Eye_Gaze Code	**P5Eye_Gaze**	**P5 Gesture**	**P5_Transcript**	**P5 Transcript Code**	**P6 Transcript Code**	**P6_Transcript**	**P6Eye_Gaze**	**P6 Gesture**	**P6 Eye_Gaze Code**
PAT1	Looking at screen				Gi	One, two Shoot	Looking at screen		PAT1
			(giggled) Move that way.	D					
PAT3	Stared at P1's controller	Touched P1's controller	[giggled]		Gi	Shoot	Stared at own controller		PAT2
							Looking at screen		PAT1
PAT1	Looking at screen		Move that way, move that way, move that way	D					
					Gi	Shoot			
			Played silently	NT	NT	Played silently			
							Glanced at P2's controller		PAT3
							Glanced at screen		PAT1
							Glanced at P2's controller		PAT3
			Get off!	Pe				touched P2's controller	
							Looking at screen		PAT1
			Played silently	NT	NT	Played silently			

Group D (Game pad)
During Game play

P7 Eye_Gaze Code	P7Eye_Gaze	P7 Gesture	P7_Transcript	P7 Transcript Code	P8 Transcript Code	P8_Transcript	P8Eye_Gaze	P8 Gesture	P8 Eye_Gaze Code
PAT1	Looks at screen		Conversation inaudible	Co_{inaud}	Co_{inaud}	Conversation inaudible	Looking at screen		PAT1
							Glanced at own controller		PAT2
							Looking at screen		PAT1
		Points at screen							

Group A (Wiimote)

P1 Eye_Gaze Code	P1Eye_Gaze	P1 Gesture	P1_Transcript	P1 Transcript Code	P2 Transcript Code	P2_Transcript	P2Eye_Gaze	P2 Gesture	P2 Eye_Gaze Code
Before Game play									
	Glanced at P2' controller		Conversation inaudible	Co_{inaud}	Co_{inaud}	Conversation inaudible	Stared at own controller	Tilts own wiimote side by side	
	Glance at own controller								
	Stared at P2s's controller	Tilts own wiimote side by side					Stared at P1's controller		
							Stared at own controller		
	Looking at the screen						Looking at the screen		
During Game Play									
PAT1	Looking at screen	Tilts own controller to the left			↓ Gi	Left, left	Looking at screen	Tilts own controller to the left	PAT1
		Press shoot button			↓ Gi	Shoot, shoot		Press shoot button	
			Played silently	NT	NT	Played silently			
		Tilts right	[makes an oh sound- unsuccessfully attempted to get the cupcake]			[makes an oh sound- unsuccessfully attempted to get the cupcake]		Tilts right	
		Points at screen	Oh, oh, strawberries	Pe ↘					

			↓Pe	Yeah, Strawberries			
			↓C^{-}	No, no	Glanced at P1's controller		PAT3
			↙ Gi	Don't shoot at it	Looking at the screen	Tilts left	PAT1
Tilts left	The Stars!	Pe ↘					
			↓C^{-}	No, no, no, no			
			↓Gi	Don't shoot, don't shoot		Tilts right and left	
Tilts right and left							
Tilts left right and shoot	Played silently	NT	NT	Played silently	Glanced at own controller	Tilts left, right and shoot	PAT2
					Looking at screen		PAT1
			↙ Pe	Here we are			
	We got them	Pe ↘					
Tilts left			↓ Gi	Left a bit, left a bit		Tilts left,	
Tilts right			↓ Gi	Right , right		Tilts right	
			↓ C^{-}	No, no			
			↓ Gi	Just stay there for a … stay there cos they are coming back		Points at screen	
Presses shoot							
			Gi	Shoot, shoot, shoot		Presses shoot	
	Played silently	NT	NT	Played silently			

Group B (Wiimote)

Before Game play

P4 Eye_Gaze Code	P4Eye_Gaze	P4 Gesture	P4_Transcript	P4 Transcript Code	P3 Transcript Code	P3_Transcript	P3Eye_Gaze	P3 Gesture	P3 Eye_Gaze Code
					↓ C^+	Alright			
					↙ Su	So do you want to go from left to right and like sort of err… almost like a routine really		Tilts left and right	
			I will go to the right	D ↘					
					↓ C^-	No			
					↙ Gi	You have to go at the same time			
			Alright	Ag ↘					
					Ex	Cos it’s just one little thing and we have to move both hands at the same time to get it to move		Points at screen	
During Game Play									
PAT1	Looking at screen				↙ Gi	So, let’s go left	Looking at screen	Tilts own controller to the left	PAT1
		Tilts own controller to the left	Ok	Ag ↘					
					↓ Gi	Press two at the same time, come on!		Press shoot button	
		Tilts right	[makes a sound]						
					↓ Gi	Just spam two. Ok we just move left and right with that		Tilts left and right	
					↙ Gi	Ok, just keep it and tilt it as fast as you can			

	Right	Ag ↘					
			↓ Pe	That one hanging up			
			↓ C+	Ok			
			↓ Pe	It's fine			
			↓ C+	Ok			
			↓ Gi	Let's stay where we are			
			↓ Pe	These are the stars, it disappears if it gets shot			
			↙ Gi	To the left		Tilts right	
Tilts right	Right, right, right	D ↘					
			↓ Ag	Yeah			
			↓ Pe	When I'm about to go further to the right…			
			↓ Gi	Just turn around the corner			
			↙ Gi	Just spam two as much as you can	Glanced at P2's controller	Presses shoot	PAT3
Presses shoot	[giggled]				Looking at screen		PAT1
Tilts left	Go, left a bit, go left a bit	Gi ↘				Tilts left	
			↓ Ag	Ok			
			↓ Gi	Don't move		keeps controller still	
			↓ C+	Yeah			
			↙ Pe	Just stay where we are for now. Once anything comes out…..			
Points at screen	Trying to get the ones at the bottom left	Ex ↘					
			↓ Gi	Just keep hitting it. Keep hitting it.	Glanced at P2's controller		PAT3
			↓ C+	Yeah	Looking at screen		PAT1

			↓ C$^+$	Alright, I see what you mean			
			↙ Gi	Just keep hitting it	Glanced at P2's controller		PAT3
	Alright [made a sound of disappointment]	Ag ↘					
Tilts to the right			↙ Gi	To the right bit, to the right bit	Looking at screen	Tilts to the right	PAT1
	Oh, no	C$^-$ ↓					
Tilts left	Left, left, left	D ↘					
						Tilts left	
			↓ Ag	Oh, Ok			
Press shoot			↓ Gi	Just keep hitting it		Press shoot	
Tilts right			↙ Gi	Ok, move that way		Tilts right	
	I think we need to press two	Su ↓					
	Right we move to the star	Gi ↘					
			↓ Ag	Ok, we'll move to the star			
Tilts left			↓ Pe	Oh, we both moved too much		Tilts left	
			↙ Gi	Just a little bit to the right	Glanced at P2's controller	Tilts right	PAT3
Tilts right	Oh righ, right	Ag					
					Looking at screen		PAT1
Presses shoot	Played silently	NT	NT	Played silently		Presses shoot	
					Glanced at P2's controller		PAT3
					Looking at screen		PAT1
Tilts left	(makes an oh sound)	Su ↘					

	Let's go back a bit				
			↓Ag	I know	Tilts left
			↓Gi	Spam two, spam two, spam two	Presses shoot
	I was too busy trying to get the last few	Ex↘			
			↓C^+	Yeah	
			↓X	I know you…	
			↓X	Is that, is that…?	
Tilts right			↓Gi	Right, oh right a bit	Tilts right
			↙ Gi	Go to the left side	(moves body to the right)
Tilts right (moves body to the right as well)					
	Oh, no	C^-↓			Tilts left
Tilts right	Don't go to the left again	Di↓			Tilts right
Points at screen	Ok, we just get these three	Di↓			
	This is catchy, isn't it?(hums game background sound)	E↘			
shooting	(makes a sound of excitement)			(makes a sound of excitement)	shooting
tilts left			↙ Pe	By the time we move that way	tilts left
	If we go that way	Pe↘			
			↓C^+	Yeah	
			↓Pe	I was gonna say by the time we move that way…	
Tilts right	Oh, oh, yeah	C^+	C^+	Oh, oh, yeah	Tilts right
Raised arm in			↙C^+	High five	Raised arm in

	mid-air and clapped						mid-air and clapped	
		I'll look good in the camera	Pe ↘			Glanced at own wiimote		PAT2
	Presses shoot			↓ Gi	(giggled) Ok, just keep hitting it	Looking at screen	Presses shoot	PAT1
				↓ Gi	Don't move		Keeps controller still	
	Keeps controller still			↙ Gi	Just spam it, by the time they get there they will get hit		Points at screen	
	Tilts right	Err, right again	D↓					
		No, no	C^-↓					
	Tilts left	Left	Gi				Tilts left	
		Oh, yeah	C^+	C^+	Oh, yeah			

Group C (Wiimote)

Before Game play

P5 Eye_Gaze Code	P5Eye_Gaze	P5 Gesture	P5_Transcript	P5 Transcript Code	P6 Transcript Code	P6_Transcript	P6Eye_Gaze	P6 Gesture	P6 Eye_Gaze Code
	Looks at P1	Tilts controller to the left Tilts controller to the right	Conversation inaudible	Co_{inaud}	Co_{inaud}	Conversation inaudible	looks at P2	Tilts controller to the left Tilts controller to the right	
During Game Play									
PAT1	Looking at screen						Looking at screen	Tilts controller to the right	PAT1
					↙ Gi	Go that way		Tilts left	
		Tilts right	(made an exclamation)						
		Presses shoot	shoot	D ↓				Presses shoot	
PAT3	Glanced at P1's controller		Shoot	Gi ↘					
					X	We have to do it at the same time			
PAT1	Looking at screen		One, two, three, four, five six	X	X	two, three, four, five, six			
		Tilts left	Let's move this way	Su		one, two, three		Tilts left	
		Tilts right						Presses shoot	
		Tilts Left	(giggled) Alright, stop					Tilts left	

Group D (Wiimote)

P7 Eye_Gaze Code	P7Eye_Gaze	P7 Gesture	P7_Transcript	P7 Transcript Code	P8 Transcript Code	P8_Transcript	P8Eye_Gaze	P8 Gesture	P8 Eye_Gaze Code
Before Game play									
	stared at P2				↙ Pe	It's cold in here	glanced at P1 looks at screen		
	looks at screen		Let's do it	Pe ↘			glanced at P1		
					↙ Pe	We can do it	glanced at own controller glanced at screen stared at own controller looks at screen		
	Staring at P2		We just hope we are doing it at the same time	Pe ↘					
	Looking at screen				↙ Pe	(giggled) We will do it at the same time. We will have to press the buttons at the same time, yeah	Stares at P1		
			Just continuously press the buttons. Just hope I'm pressing it as well	Pe			Looking at screen Glanced at own controller Looking at screen		
During Game Play									
PAT1	Looking at screen						Looking at screen		PAT1
					E	Where are you going?			
PAT3	Glanced at P2's controller								
PAT1	Looking at screen						Glanced at P1's controller		PAT3
							Glanced at own controller		PAT2
							Looking at screen		PAT1

Group A (Dance Mat)

During Game play

P2 Eye_Gaze Code	P2Eye_Gaze	P2 Gesture	P2_Transcript	P2 Transcript Code	P1 Transcript Code	P1_Transcript	P1Eye_Gaze	P1 Gesture	P1 Eye_Gaze Code
PAT2	Glanced at own dance mat	Steps left					Glanced at own dance mat	Steps left	PAT2
PAT1	Looking at screen						Looking at screen		PAT1
PAT2	Glanced at own controller	Steps on shoot	Fire	Gl↓			Glanced at own controller	Steps on shoot	PAT2
PAT1	looking at screen						Looking at screen		PAT1
							Glanced at own controller		PAT2
PAT2	Glanced at own controller						Glanced at P2's controller		PAT3
PAT3	Glanced at P1's controller								
PAT6	Turns to ask help from researcher	Points at own dance mat	Is that err, shooting?	E↘			Looking at screen		PAT1
PAT1	Looking at screen								
PAT2	Glanced at own controller						Glanced at P2's controller		PAT3
PAT3	Glanced at P1's controller				↙Gi	Keep going	Stared at own controller		PAT2
PAT1	Stared at screen								
							Looking at screen		PAT1
PAT3	Glanced at P1's controller		Is not…	Pe↓					
PAT1	Looking at screen								

					Glanced at own controller	PAT2
PAT2	Glanced at own controller					
					Looking at screen	PAT1
PAT1	Looking at screen				Glanced at P2's controller	PAT3
PAT2	Glanced at own controller				Looking at screen	PAT1
PAT3	Stared at P1's controller	Get in bit, tata, tata.	Gi↓			
					Glanced at P2's controller	PAT3
					Glanced at own controller	PAT2
PAT1	Stared at screen				Glanced at P2's controller	PAT3
		Is it not working?	E↓		Stared at screen	PAT1
PAT2	Glanced at own controller				Glanced at P2's controller	PAT3
PAT3	Stared at P1's controller				Glanced at own controller	PAT2
PAT1	Looking at screen	(giggled) We'll get this	C+↓		Looking at screen	PAT1
PAT2	Glanced at own controller				Stared at own controller	PAT2
PAT3	Stared at P1's controller				Looking at screen	PAT1
PAT1	Looking at screen		Pe↓			
PAT2	Glanced at own controller	It's almost frustrating			Glanced at P2's controller	PAT3
			Gi↓		Glanced at own controller	PAT2
PAT1	Looking at screen	Go on				

PAT2	Glanced at own controller					Looking at screen	PAT1
PAT3	Glanced at P1’s controller					Glanced at P2’s controller	PAT3
						Glanced at own dance mat	PAT2
PAT1	Looking at screen		Su↘			Looking at screen	PAT1
		Let’s see how it goes if we stand on it				Glanced at P2’s controller	PAT3
				↙Ag	Yeah	Looking at screen	PAT1
PAT4	Stared at P1		C^{+}↓				
		Perfect					
PAT1	Looking at the screen		Gi↓			Glanced at P2’s controller	PAT3
		Oh stand on it				Glanced at own controller	PAT2
PAT3	Glanced at P1’s controller	Go on!	Gi↓			Looking at screen	PAT1
PAT1	Looking at screen						
PAT2	Glanced at own controller						
PAT1	Looking at screen						
PAT2	Glanced at own controller						
PAT1	Looking at screen		Gi↘			Stared at own controller	PAT2
PAT3	Glanced at P1’s controller	Go on!					
PAT1	Looking at screen					Looking at screen	PAT1
PAT2	Glanced at own controller						

PAT3	Glanced at P1's controller							
PAT1	Looking at screen					Looked down to adjust his belt.		PAT5
PAT5	Turns gaze to the left.							
						Looking at screen		PAT1
PAT1	Looking at screen							
					We can't get there(points at screen			
						Glanced at own controller		PAT2
						Looking at screen		PAT1
				Gi↓		Glanced at P2's controller		PAT3
			(points at screen)					
		Steps left	Left, left			Looking at screen	Steps left	PAT1
PAT2	Glanced at own controller							
						Glanced at P2's controller		PAT3
PAT1	Looking at screen			Gi↓		Looking at screen		PAT1
			Go right					
						Glanced at P2's controller		PAT3
PAT3	Glanced at P1's controller							
						Looking at screen		PAT1
PAT2	Glanced at own controller							
PAT1	Looking at screen			Gi↓				
			Come on! Hold it			Glanced at own controller		PAT2
		Steps on shoot	down, hold it down Just fire	Gi				
PAT3	Glanced at P1's controller					Looking at screen		PAT1
							Steps on shoot	
PAT1	Looking at screen							

PAT3	Glanced at P1’s controller		
PAT2	Glanced at own controller		
PAT1	Looking at screen	Glanced at own controller	PAT2
PAT3	Glanced at P1’s controller	Glanced at P2’s controller	PAT3
PAT2	Glanced at own controller	Looking at screen	PAT1
PAT1	Looking at screen		
PAT2	Glanced at own controller		
PAT1	Looking at screen		

Group B (Dance Mat)

During Game play

P4 Eye_Gaze Code	**P4Eye_Gaze**	**P4 Gesture**	**P4_Transcript**	**P4 Transcript Code**	**P3 Transcript Code**	**P3_Transcript**	**P3Eye_Gaze**	**P3 Gesture**	**P3 Eye_Gaze Code**
PAT1	looking at screen	Steps right					Looking at screen		PAT1
							Glanced at own controller	Steps on shoot	PAT2
							Looking at screen		PAT1
PAT2	glanced at own controller	Steps on shoot	Fire	Gi ↘				Steps on right	
PAT1	looking at screen				X	Just slow it down a bit	Glanced at own controller	Steps shoot	PAT2
							Looking at screen		PAT1
			Let's fire it for a bit	Su ↘					
					↓Ag	Yeah			
					↓Gi	Hold on there			
PAT2	Glanced at own controller								
PAT1	Looking at screen				↙Su	I should have…			
PAT2	Glanced at own controller	Steps left	Left, left, left	Gi ↘					
					↓Ag	Yeah			
					↓Gi	Left, left, left		Steps left	
PAT1	Looking at screen								
PAT2	Glanced at own controller						Glanced at own controller		PAT2
PAT1	Looking at screen						Looking at screen		PAT1
							Glanced at own		PAT2

							controller		
PAT2	Glanced at own controller						Looking at screen		PAT1
PAT3	Glanced at P1’s controller								
PAT1	Looking at screen				↙Pe	The star!	Glanced at own controller		PAT2
		Steps left	Just leave it. It’s only ten points anyway	Pe↓			Looking at screen	Steps right	PAT1
PAT2	Glanced at own controller	Steps on shoot					Glanced at own controller		PAT2
PAT1	Looking at screen						Looking at screen		PAT1
PAT2	Glanced at own controller							Steps on shoot	
PAT1	Looking at screen						Glanced at own controller		PAT2
		Steps right	Oh, right, right, right, right	Gi ↘			Looking at screen		PAT1
PAT2	Glanced at own controller				↙ D	Left, left, left	Glanced at own controller	Steps left	PAT2
PAT1	Looking at screen		Oh, I want to go right cos I want to get the bomb	Ex↘			Looking at screen		PAT1
					↓Ag	Ok			
					↓Ag	Ok			
PAT2	Glanced at own controller				↓Gi	Shoot, shoot, shoot			
					↓Gi	Keep shooting			
PAT1	Looking at screen				↙ Ex	Cos the left bit…(pointing at screen)			
		Steps left	Left slightly	Gi↓					
PAT2	Glanced at own controller		Then we move away from the bomb	Ex↘					

PAT1	Looking at screen				↓Ag	Yeah			
							Glanced at own controller		PAT2
					↙Gi	Just keep shooting	Stared at screen	Steps left	PAT1
			Oh, yeah	Ag↘					
		Steps shoot							
					↙Gi	Oh, oh, left a bit faster		Steps shoot	
PAT2	Stared at own controller	Steps left	Did we get it?	E↘			Glanced at own controller		PAT2
PAT1	Looking at screen				↙Pe	I’m not sure	Looking at screen		PAT1
							Glanced at own controller	Step left	PAT2
PAT2	Glanced at own controller	Steps on shoot							
							Looking at screen		PAT1
PAT1	Looking at screen	Steps left	Oh, oh, left, left, left	Gi↘				Steps on shoot	
					↙Ag	Ok, ok			
PAT2	Glanced at own controller		The dance mat is not flat on the ground	Pe↘					
PAT1	Looking at screen						Glanced at own controller	Steps left	PAT2
					↙Pe	Come on! I got my foot down on it but it’s not registering it	Looking at screen		PAT1
PAT2	Glanced at own controller								
PAT1	Looking at screen								
PAT2	Glanced at own controller								
PAT1	Looking at screen	Steps right	Can we go to the right?	Su↓			Glanced at own controller		PAT2
PAT3	Glanced at P1’s controller						Looking at screen		PAT1
PAT1	Looking at screen						Glanced at own	Steps right	PAT2

							controller		
				Gi↘			Looking at screen		PAT1
			Fire		↙Pe	It's a bit jerky, isn't it?			
PAT2	Glanced at own	Steps on shoot		Gi↓					
	controller		Fire						
PAT1	Looking at screen	Steps right		Gi↓			Stared at own		PAT2
		Steps on shoot	Right	Pe ↘			controller	Steps on	
			Oh, oh, it's alright we				Looking at screen	shoot	PAT1
			got at the bomb		↙Gi	Shoot it			
PAT2	Glanced at own								
	controller								
PAT1	Looking at screen	Steps left		Gi ↘					
			Left		↙	Go on	Glanced at own		PAT2
PAT2	Glanced at own						controller		
	controller						Looking at screen		PAT1
PAT1	Looking at screen								
PAT2	Glanced at own						Glanced at own	Steps left	PAT2
	controller	Steps on shoot					controller		
PAT1	Looking at screen	Steps left					Looking at screen		PAT1
		Steps on shoot					Glanced at own		PAT2
							controller		
PAT2	Glanced at own	Steps right					Looking at screen		PAT1
	controller								
PAT1	Looking at screen								
PAT3	Stared at P1's	Steps on shoot		GN↓			Glanced at own		PAT2
	controller		Fire				controller		
PAT1	Looking at screen						Looks at screen	Steps right	PAT1
PAT2	Glanced at own						Glanced at own		PAT2
	controller						controller		
PAT1	Looking at screen			Gi ↘			Looking at screen		PAT1
			Stamp on the floor						
			and see how it goes.		↙Nm	You can see it on the top		Steps on	

						bit (pointing at the screen)		shoot	
PAT2	Glanced at own controller		Keep firing	Gi↘					
PAT1	Looking at screen				↙Ag				
						Ok	Glanced at own controller		PAT2
							Looking at screen		PAT1
					↙Gi	Put down on it	Glanced at own controller		PAT2
				Nm↘			Looking at screen		PAT1
PAT2	Glanced at own controller		You can see it at the top bit		X			Steps right	
PAT1	Looking at screen					Yeah, you can see it just…(pointing at screen)		Steps on shoot	
PAT2	Glanced at own controller	Steps right			↓Su				
PAT1	Looking at screen	Steps on shoot				Maybe we should hold it all the way down	Glanced at own controller		PAT2
PAT2	Glanced at own controller								
PAT1	Looking at screen	Steps right					Looking at screen		PAT1
PAT2	Glanced at own controller						Glanced at own controller		PAT2
PAT1	Looking at screen						Looking at screen	Steps right	PAT1
PAT2	Glanced at own controller				↙ Pe			Steps on shoot	
PAT1	Looking at screen	Steps left Steps on shoot				Ok, this is not moving	Glanced at P2’s controller		PAT3
PAT2	Glanced at own controller						Looking at screen		PAT1
PAT1	Looking at screen			Pe↘			Glanced at P2’s controller		PAT3
			If you stand on it then it should do it				Looking at screen		PAT1
					↙Pe		Glanced at P2’s		PAT3

						controller		
					I've been doing it and it's like… (pointing at screen)	Looking at screen		PAT1
PAT3	Stared at P1's controller			Su↓		Stared at own controller		PAT2
			Maybe because you are pressing two. Think about it because you are pressing that one as well	Ex↓				
						Looking at screen		PAT1
PAT1	Looking at screen							
PAT3	Stared at P1's controller							
PAT1	Looking at screen							
						Glanced at own controller		PAT2
						Looking at screen		PAT1
PAT2	Glanced at own controller						Steps right	
PAT1	Looking at screen							
PAT3	Glanced at P1's controller							
PAT1	Looking at screen							
PAT2	Glanced at own controller							
PAT1	Looking at screen					Glanced at own controller		PAT2
PAT3	Glanced at P2's controller					Looking at screen		PAT1
PAT1	Looking at screen					Glanced at own controller		PAT2
						Looking at screen		PAT1
PAT2	Glanced at own controller	Steps right				Glanced at own controller		PAT2
PAT1	Looking at screen					Looking at screen		PAT1
PAT6	Turns to			Pe↘		Glanced at own		PAT2

	researcher						controller		
PAT2			It’s stopped working				Looking at screen		PAT1
	Stared at own								
PAT1	controller				↙ Pe				
	Looking at screen							Steps right	
				Gi					
PAT2		Steps on shoot				Come on!	Glanced at own		PAT2
	Glanced at own		Fire, fire, fire, fire				controller		
PAT1	controller						Looking at screen		PAT1
	Looking at screen						Glanced at own		PAT2
							controller		
							Looking at screen		PAT1
							Glanced at own		PAT2
PAT2							controller		
	Glanced at own						Looking at screen	Steps on	PAT1
PAT1	controller							shoot	
PAT2	Looking at screen	Steps left							
	Glanced at own								
PAT1	controller								
PAT2	Looking at screen								
	Glanced at own								
PAT1	controller						Stared at own		PAT2
	Looking at screen						controller		
							Looking at screen		PAT1
PAT3								Steps left	
	Stared at P1’s								
PAT1	controller						Stared at P2’s		PAT3
	Looks at screen						controller		
							Looking at screen		PAT1
PAT2									
	Glanced at own								
PAT1	controller						Glanced at own		PAT2
	Looking at screen	Steps on shoot					controller		

			Looking at screen	PAT1
PAT2				
PAT1	Glanced at own controller Looking at screen			
			Steps on shoot	

Group C (Dance Mat)
During Game play

P5 Eye_Gaze Code	**P5Eye_Gaze**	**P5 Gesture**	**P5_Transcript**	**P5 Transcript Code**	**P6 Transcript Code**	**P6_Transcript**	**P6Eye_Gaze**	**P6 Gesture**	**P6 Eye_Gaze Code**
PAT3	Glanced at P1's controller	Steps on right	Go that way, that way, that way	Gi↓			Looking at screen	Steps on right	PAT1
PAT2	Stared at own controller								
PAT1	Looking at screen	Steps on shoot	Shoot, shoot	Gi↓				Steps on shoot	
PAT3	Stared at P1's controller		Keep your foot on it. Just put your foot on it.	Gi ↘			Glanced at own controller		PAT2
PAT1	Looking at screen						Looking at screen		PAT1
PAT2	Glanced at own controller				↙ Su	We need to do it at the same time.			
		Steps on left	Go that way, go that way	Gi↓					
							Glanced at own controller	Steps on left	PAT2
PAT1	Looking at screen						Looking at screen		PAT1
PAT3	Stared at P1's controller		(pulls P1's arm) one, two	Gi↓					
PAT1	Looking at screen								
PAT2	Glanced at own controller								
PAT1	Looking at screen								
PAT2	Glanced at own controller								
PAT1	Looking at screen	Steps on shoot						Steps on shoot	
PAT3	Glanced at P1's controller	Steps on left	We are doing it differently	X ↓			Glanced at P1's controller	Steps on left	PAT3
PAT1	Looking at screen						Looking at screen		PAT1
PAT3	Stared at P1's								

	controller								
							Glanced at P1’s controller		PAT3
PAT2	Glanced at own controller								
PAT1	Looking at screen						Looking at screen		PAT1
PAT2	Stared at own controller		(touches P2 and points at own controller)				Stared at P1’s controller		PAT3
PAT1	Looking at screen	Steps on right					Glanced at own controller	Steps on right	PAT2
			(giggled) It doesn’t work!	Pe ⩛					
							Looking at screen		PAT1
PAT3	Stared at P2’s controller		(pulls P1’s arm)				Glanced at P1’s controller		PAT3
							Looking at screen		PAT1
PAT1	Looking at screen								
PAT2	Glanced at own controller								
PAT1	Looking at screen								
PAT2	Glanced at own controller	Steps on shoot							
PAT3	Stared at P2’s controller						Glanced at own controller	Steps on left	PAT2
PAT1	Looking at screen								
PAT3	Stared at P2’s controller								
							Glanced at P1’s controller		PAT3
							Glanced at own controller		PAT2
PAT1	Looking at screen						Looking at screen	Steps on shoot	PAT1
			(giggled)	X	X	One, two, three.			
					⩛ Gi	On every three you step on it			
PAT2	Glanced at own dance mat		It’s not working!	C ⩛					

PAT1	Looking at screen				
PAT2	Glanced at own controller				
PAT1	Looking at screen				
PAT3	Glanced at P2’s controller				
PAT1	Looking at screen				
PAT3	Glanced at P2’s controller				
PAT1	Looking at screen				
PAT3	Glanced at P2’s controller				
PAT2	Glanced at own controller				
PAT1	Looking at screen		Glanced at own controller	Steps left	PAT2
PAT2	Glanced at own controller		Looking at screen		PAT1
PAT1	Looking at screen	Steps left			
				Steps shoot	
		Steps shoot			
			Glanced at P1’s controller		PAT3
			Looking at screen		PAT1
PAT3	Glanced at P2’s controller				
PAT1	Looking at screen				

Group D (Dance mat)

Before Game play

P8 Eye_Gaze Code	P8Eye_Gaze	P8 Gesture	P8_Transcript	P8 Transcript Code	P7 Transcript Code	P7_Transcript	P7Eye_Gaze	P7 Gesture	P7 Eye_Gaze Code
	Looks at P1		How are we gonna do this?	E ↘			looks at P2		
	Stares at P1's controller				X	You'll be the one who decides where to go and I'll just follow	stares at own controller		
	Looking at screen						looking at screen		
During Game Play									
PAT1	Looking at screen	Steps left	Go Left	Gi ↓			Looking at screen	Steps left	PAT1
PAT2	Glanced at own controller						Glanced at own controller		PAT2
PAT1	Looking at screen		Left, Left	Gi ↘			Looking at screen		PAT1
					↙ Ag	Left			
			Up	Gi ↓					
PAT2	Glanced at own controller	Steps on shoot					Glanced at P2's controller	Steps on shoot	PAT3
PAT1	Looking at screen						Looking at screen		PAT1
PAT3	Glanced at P1's controller								
PAT1	Looking at screen								
							Glanced at P2's controller		PAT3
							Looking at screen		PAT1
			Fire	Gi ↓					
			It's not firing	C^- ↓					
			Fire	Gi ↘			Stared at P2's controller	Steps right	PAT3
PAT2	Glanced at own controller				↙ Pe	Oh	Looking at screen		PAT1
PAT1	Looking at screen								

PAT3	Glanced at P1's controller				Glanced at own controller		PAT2
PAT1	Looking at screen				Looking at screen		PAT1
					Glanced at P2's controller		PAT3
					Glanced at own controller		PAT2
					Looking at screen		PAT1
					Glanced at P2's controller		PAT3
					Looking at screen	Steps left	PAT1
						Steps on shoot	
		Steps right	Right	Gi↓	Glanced at own controller	Steps left	PAT2
PAT3	Glanced at P1's controller				Looking at screen		PAT1
PAT1	Looking at screen				Glanced at own controller	Steps on right	PAT2
					Looking at screen		PAT1
PAT2	Stared at own controller						
PAT3	Stared at P1's controller	Steps on shoot	Up	Gi↓			
						Steps on shoot	
PAT1	Looking at screen						
					Glanced at own controller		PAT2
		Steps left	Left, oh left	Gi↓	Looking at screen	Steps left	PAT1
					Glanced at own controller		PAT2
PAT2	Glanced at own controller	Steps on shoot	Oh	C^{+}↓	Looking at screen		PAT1
PAT1	Looking at screen				Glanced at own controller	Steps on shoot	PAT2
					Looking at screens		PAT1

PAT2	Glanced at own controller	Come on! It’s not doing it	Pe ↘					
PAT3	Glanced at P1’s controller							
PAT1	Looking at screen							
						Glanced at P1’s controller		PAT3
						Stared at own controller		PAT2
				↙ Pe	You have to lift it up	Looking at screen		PAT1
						Glanced at P1’s controller	Steps on right	PAT3
						Looking at screen		PAT1
						Glanced at own controller		PAT2
PAT3	Glanced at P2’s controller					Looking at screen		PAT1
PAT1	Looking at screen					Glanced at own controller	Steps on shoot	PAT2
PAT2		Keep firing	Gi↓			Looking at screen		PAT1
	Glanced at own controller					Glanced at own controller		PAT2
PAT1	Looking at screen					Glanced at P2’s controller		PAT3
PAT3	Stared at P1’s controller					Looking at screen		PAT1
		Come on!	Gi↘			Stared at P2’s controller		PAT3
						Looking at screen		PAT1
						Stared at P2’s controller		PAT3
PAT1	Looking at screen					Looking at screen		PAT1
						Glanced at P2’s controller		PAT3
						Looking at screen	Steps left	PAT1
						Glanced at P2’s		PAT3

						controller		
				Gi	Left, left	Looking at screen		PAT1
		Up	Gi					
PAT3	Stared at P1’s controller			E	You want it all up		Steps on shoot	
PAT1	Looking at screen							
PAT3	Glanced at P1’s controller							
PAT1	Looking at screen					Glanced at own controller		PAT2
		Keep firing	Gi					
						Looking at screen		PAT1
						Glanced at own controller		PAT2
						Looking at screen		PAT1
						Glanced at P2’s controller		PAT3
						Looking at screen		PAT1

C. Except from Log Files

Player 1’s (Group A) actions while playing with dance mat

Date	Time	Code for Key press and release	Key Presses/Releases
17/07/2013	10:50:43	3	Player 1 PRESSES LEFT KEY
17/07/2013	10:50:43	6	Player 1 RELEASES LEFT KEY
17/07/2013	10:50:43	3	Player 1 PRESSES LEFT KEY
17/07/2013	10:50:44	6	Player 1 RELEASES LEFT KEY
17/07/2013	10:50:44	3	Player 1 PRESSES LEFT KEY
17/07/2013	10:50:44	6	Player 1 RELEASES LEFT KEY
17/07/2013	10:50:44	3	Player 1 PRESSES LEFT KEY
17/07/2013	10:50:44	6	Player 1 RELEASES LEFT KEY
17/07/2013	10:50:45	3	Player 1 PRESSES LEFT KEY
17/07/2013	10:50:45	6	Player 1 RELEASES LEFT KEY
17/07/2013	10:50:45	3	Player 1 PRESSES LEFT KEY
17/07/2013	10:50:45	6	Player 1 RELEASES LEFT KEY
17/07/2013	10:50:45	3	Player 1 PRESSES LEFT KEY
17/07/2013	10:50:45	6	Player 1 RELEASES LEFT KEY
17/07/2013	10:50:46	4	Player 1 PRESSES SHOOT KEY

Group A agreement/disagreement while playing with the dance mat

Date	Time	Code for Key press and release	Agreement/Disagreement
17/07/2013	10:52:28	0	NO AGREEMENT!COLLABORATION DID NOT OCCUR
17/07/2013	10:52:29	0	NO AGREEMENT!COLLABORATION DID NOT OCCUR
17/07/2013	10:52:31	1	AGREEMENT! COLLABORATION OCCURED
17/07/2013	10:52:32	1	AGREEMENT! COLLABORATION OCCURED
17/07/2013	10:52:32	1	AGREEMENT! COLLABORATION OCCURED
17/07/2013	10:52:35	1	AGREEMENT! COLLABORATION OCCURED
17/07/2013	10:52:36	1	AGREEMENT! COLLABORATION OCCURED
17/07/2013	10:52:36	1	AGREEMENT! COLLABORATION OCCURED
17/07/2013	10:52:40	0	NO AGREEMENT!COLLABORATION DID NOT OCCUR
17/07/2013	10:52:41	0	NO AGREEMENT!COLLABORATION DID NOT OCCUR
17/07/2013	10:52:41	0	NO AGREEMENT!COLLABORATION DID NOT OCCUR
17/07/2013	10:52:41	1	AGREEMENT! COLLABORATION OCCURED
17/07/2013	10:52:42	1	AGREEMENT! COLLABORATION OCCURED
17/07/2013	10:52:42	1	AGREEMENT! COLLABORATION OCCURED
17/07/2013	10:52:42	1	AGREEMENT! COLLABORATION OCCURED
17/07/2013	10:52:43	0	NO AGREEMENT!COLLABORATION DID NOT OCCUR
17/07/2013	10:52:43	1	AGREEMENT! COLLABORATION OCCURED

D. Thematic Analysis of Interview Data Grouped according to controller types

P1-P8 represents the children who participated in the interview sessions

Dance mat		
Group	**Transcription**	**Codes**
A	**P1:** [1]Uhmm, well, it was just that we decided pressing where they [aliens] wanted to go. And then we will say to the other person go right. [2]So it takes us more time to react. **P2:** [3]It's harder to work together than work alone	[1]Strategy-using the alien movement [2]Reaction time-slow [3]Difficult to work together
B	**P3:** [1]Err, I think we were both trying to do different things and [4]then we looked up at the little bars, the circles… **P4:** [4][cuts in] Yeah, and we, and we started…. **P3:** …[4]which showed us what each other was doing. [5]And then we thought, oh alright I would do what each other was doing… **P4:** [5][cuts in] we stopped again **P3:** [5]and then we stopped again and then	[1]No initial Strategy [4]Noticed map [5]Strategized using the map
C	**P5:** [6]Erm, it was just hard to get it going **P6:** [6]Yeah, you gonna get coordinated [2]but takes a bit to get together. Then you lose it and then you go back again.	[6]Difficult to coordinate
D	**P7:** I think what happened was… **P8:** [cuts in] pressing random buttons **P7:** [7]When there were long spaces, I think we responded really quickly but when we were on the shorter one I reckon we were on the wrong one entirely. **P8:** [8]I thinks it's cos when we were clicking on the buttons, err, sometimes we weren't clicking it at the exact same time so **P7:** [8]Yeah **P7:** [9]I think the dance mat was a little bit unresponsive in some places in the shooting **P7:** [9]I think it was a little bit jerky moving, [10]so we have to be a bit slow in, in places **P7:** [9,10]Yeah	[7]Reaction time - quick [8]Poor coordination [9]Hardware issues [10]Slow reaction due to hardware issues

Gamepad		
Group	**Transcription**	**Code**
A	**P2:** [1,2,3] It's still the exact same reason but because it's sort of working together… **P1**: [1,2,3][cuts in] Yeah **P2:** [3]**…**and you learn how to do it easier so you're just moving out more and shooting	
B	**P4:** [11]Err, I think it's more of a case the buttons are easier to press… **P3:** [11][cuts in] yeah, it's easier to (unclear) **P4:** [11]it's easier to go on and off, on and off. When we are actually doing it at the same time, that's on and as soon as we stop it's an off again.	[11]Easy to use controller
C	**P6:** [8]Em, I don't think we were pressing the red button at the same time very easily. [7]We were both pressing it very fast [8]but obviously not at the same time.	

D	**P7:** [12]It might be that when you've got that kind of controller, your immediate response is to play a single player cos that's how you normally play it at home. **P7:** [13]I think with the other two you have to work as a team cos you have never used that kind of equipment before.	[12]Familiarity with controller [13]Unfamiliarity with controllers
Wiimote		
Group	**Transcription**	**Code**
A	**P1:** not the same sort of reason. ….sometimes you… **P2:** [cuts in] when you… **P1:** …[14] just accidentally tilt it **P2:** [14]Yeah	[14]Accidental tilting
B	**P4:** [15]Yeah, cos it's so big. It's easy to see what the other person is doing **P3:** [15]Hmm **P4:** [15]Cos you can see them going like that (gestures)	[15]Visibility - good
C	**P5:** [16]I kept slipping going that way without realizing **P5:** [16]when we were shooting I kept slipping that way **P6:** [16]Yeah, it's hard to get it really straight. Sometimes you are like that and then…	[16]Poor usage of controller (Accidental tilting)
D	**P8:** [13]I think we were just getting used to it. That was the first mode to play a game that we tried collaborating. **P7:** I think he just didn't do the right ones (laughs) **P8:** [12]Even though these are wiimotes, they look different so you try and play it differently. **P8**: I think the wiimotes are more interesting and maybe more fun. It is really fun to play with the wiimotes.	[17]Unfamiliarity with controllers [18]Familiarity with controller

R represents the researcher

Questions asked by the Researcher include:

Group A

R: This is a chart of how you guys fared during game play using the dance mat. This point here represents agreement while here represents disagreement. From this chart you can see that you were not doing very well at the beginning but did very well half way through. What happened? What actually changed?

R: So what about the game pad? Wow! There are lots of disagreement and agreement

R: Is it the same sort of reason for plastic bar? Aww… you didn't do well here

Group B

R: This is a chart of how you guys fared during game play using the dance mat. This point here represents agreement while here represents disagreement. From this chart you can see that you started off in agreement and then you disagreed and then went back into agreement. Generally, you did well! So what happened? How did you do that?

R: What about the game pad? Aww, there are lots of agreement and disagreement

R: so what about the plastic bar thingy? That one there!

Group C

R: This is a chart of how you guys fared during game play using the dance mat. This point here represents agreement while here represents disagreement. From this chart you can see that you were always pressing the same buttons at the same time. What made you do the same thing?

R: What about the, em game pad one? You did really well as well!
R: So what about the plastic bar? Aww… you did not collaborate well in this one

Group D
R: This chart shows how you guys fared during game play. This point shows when you guys were in agreement while here shows when you were not in agreement. So, you can see that for most of the time you guys were in agreement but at some point you were not in agreement. What actually happened?

R: What about the game pad? There are lots of disagreement and a couple of agreement as well. What could have happened? What could have caused this?

R: This one is for plastic bar. Wow! There are a lot of things going on here - agreement, disagreement, agreement, disagreement. So what happened?

First Level Code	**Second Level Code**
Strategized using the aliens **(A_D, A_G)** Strategized using the map **(B_D)**	Strategy
Reaction Time – Slow **(A_D, A_G, D_D)** Reaction Time – Quick **(D_D)** Difficult to coordinate **(C_D, C_G)** Poor Coordination (D_D)	Synchronicity of Response
Difficult to collaborate **(A_D, A_G)**	
Interaction Issues **(D_D)**	
Ease of use of Controller **(B_G)**	
Poor Controller Usage **(A_T, C_T)**	
Visibility **(B_T)**	
familiarity with controller **(D_G)**	Familiarity
Familiarity with controller but different usage **(D_T)**	
Unfamiliarity **(D_T , D_G)**	

For Illustration, **D_G** means Group D while plying with game pad.

E. Children IMI enjoyment/interest scale

Version:

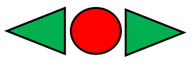
Group: Code: ______ Playing with: ______________________

Tick off a smiley for each question in the table (playing with DANCE MAT)

I enjoyed playing this game very much	Totally disagree				Totally agree
This game was fun to play	Totally disagree				Totally agree
I thought this was an exciting game	Totally disagree				Totally agree
This game held my attention very well	Totally disagree				Totally agree
I would describe this game as very interesting	Totally disagree				Totally agree
I thought this game was quite enjoyable	Totally disagree				Totally agree
While I was playing this game, I was thinking about how much I enjoyed it	Totally disagree				Totally agree

F. Participants' responses to questions (4, 4b, 5, 6, 6b and 7) in the questionnaire

Group	Players	Q4	Q4b	Q5	Q6	Q6b	Q7
A	Yellow	Yes	To show which buttons are pressed at what time by who	Maybe	Maybe	It was good talking to someone while doing it but you couldn't do what you wanted to do	Shout where to go, look and agree/disagree
	Blue	Yes	To show if we were working together	No	No	It is more enjoyable and harder playing with someone and working together than alone	Co-operation/speaking
B	Yellow	Yes	To show when your partner was pushing buttons without looking at them	No	No	It's too easy on your own, it's mindless. With two players you have to think and co-operate.	Talking to partner discussing courses of action.
	Blue	Yes	Showing what each player was doing	maybe	maybe	It was more engaging	Talked
C	Yellow	Yes	To show when you were both pressing	No	No	It made me think	Talked
	Blue	Yes	To see which button is being pressed	No	No	More fun trying to work together	Talking to do it right
D	Yellow	Yes		Yes	Yes	There were few issues when playing together	Looked at icons on the top right
	Blue	Yes	To show when we were moving right/left together and shooting at the same time	No	No	I preferred the teamwork as it makes it more interesting and fun to play	Followed the on screen guide as what he was doing.

Q4: Did you notice this picture  on the top right corner of the screen?

Q4b: If you ticked yes to 4(a), what do you think was the purpose of the picture?
Q5: Would you prefer to play the game alone?
Q6a: Did you enjoy playing alone more than playing with **YELLOW**?
Q6b: Give a brief explanation to your answer, please.
Q7: How did you agree in order to play?

G. Smileyometer, Again-Again and Funsorter results

TableA: Participants' ratings of their experience playing with the three controllers and responses to whether they would like to play the game again using the three controllers (game pad, dance mat and tangible)

	Ratings of Fun (Smileyometer scale, 1 = worst, 5 = best)			**Play Again? (Again Again scale , 1=No, 2 = Maybe, 3 = Yes)**		
	Gamepad	Tangible	Dancemat	Gamepad	Tangible	Dancemat
P1	5	3	5	3	2	2
P2	4	3	5	3	3	1
P3	4	3	2	3	3	1
P4	3	3	5	2	2	2
P5	4	2	3	2	1	1
P6	4	3	5	3	3	1
P7	3	4	5	3	3	2
P8	4	3	2	3	2	1

TableB: Participants' rankings of the three controllers (GP = Game pad, DM = Dance mat, T = Tangible. Scale: 1 = Worst, 3 = Best)

	Easiest to Play			***Most Fun***			***Liked the Most***		
	GP	*W*	*DM*	*GP*	*W*	*DM*	*GP*	*W*	*DM*
P1	*3*	*2*	*1*	*1*	*2*	*3*	*3*	*2*	*1*
P2	*3*	*1*	*2*	*1*	*2*	*3*	*3*	*1*	*2*
P3	*3*	*2*	*1*	*3*	*2*	*1*	*3*	*2*	*1*
P4	*3*	*2*	*1*	*1*	*2*	*3*	*3*	*2*	*1*
P5	*3*	*2*	*1*	*1*	*2*	*3*	*1*	*2*	*3*
P6	*2*	*3*	*1*	*1*	*2*	*3*	*2*	*3*	*1*
P7	*2*	*3*	*1*	*1*	*2*	*3*	*2*	*3*	*1*
P8	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*2*	*1*

H. Average scores Calculation for the participants' ratings using the Children IMI interest/enjoyment scale.

SINGLE PLAYER **GAME PAD**

INTEREST/ENJOYMENT	1	2	3	4	5
I enjoyed playing this game very much	0	0	4	4	0
This game was fun to play	0	1	4	2	1
I thought this was an exciting game	0	3	3	2	0
This game held my attention very well	0	2	3	2	1
I would describe this game as very interesting	0	3	3	2	0
I thought this game was quite enjoyable	0	0	2	6	0
While I was playing this game, I was thinking about how much I enjoyed it	0	3	4	1	0
Total	0	12	23	19	2

$$\frac{(0 \times 1) + (12 \times 2) + (23 \times 3) + (19 \times 4) + (2 \times 5)}{0 + 12 + 23 + 19 + 2} = \frac{179}{56} = 3.19$$

Single Player **DANCEMAT**

INTEREST/ENJOYMENT	1	2	3	4	5
I enjoyed playing this game very much	0	1	4	3	0
This game was fun to play	0	1	3	3	1
I thought this was an exciting game	0	3	4	1	0
This game held my attention very well	0	1	6	1	0
I would describe this game as very interesting	0	4	3	1	0
I thought this game was quite enjoyable	0	3	4	0	1
While I was playing this game, I was thinking about how much I enjoyed it	1	3	3	1	0
Total	1	16	27	10	2

$$\frac{(1 \times 1) + (16 \times 2) + (27 \times 3) + (10 \times 4) + (2 \times 5)}{1 + 16 + 27 + 10 + 2} = \frac{164}{56} = 2.92$$

Single Player **WIIMOTE**

INTEREST/ENJOYMENT	1	2	3	4	5
I enjoyed playing this game very much	0	1	4	2	1
This game was fun to play	0	1	3	4	0
I thought this was an exciting game	0	3	1	4	0
This game held my attention very well	0	2	2	4	0
I would describe this game as very interesting	0	3	3	2	0
I thought this game was quite enjoyable	0	1	4	3	0
While I was playing this game, I was thinking about how much I enjoyed it	0	4	3	1	0
Total	0	15	20	20	1

$$\frac{(0 \times 1) + (15 \times 2) + (20 \times 3) + (20 \times 4) + (1 \times 5)}{0 + 15 + 20 + 20 + 1} = \frac{175}{56} = 3.13$$

Collaborative **GAME PAD**

INTEREST/ENJOYMENT	1	2	3	4	5
I enjoyed playing this game very much	0	0	2	4	2
This game was fun to play	0	0	3	4	1
I thought this was an exciting game	0	3	2	2	1
This game held my attention very well	0	2	3	2	1
I would describe this game as very interesting	0	2	3	2	1
I thought this game was quite enjoyable	0	0	5	1	2
While I was playing this game, I was thinking about how much I enjoyed it	0	4	2	2	0
Total	0	11	20	17	8

$$\frac{(0 \times 1) + (11 \times 2) + (20 \times 3) + (17 \times 4) + (8 \times 5)}{0 + 11 + 20 + 17 + 8} = \frac{190}{56} = 3.39$$

Collaborative **Dance mat**

INTEREST/ENJOYMENT	1	2	3	4	5
I enjoyed playing this game very much	0	4	2	2	0
This game was fun to play	0	1	5	2	0
I thought this was an exciting game	0	3	4	1	0
This game held my attention very well	0	2	5	1	0
I would describe this game as very interesting	0	3	4	1	0
I thought this game was quite enjoyable	0	3	4	1	0
While I was playing this game, I was thinking about how much I enjoyed it	0	4	4	0	0
Total	0	20	28	8	0

$$\frac{(0 \times 1) + (20 \times 2) + (28 \times 3) + (8 \times 4) + (0 \times 5)}{0 + 20 + 28 + 8 + 0} = \frac{156}{56} = 2.78$$

Collaborative **WIIMOTE**

INTEREST/ENJOYMENT	1	2	3	4	5
I enjoyed playing this game very much	0	1	1	5	1
This game was fun to play	0	1	2	3	2
I thought this was an exciting game	0	2	3	2	1
This game held my attention very well	0	2	2	3	1
I would describe this game as very interesting	0	3	2	2	1
I thought this game was quite enjoyable	0	1	1	4	2
While I was playing this game, I was thinking about how much I enjoyed it	0	3	3	1	1
Total	0	13	14	20	9

$$\frac{(0 \times 1) + (13 \times 2) + (14 \times 3) + (20 \times 4) + (9 \times 5)}{0 + 13 + 14 + 20 + 9} = \frac{193}{56} = 3.45$$

I. Performance Calculation for the Three Controllers

Dance mat

Group	Key Press (Player 1)	Key Press (Player 2)	Total Key Press	No. of Agreement	No. of Disagreement	Performance (2dp)
A	371	420	791	309	6	2.56
B	643	739	1382	332	94	4.16
C	294	302	596	134	13	4.45
D	273	240	513	100	28	5.13

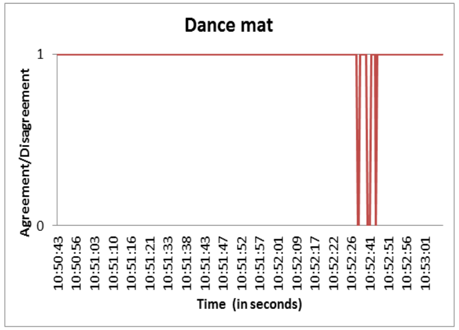
Game Pad

Group	Key Press (Player 1)	Key Press (Player 2)	Total Key Press	No. of Agreement	No. of Disagreement	Performance (2dp)
A	417	481	898	344	80	2.61
B	437	514	951	284	231	3.35
C	151	177	328	148	25	2.22
D	248	237	485	208	102	2.33

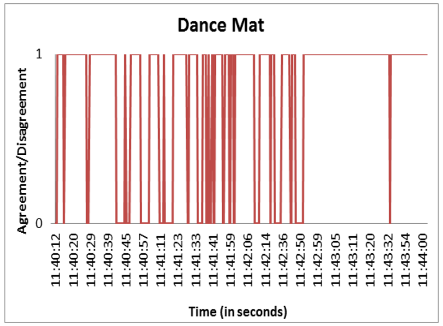
Wiimote

Group	Key Press (Player 1)	Key Press (Player 2)	Total Key Press	No. of Agreement	No. of Disagreement	Performance (2dp)
A	2441	1760	4201	1505	597	2.79
B	5815	7067	12882	3710	2889	3.47
C	2097	1782	3879	1124	1541	3.45
D	3274	4193	7467	2297	2296	3.25

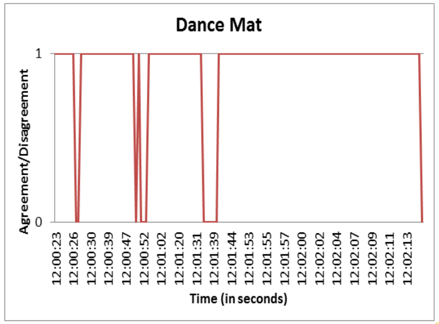
J Graphs used during interview sessions with participants



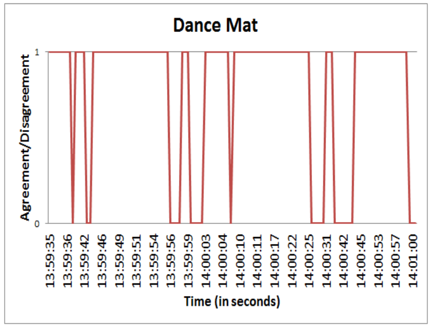
Group A (using Dance mat)



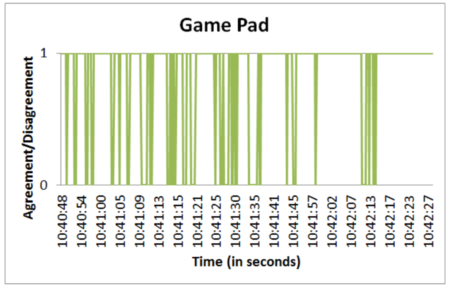
Group B (using Dance mat)



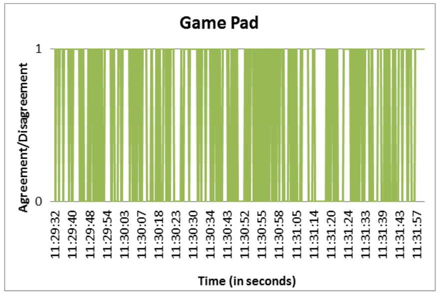
Group C (using Dance mat)



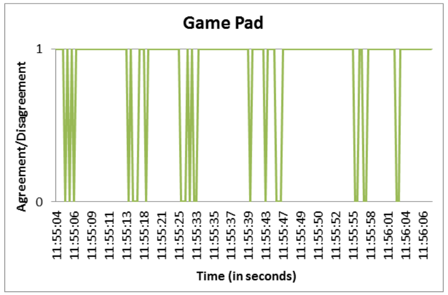
Group D (using Dance mat)



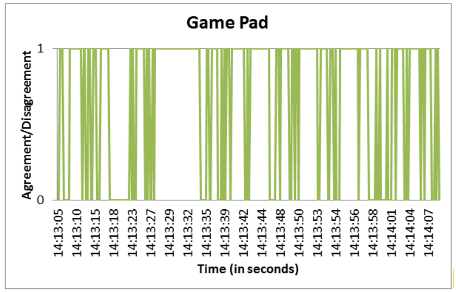
Group A (using Game pad)



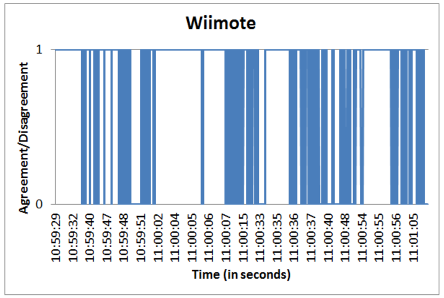
Group B (using Game pad)



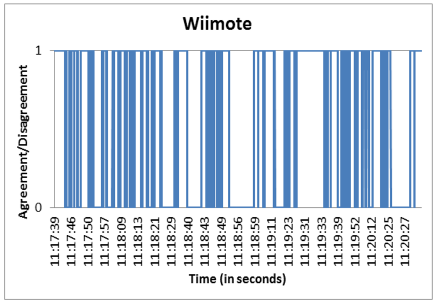
Group C (using Game pad)



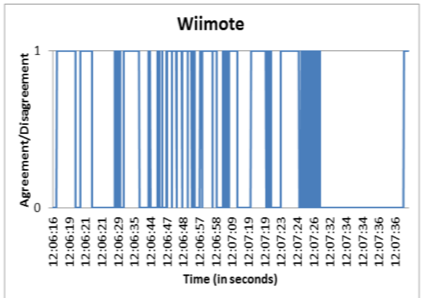
Group D (using Game pad)



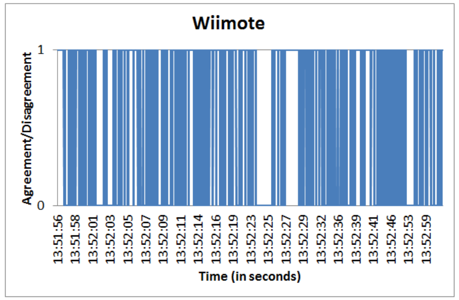
Group A (using Wiimote)



Group B (using Wiimote)



Group C (using Wiimote)



Group D (using Wiimote)

11.5 Appendix5: Chapter 7 Documents

A. Pre-test questionnaire

Group: Code: I am a Boy ☐ / Girl ☐ I am ___ years old

1) How often do you play games with methods that involve the following? Please, tick in the box

	Never	Rarely (e.g. yearly)	Sometimes (e.g. monthly)	Often (e.g. weekly)	Always (e.g. daily)
Pressing buttons on controlle 1) PlayStation controller 					
2) Wiimote 					
3) Xbox controller 					
Moving the controller e.g.					
1) Moving Wiimote 					
2) Moving WiiU 					
3) Tilting PlayStation Controller 					
Tilting tablets, iPads, iPhones. Android 					
Touching tablets, iPads, iPhones, Android, WiiU 					
Balance board 					
Dance mat 					
PC keyboard/Mouse 					
Pressing buttons on a portable game device e.g. 1) PSP 					
2) Nintendo DS/3DS  (pressing buttons)					
3) WiiU 					
Touching the screen on a portable game device e.g. 1) Nintendo DS/3DS (touching the screen) 					
Moving your body e.g. Xbox Kinect 					

2) What is your favourite controller? Please write in the space below

3) What is your least favourite controller? Please write in the space below

B. Analysis code (MySQL)

```
SELECT * FROM Database_Name.Table_Name;
ALTER TABLE ` Database_Name `.`Table_Name`
ADD COLUMN `Full_Datetime` VARCHAR(45) NOT NULL AFTER `Action`;

update Table_Name SET full_datetime = concat(Date, '  ', Time);

ALTER TABLE Table_Name CHANGE COLUMN Full_Datetime Full_Datetime  DATETIME(6) NULL;
ALTER TABLE Table_Name ADD COLUMN TimeLapse FLOAT NULL AFTER Full_Datetime;
SELECT * FROM Database_Name.Table_Name;

DROP PROCEDURE IF EXISTS sp_CalcAgreementTimeLapse;
DELIMITER $$
CREATE  PROCEDURE sp_CalcAgreementTimeLapse
(
)
BEGIN
	/*Variables*/
	DECLARE rowsCount INT;
	DECLARE i INT DEFAULT 1;
	DECLARE sFDateTime DATETIME(6); -- start time
	DECLARE eFDateTime DATETIME(6); -- end time
	DECLARE pFDateTime DATETIME(6); -- current
	DECLARE pId INT;

	UPDATE Table_Name SET Full_Datetime=CONCAT(Date,' ', Time);

	DROP TEMPORARY TABLE IF EXISTS temptbAgLog;
	CREATE TEMPORARY TABLE temptbAgLog (PKey INT NOT NULL AUTO_INCREMENT PRIMARY KEY, Id INT DEFAULT
NULL, FDateTime datetime(6) DEFAULT NULL);

	INSERT INTO temptbAgLog(Id, FDateTime) SELECT Id, Full_Datetime FROM Table_Name ORDER BY Id;

	SET rowsCount=(SELECT COUNT(PKey) FROM temptbAgLog);
	WHILE i<=rowsCount DO
		-- SET VARIABLES
		SELECT Id, FDateTime
		 INTO pId, pFDateTime
		 FROM temptbAgLog WHERE PKey=i;

		 IF (i-1)=0 THEN
		    SET eFDateTime=pFDateTime;
		ELSEIF (i-1)!=0 THEN
		    SET sFDateTime=pFDateTime;

	 UPDATE Table_Name SET TimeLapse=TIMESTAMPDIFF(MICROSECOND,eFDateTime,sFDateTime)/1000 WHERE
Id=pId;

		END IF;

		SET i=i+1;
	END WHILE;

END$$

CALL sp_CalcAgreementTimeLapse();

select * from Table_Name;
```

C. Analysis code

DBConnect Class- where MySQL related codes reside

```
import java.sql.*;
public class DBConnect {
//variable declaration
   private Connection con;
   private Statement st;
   private ResultSet rs;
   String PresentState = "Dead";
   String PreviousState;
   String table = "l9";
   int QueryState = 0;
   int[] AgreementState = new int[] {9,11,13,18,19,25,26,27,29,36,37,41,43,44,45};
   int[] DisagreementState = new int []{1,2,3,4,5,8,10,11,12,13,16,17,19,20,21,24,25,26,28,29,32,33,34,35,37,40,41,42,43,
44};
   int[] UndefinedState = new int[]{6,7,14,15,22,23,30,31,38,39,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63};
   int DeadState = 0;
   int DeadStart = 0;
   int DeadStop;
   int DeadDuration;
   int DeadSlot;
   int d = 1; // array counter
   int AgreementStart;
   int AgreementStop;
   int AgreementDuration;
   int AgreementSlot;
   int as = 1;// array counter
   int DisagreementStart;
   int DisagreementStop;
   int DisagreementDuration;
   int DisagreementSlot;
   int ds = 1; // array counter
   int UndefinedStart;
   int UndefinedStop;
   int UndefinedDuration;
   int UndefinedSlot;
   int u = 1;
   int D1;
   int D2;
   int D3;
   int D4;
   int D5;
   int D6;
   int  p1RightState=0;
   int  p1LeftState =0;
   int  p1ShootState =0;
   int  p1RightNewState;
   int  p1LeftNewState;
   int  p1ShootNewState;
   int  p2RightState =0;
   int  p2LeftState =0;
   int  p2ShootState =0;
   int  p2RightNewState;
   int  p2LeftNewState;
   int  p2ShootNewState;
   int rowCount = 0;
   int timeslot = 10000; //10-second time slot
   int i=0;
   boolean Found;
   int timelapse;
```

```
    String[] Descriptor;
    int inserted;

   //connect to MySQL database
    public DBConnect(){
       try{
          Class.forName("com.mysql.jdbc.Driver");
          con = DriverManager.getConnection("jdbc:mysql://localhost:3306/learning", "root", "Neamy1983.");
          st = con.createStatement();

       }catch(Exception ex){
          System.out.println("Error: " + ex);
       }
    }
//database querries
 public void getData(){
       try{
          String query = "select * from " +table;  //where (Timelapse < 10000 or TimeLapse = 10000)";
          rs = st.executeQuery(query);
          System.out.println("Records from database");

          //Entering "Agreement state from another state
         while(rowCount<=8712){ //check
             System.out.println(rowCount);
             if(rs.next()){
                 String action = rs.getString(4);
                 timelapse = rs.getInt(6);
                 Descriptor = action.split("_");
                 PreparedStatement pstmt = con.prepareStatement("INSERT INTO statetransition(presentState,Time,Source)
VALUES (?,?,?)");
                 pstmt.setString(1, PresentState);
                 pstmt.setInt(2, timelapse);
                 pstmt.setString(3, table);
                 pstmt.executeUpdate();
                if (Descriptor[0].equals("Player1")){
                        if (Descriptor[1].equals("rightKeyPress")){
                               if(Descriptor[2].equals("Start")){
                                     D1=32;
                                     p1RightNewState = 1;
                                     if(p1RightState != p1RightNewState){
                                     P1RightStart = timelapse;
                                     //System.out.println(p1RightNewState + "\t" + rowCount);
                                     PreparedStatement pstmt1 = con.prepareStatement("INSERT INTO p1rightkey(count,
P1RightKeyStart,Source) VALUES (?,?,?)");
                                     pstmt1.setInt(1, p1rk);
                                     pstmt1.setInt(2, P1RightStart);
                                     pstmt1.setString(3, table);
                                     pstmt1.executeUpdate();
                                     p1RightState = p1RightNewState;
                                     QueryState=QueryState | D1;
                                     //P1Right = true;
                                     }//end if()
                               }//end if (start)
                               else if(Descriptor[2].equals("Stop")){
                                     D1=32;
                                     p1RightNewState = 0;
                                     if(p1RightState != p1RightNewState ){
                                     P1RightStop = timelapse;
                                     //System.out.println(p1RightNewState + "\t" + rowCount);
                                     PreparedStatement pstmt1 = con.prepareStatement("UPDATE p1rightkey SET P1RightKeyStop= ?
WHERE count=? AND Source = ?");
                                     pstmt1.setInt(1, P1RightStop);
                                     pstmt1.setInt(2, p1rk);
```

```
                        pstmt1.setString(3, table);
                        pstmt1.executeUpdate();
                        p1RightState = p1RightNewState;
                        p1rk = p1rk+1;
                        QueryState=QueryState & ~D1;
                        //P1Right = false;
                        }//end if()
                    }//end stop()
                }//end if(rightpress)
                else if (Descriptor[1].equals("leftKeyPress")){
                    if(Descriptor[2].equals("Start")){
                        D2=16;
                        p1LeftNewState = 2;
                        if(p1LeftState != p1LeftNewState){
                        P1LeftStart = timelapse;
                        PreparedStatement pstmt1 = con.prepareStatement("INSERT INTO p1leftkey(count,
P1LeftKeyStart,Source) VALUES (?,?,?)");
                        pstmt1.setInt(1, p1lk);
                        pstmt1.setInt(2, P1LeftStart);
                        pstmt1.setString(3, table);
                        pstmt1.executeUpdate();
                        p1LeftState = p1LeftNewState;
                        QueryState=QueryState | D2;
                        //P1Left = true;
                        }//end if()
                    }//end if (start)
                    else if(Descriptor[2].equals("Stop")){
                        D2=16;
                        p1LeftNewState = 0;
                        if(p1LeftState != p1LeftNewState ){
                        P1LeftStop = timelapse;
                        PreparedStatement pstmt1 = con.prepareStatement("UPDATE p1leftkey SET P1LeftKeyStop= ?
WHERE count=? AND Source = ?");
                        pstmt1.setInt(1, P1LeftStop);
                        pstmt1.setInt(2, p1lk);
                        pstmt1.setString(3, table);
                        pstmt1.executeUpdate();
                        p1lk = p1lk+1;
                        p1LeftState = p1LeftNewState;
                        QueryState=QueryState & ~D2;
                        //P1Left = false;
                        }//end if()
                    }//end if(stop)
                }//end else if (leftpress)
                else if (Descriptor[1].equals("shootKeyPress")){
                    if(Descriptor[2].equals("Start")){
                        D3=8;
                        p1ShootNewState = 3;
                        if(p1ShootState != p1ShootNewState){
                        P1ShootStart = timelapse;
                        PreparedStatement pstmt1 = con.prepareStatement("INSERT INTO p1firekey(count,
P1FireKeyStart,Source) VALUES (?,?,?)");
                        pstmt1.setInt(1, p1fk);
                        pstmt1.setInt(2, P1ShootStart);
                        pstmt1.setString(3, table);
                        pstmt1.executeUpdate();
                        p1ShootState = p1ShootNewState;
                        QueryState=QueryState | D3;
                        //P1Shoot = true;
                        }//end if()
                    }//end if (start)
                    else if(Descriptor[2].equals("Stop")){
                        D3=8;
```

```
                                p1ShootNewState = 0;
                                if(p1ShootState != p1ShootNewState ){
                                P1ShootStop = timelapse;
                                PreparedStatement pstmt1 = con.prepareStatement("UPDATE p1firekey SET P1FireKeyStop= ?
WHERE count=? AND Source = ?");
                                pstmt1.setInt(1, P1ShootStop);
                                pstmt1.setInt(2, p1fk);
                                pstmt1.setString(3, table);
                                pstmt1.executeUpdate();
                                p1fk = p1fk +1;
                                p1ShootState = p1ShootNewState;
                                QueryState=QueryState & ~D3;
                                //P1Shoot = false;
                                }//end if
                         }//endelse if (stop)
                      }// end if(firepress)
                }//end if (player1)
                else if(Descriptor[0].equals("Player2")){
                      if (Descriptor[1].equals("rightKeyPress")){
                           if(Descriptor[2].equals("Start")){
                                D4=4;
                                p2RightNewState = 1;
                                if(p2RightState != p2RightNewState){
                                P2RightStart = timelapse;
                                PreparedStatement pstmt1 = con.prepareStatement("INSERT INTO p2rightkey(count,
P2RightKeyStart,Source) VALUES (?,?,?)");
                                pstmt1.setInt(1, p2rk);
                                pstmt1.setInt(2, P2RightStart);
                                pstmt1.setString(3, table);
                                pstmt1.executeUpdate();
                                p2RightState = p2RightNewState;
                                QueryState=QueryState | D4;
                                //P2Right = true;
                                }//end if()
                           }//end if(start)
                           else if(Descriptor[2].equals("Stop")){
                                D4=4;
                                p2RightNewState = 0;
                                if(p2RightState != p2RightNewState ){
                                P2RightStop = timelapse;
                                PreparedStatement pstmt1 = con.prepareStatement("UPDATE p2rightkey SET P2RightKeyStop= ?
WHERE count=? AND Source = ?");
                                pstmt1.setInt(1, P2RightStop);
                                pstmt1.setInt(2, p2rk);
                                pstmt1.setString(3, table);
                                pstmt1.executeUpdate();
                                p2rk = p2rk+1;
                                p2RightState = p2RightNewState;
                                QueryState=QueryState & ~D4;
                                //P2Right = false;
                                }//end if(P2right)
                           } //end if(stop)
                      }//end if (right)
                      else if (Descriptor[1].equals("leftKeyPress")){
                           if(Descriptor[2].equals("Start")){
                                D5=2;
                                p2LeftNewState = 2;
                                if(p2LeftState != p2LeftNewState){
                                P2LeftStart = timelapse;
                                PreparedStatement pstmt1 = con.prepareStatement("INSERT INTO p2leftkey(count,
P2LeftKeyStart,Source) VALUES (?,?,?)");
                                pstmt1.setInt(1, p2lk);
                                pstmt1.setInt(2, P2LeftStart);
```

```
                    pstmt1.setString(3, table);
                    pstmt1.executeUpdate();
                    p2LeftState = p2LeftNewState;
                    QueryState=QueryState | D5;
                    //P2Left = true;
                    } //end if p2left
                } //end if (start0
                else if(Descriptor[2].equals("Stop")){
                    D5=2;
                    p2LeftNewState = 0;
                    if(p2LeftState != p2LeftNewState ){
                    P2LeftStop = timelapse;
                    PreparedStatement pstmt1 = con.prepareStatement("UPDATE p2leftkey SET P2LeftKeyStop= ?
WHERE count=? AND Source = ?");
                    pstmt1.setInt(1, P2LeftStop);
                    pstmt1.setInt(2, p2lk);
                    pstmt1.setString(3, table);
                    pstmt1.executeUpdate();
                    p2lk = p2lk+1;
                    p2LeftState = p2LeftNewState;
                    QueryState=QueryState & ~D5;
                    //P2Left = false;
                    } //end if(p2left)
                }//end else if (stop)
            }//end else if(leftpress)
            else if (Descriptor[1].equals("shootKeyPress")){
                if(Descriptor[2].equals("Start")){
                    D6=1;
                    p2ShootNewState = 3;
                    if(p2ShootState != p2ShootNewState){
                    P2ShootStart = timelapse;
                    PreparedStatement pstmt1 = con.prepareStatement("INSERT INTO p2firekey(count,
P2FireKeyStart,Source) VALUES (?,?,?)");
                    pstmt1.setInt(1, p2fk);
                    pstmt1.setInt(2, P2ShootStart);
                    pstmt1.setString(3, table);
                    pstmt1.executeUpdate();
                    p2ShootState = p2ShootNewState;
                    QueryState=QueryState | D6;
                    //P2Shoot = true;
                    } //end if p2shoot)
                }// end if(start)
                else if(Descriptor[2].equals("Stop")){
                    D6=1;
                    p2ShootNewState = 0;
                    if(p2ShootState != p2ShootNewState ){
                    P2ShootStop = timelapse;
                    PreparedStatement pstmt1 = con.prepareStatement("UPDATE p2firekey SET P2FireKeyStop= ?
WHERE count=? AND Source = ?");
                    pstmt1.setInt(1, P2ShootStop);
                    pstmt1.setInt(2, p2fk);
                    pstmt1.setString(3, table);
                    pstmt1.executeUpdate();
                    p2fk = p2fk +1;
                    p2ShootState = p2ShootNewState;
                    QueryState=QueryState & ~D6;
                    //P2Shoot = false;
                }
            }
        }
        Found=false;
        i=0;
        while((!Found) && (i<=14)){   //15 Agreement states in total
```

```
                    //System.out.println(i);
                       if(QueryState==AgreementState[i]){  //Compare QueryState with AgreementState combinations until a
match is found
                              Found=true;
                              PreviousState=PresentState;
                              PresentState="Agreement";
                              if(!PresentState.equals(PreviousState)){
                                     AgreementStart = timelapse;
                                     AgreementSlot = timelapse/timeslot;
                                     PreparedStatement pstmt2 = con.prepareStatement("INSERT INTO
agreement(count,StartTime,TimeSlot,Source) VALUES (?,?,?,?)");
                                     pstmt2.setInt(1, as);
                                     pstmt2.setInt(2, AgreementStart);
                                     pstmt2.setInt(3, AgreementSlot);
                                     pstmt2.setString(4, table);
                                     pstmt2.executeUpdate();
                                            if(PreviousState.equals("Disagreement")){
                                            DisagreementStop = timelapse;
                                            DisagreementDuration = DisagreementStop - DisagreementStart;
                                            PreparedStatement pstmt1 = con.prepareStatement("UPDATE disagreement SET StopTime= ?
,Duration = ? WHERE count=? AND Source = ?");
                                            pstmt1.setInt(1, DisagreementStop);
                                            pstmt1.setInt(2, DisagreementDuration);
                                            pstmt1.setInt(3, ds);
                                            pstmt1.setString(4, table);
                                            pstmt1.executeUpdate();
                                            ds = ds+1;
                                     }
                                     else if(PreviousState.equals("Dead")){
                                            DeadStop = timelapse;
                                            DeadDuration = DeadStop - DeadStart;
                                            PreparedStatement pstmt1 = con.prepareStatement("UPDATE deadstate SET StopTime= ?
,Duration = ? WHERE count=? AND Source = ?");
                                            pstmt1.setInt(1, DeadStop);
                                            pstmt1.setInt(2, DeadDuration);
                                            pstmt1.setInt(3, d);
                                            pstmt1.setString(4, table);
                                            pstmt1.executeUpdate();
                                            d=d+1;
                                     }
                                     else if(PreviousState.equals("Undefined")){
                                            UndefinedStop = timelapse;
                                            UndefinedDuration = UndefinedStop - UndefinedStart;
                                            PreparedStatement pstmt1 = con.prepareStatement("UPDATE undefined SET StopTime= ?
,Duration = ? WHERE count=? AND Source = ?");
                                            pstmt1.setInt(1, UndefinedStop);
                                            pstmt1.setInt(2, UndefinedDuration);
                                            pstmt1.setInt(3, u);
                                            pstmt1.setString(4, table);
                                            pstmt1.executeUpdate();
                                            u=u+1;
                                     }
                              }
                       }
                       else{
                              i=i+1;
                       }
                }

                i=0;
                while((!Found) && (i<=29)){       //30 disagreement states
                   DisagreementStart = timelapse;
                         if(QueryState==DisagreementState[i]){  //Compare QueryState with DisagreementState combinations
```

```
                        Found=true;
                        PreviousState=PresentState;
                        PresentState="Disagreement";
                        if(!PresentState.equals(PreviousState)){
                              DisagreementStart = timelapse;
                              DisagreementSlot=timelapse/timeslot;
                              PreparedStatement pstmt3 = con.prepareStatement("INSERT INTO
disagreement(count,StartTime,TimeSlot,Source) VALUES (?,?,?,?)");
                              pstmt3.setInt(1, ds);
                              pstmt3.setInt(2, DisagreementStart);
                              pstmt3.setInt(3, DisagreementSlot);
                              pstmt3.setString(4, table);
                              pstmt3.executeUpdate();
                              if(PreviousState.equals("Agreement")){
                                    AgreementStop = timelapse;
                                    AgreementDuration = AgreementStop - AgreementStart;
                                    PreparedStatement pstmt1 = con.prepareStatement("UPDATE agreement SET StopTime= ?
,Duration = ? WHERE count=? AND Source = ?");
                                    pstmt1.setInt(1, AgreementStop);
                                    pstmt1.setInt(2, AgreementDuration);
                                    pstmt1.setInt(3, as);
                                    pstmt1.setString(4, table);
                                    pstmt1.executeUpdate();
                                    as = as+1;
                              }
                              else if(PreviousState.equals("Dead")){
                                    DeadStop = timelapse;
                                    DeadDuration = DeadStop - DeadStart;
                                    PreparedStatement pstmt1 = con.prepareStatement("UPDATE deadstate SET StopTime= ?
,Duration = ? WHERE count=? AND Source = ?");
                                    pstmt1.setInt(1, DeadStop);
                                    pstmt1.setInt(2, DeadDuration);
                                    pstmt1.setInt(3, d);
                                    pstmt1.setString(4, table);
                                    pstmt1.executeUpdate();
                                    d=d+1;
                              }
                              else if(PreviousState.equals("Undefined")){
                                    UndefinedStop = timelapse;
                                    UndefinedDuration = UndefinedStop - UndefinedStart;
                                    PreparedStatement pstmt1 = con.prepareStatement("UPDATE undefined SET StopTime= ?
,Duration = ? WHERE count=? AND Source = ?");
                                    pstmt1.setInt(1, UndefinedStop);
                                    pstmt1.setInt(2, UndefinedDuration);
                                    pstmt1.setInt(3, u);
                                    pstmt1.setString(4, table);
                                    pstmt1.executeUpdate();
                                    u=u+1;
                              }
                        }
                  }
                  else{
                        i=i+1;
                  }
            }

            i=0;
            while((!Found) && (i<=27)){
                  if(QueryState==UndefinedState[i]){  //Compare QueryState with NotAllowed State combinations
                        Found=true;
                        PreviousState=PresentState;
                        PresentState="Undefined";
                        if(!PresentState.equals(PreviousState)){
```

```
					UndefinedStart = timelapse;
					UndefinedSlot = timelapse/timeslot;
					PreparedStatement pstmt4 = con.prepareStatement("INSERT INTO undefined
(count,StartTime,TimeSlot,Source) VALUES (?,?,?,?)");
					pstmt4.setInt(1, u);
					pstmt4.setInt(2, UndefinedStart);
					pstmt4.setInt(3,  UndefinedSlot);
					pstmt4.setString(4, table);
					pstmt4.executeUpdate();
					if(PreviousState.equals("Agreement")){
						AgreementStop = timelapse;
						AgreementDuration = AgreementStop - AgreementStart;
						PreparedStatement pstmt1 = con.prepareStatement("UPDATE agreement SET StopTime= ?
,Duration = ? WHERE count=? AND Source = ?");
						pstmt1.setInt(1, AgreementStop);
						pstmt1.setInt(2, AgreementDuration);
						pstmt1.setInt(3, as);
						pstmt1.setString(4, table);
						pstmt1.executeUpdate();
						as = as+1;
					}
					else if(PreviousState.equals("Dead")){
						DeadStop = timelapse;
						DeadDuration = DeadStop - DeadStart;
						PreparedStatement pstmt1 = con.prepareStatement("UPDATE deadstate SET StopTime= ?
,Duration = ? WHERE count=? AND Source = ?");
						pstmt1.setInt(1, DeadStop);
						pstmt1.setInt(2, DeadDuration);
						pstmt1.setInt(3, d);
						pstmt1.setString(4, table);
						pstmt1.executeUpdate();
						d=d+1;
					}
					else if(PreviousState.equals("Disagreement")){
						DisagreementStop = timelapse;
						DisagreementDuration = DisagreementStop - DisagreementStart;
						PreparedStatement pstmt1 = con.prepareStatement("UPDATE disagreement SET StopTime= ?
,Duration = ? WHERE count=? AND Source = ?");
						pstmt1.setInt(1, DisagreementStop);
						pstmt1.setInt(2, DisagreementDuration);
						pstmt1.setInt(3, ds);
						pstmt1.setString(4, table);
						pstmt1.executeUpdate();
						ds=ds+1;
					}
				}
			}
			else{
				i=i+1;
			}
		}
		i=0;
		while(!Found){
			if(QueryState == DeadState){  //Compare QueryState with DisagreementState combinations
				Found=true;
				PreviousState=PresentState;
				PresentState="Dead";
				if(!PresentState.equals(PreviousState)){
					DeadStart = timelapse;
					DeadSlot = timelapse/timeslot;
					PreparedStatement pstmt5 = con.prepareStatement("INSERT INTO deadstate
(count,StartTime,TimeSlot,Source) VALUES (?,?,?,?)");
					pstmt5.setInt(1, d);
```

```
                                pstmt5.setInt(2, DeadStart);
                                pstmt5.setInt(3,  DeadSlot);
                                pstmt5.setString(4, table);
                                pstmt5.executeUpdate();
                                if(PreviousState.equals("Agreement")){
                                      AgreementStop = timelapse;
                                      AgreementDuration = AgreementStop - AgreementStart;
                                      PreparedStatement pstmt1 = con.prepareStatement("UPDATE agreement SET StopTime= ?
,Duration = ? WHERE count=? AND Source = ?");
                                      pstmt1.setInt(1, AgreementStop);
                                      pstmt1.setInt(2, AgreementDuration);
                                      pstmt1.setInt(3, as);
                                      pstmt1.setString(4, table);
                                      pstmt1.executeUpdate();
                                      as = as+1;
                                }
                                else if(PreviousState.equals("Disagreement")){
                                      DisagreementStop = timelapse;
                                      DisagreementDuration = DisagreementStop - DisagreementStart;
                                      PreparedStatement pstmt1 = con.prepareStatement("UPDATE disagreement SET StopTime= ?
,Duration = ? WHERE count=? AND Source = ?");
                                      pstmt1.setInt(1, DisagreementStop);
                                      pstmt1.setInt(2, DisagreementDuration);
                                      pstmt1.setInt(3, ds);
                                      pstmt1.setString(4, table);
                                      pstmt1.executeUpdate();
                                      ds=ds+1;
                                }
                                else if(PreviousState.equals("Undefined")){
                                      UndefinedStop = timelapse;
                                      UndefinedDuration = UndefinedStop - UndefinedStart;
                                      PreparedStatement pstmt1 = con.prepareStatement("UPDATE undefined SET StopTime= ?
,Duration = ? WHERE count=? AND Source = ?");
                                      pstmt1.setInt(1, UndefinedStop);
                                      pstmt1.setInt(2, UndefinedDuration);
                                      pstmt1.setInt(3, u);
                                      pstmt1.setString(4, table);
                                      pstmt1.executeUpdate();
                                      u=u+1;
                                }
                          }
                    }
                    else{
                          i=i+1;
                    }
              }
           } rowCount=rowCount+1;
         } con.close();
        }catch(SQLException ex){
        System.out.println(ex);
        ex.printStackTrace();
    }
   }
}
```

Main Class

```
public class Main {
     public static void main(String[] args) {
     DBConnect connect = new DBConnect();
     connect.getData();
   }
 }
```

D. How participants played game using various interaction methods

	Never		Rarely		Sometimes		Often		Always	
Pressing buttons on a PlayStation Controller	2	4.0%	4	8.0%	12	24.0%	12	24.0%	20	40.0%
Pressing buttons on a Wiimote	16	33.3%	11	22.9%	5	10.4%	13	27.1%	3	6.3%
Pressing buttons on an Xbox Controller	4	8.0%	4	8.0%	9	18.0%	9	18.0%	24	48.0%
Moving the Wiimote	18	37.5%	9	18.8%	9	18.8%	9	18.8%	3	6.3%
Moving WiiU	31	67.4%	5	10.9%	5	10.9%	1	2.2%	4	8.7%
Tilting PlayStation Controller	8	16.0%	3	6.0%	15	30.0%	10	20.0%	14	28.0%
Tilting Tablet, iPad, iPhone, Android	2	4.0%	5	10.0%	9	18.0%	11	22.0%	23	46.0%
Touching Tablet, iPad, iPhone, Android, WiiU	4	8.3%	4	8.3%	4	8.3%	10	20.8%	26	52.0%
Balance Board	32	64.0%	9	18.0%	8	16.0%	1	2.0%	0	0.0%
Dance Mat	23	46.0%	9	18.0%	12	24.0%	5	10.0%	1	2.0%
PC Keyboard and Mouse	3	6.0%	9	18.0%	14	28.0%	8	16.0%	16	32.0%
Pressing button on a PSP	23	46.9%	9	18.4%	4	8.2%	6	12.2%	7	14.3%
Pressing button on a Nintendo DS/3DS	18	36.7%	8	16.3%	9	18.4%	6	12.2%	8	16.3%
Pressing button on a WiiU	33	70.2%	3	6.4%	4	8.5%	2	4.3%	5	10.6%
Touching the Screen on Nintendo DS/3DS	19	38.0%	11	22.0%	10	20.0%	3	6.0%	7	14.0%
Moving your body e.g. Xbox Kinect	13	26.0%	8	16.0%	11	22.0%	9	18.0%	9	18.0%

E. Summary of behaviours of Children

	G1	G2	G3	G4	G5	G6	G7	G8-G15 were not analysed in this section	G16	G17	G18	G19	G20	G21	G22	G23	G24	G25
Dominating	6	68	59	42	17	70	12		33	34	20	11	19	5	42	35	23	42
Non-Conflict situation	-	13	21	11	5	3	-		21	6	10	15	6	1	7	10	1	12
Conflict resolved	-	3	12	2	2	2	1		10	1	1	5	1	1	-	3	-	3
Conflict not resolved due to game over	-	-	1	-	-	-	-		1	-	-	2	-	-	1	1	-	1
Conflict takes longer to be resolved	-	1	-	-	-	-	-		1	-	-	1	-	-	-	-	-	-
Enquiry from partner about game duration	1	-	1	1	-	1	2		-	-	-	-	-	-	-	-	-	-
Enquiry from partner about game play	-	4	4	3	-	2	6		3	2	1	4	4	1	2	2	-	2
Enquiry from researcher about research work	-	-	-	-	-	-	-		-	-	-	-	-	2	-	-	-	-
Enquiry from researcher about game duration	1	-	-	2	1	-	2		-	-	-	2	2	4	1	1	-	-
Enquiry from researcher about game play	-	1	-	-	-	-	2		-	1	-	1	-	2	-	-	-	1
Enquiry from researcher about quitting game	-	-	-	2	-	-	3		-	-	-	-	-	-	-	-	-	-
Enquiry from researcher about game	-	-	-	-	-	-	-		-	-	-	2	-	-	-	-	-	-
Deictic	1	-	2	1	-	-	1		-	6	-	1	-	-	3	-	-	-
Not allowing partner dominate	1	-	1	-		-	-		-	3	-	-	-	-	-	-	-	-
Giving suggestion – Suggestion accepted	-	9	1	-	1	2	-		2	1	-	-	2	1	2	1	-	1
Giving suggestion -Suggestion ignored	-	-	1	-	-	-	-		-	-	-	-	1	1	-	-	-	-
Inter group interaction	-	2	3	8	15	-	-		-	1	4	3	3	-	-	1	-	-
Aggressive behaviour	-	2	-	4	-	-	-		-	-	-	-	-	-	-	-	-	-
Encouragement	-	-	1	1	6	-	1		-	-	-	-	-	-	-	-	-	-
Tutoring behaviour											1	1	-	-	-	-	-	-
Noticed map	-	-	-	1	1	-	-		-	1	-	-	-	-	-	-	-	-
Pointing	-	8	6	11	3	2	4		4	2	1	1	6	3	8	5	6	8

F. How long it took each group to reach agreement the first time

First time each group reached agreement		
Group	**Time (milliseconds)**	**Time (seconds)**
1	16	0.016
2	1861	1.861
3	4463	4.463
4	2397	2.397
5	1780	1.780
6	1329	1.329
7	349	0.349
8	699	0.699
9	2052	2.052
10	345	0.345
11	3264	3.264
12	35	0.035
13	615	0.615
14	3726	3.726
15	3313	3.313
16	464	0.464
17	637	0.637
18	4677	4.677
19	574	0.574
20	1020	1.020
21	1511	1.511
22	660	0.660
23	2754	2.754
24	2158	2.158
25	416	0.416
	Average	**1.605**

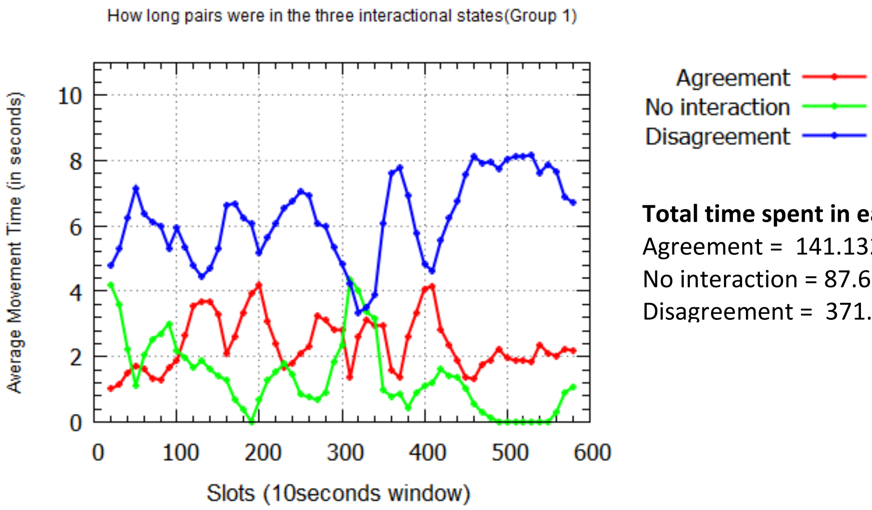
G. Agreement Percentage Calculation

1d	P1Fire (ms)	P2Fire (ms)	P1Left (ms)	P2Left (ms)	P1Right (ms)	P2Right (ms)	total Key presses (ms)	Agreement (ms)	Ratio of Agreement to keypress	Agreement percentage
1	292505	231873	16871	44980	125110	150127	861466	141132	0.163827708	16.38
2	227571	258082	38857	52308	33768	72391	682977	122280	0.179039704	17.90
3	242378	221951	51028	98544	83457	48992	746350	133430	0.178776713	17.88
4	216209	286272	19932	47408	62545	55343	687709	125831	0.182971286	18.30
5	221884	229266	43765	13123	15466	44507	568011	100377	0.176716648	17.67
6	166972	204642	50181	37524	51936	77749	589004	99834	0.169496302	16.95
7	277084	328174	108728	120713	131292	134088	1100079	217303	0.197533995	19.75
8	200145	217276	63424	110346	112297	146909	850397	176914	0.208036952	20.80
9	180649	204649	30885	60739	60065	63153	600140	102957	0.171554971	17.16
10	162639	237295	58413	21132	240596	76728	796803	79477	0.099744855	9.97
11	373548	263394	20090	49916	90719	19061	816728	181154	0.221804567	22.18
12	256598	237865	4450	1009	13980	3386	517288	118749	0.229560709	22.96
13	205898	185586	39798	70182	55710	65640	622814	156181	0.250766682	25.08
14	219044	226791	125013	135613	138167	129344	973972	198077	0.203370323	20.34
15	307476	305929	63497	43105	58627	28926	807560	178408	0.220922284	22.09
16	207330	92850	139585	81670	104837	124549	750821	95116	0.126682658	12.67
17	235229	214118	38113	104005	65029	54303	710797	114513	0.161105069	16.11
18	247558	242682	20043	36849	61017	21231	629380	122913	0.195292192	19.53
19	230639	203017	19100	54970	112638	20840	641204	98774	0.154044579	15.40
20	298093	236528	74853	60356	97712	67678	835220	162083	0.194060248	19.41
21	216899	266618	8185	14665	58152	17335	581854	106799	0.183549481	18.35
22	181091	185666	108385	127152	81208	132512	816014	125179	0.153403005	15.34
23	209897	334224	70865	32270	55999	45199	748454	186607	0.249323272	24.93
24	403851	259248	155784	176079	138515	142926	1276403	244946	0.191903341	19.19
25	137597	181291	82751	149322	87319	65007	703287	113808	0.161822983	16.18

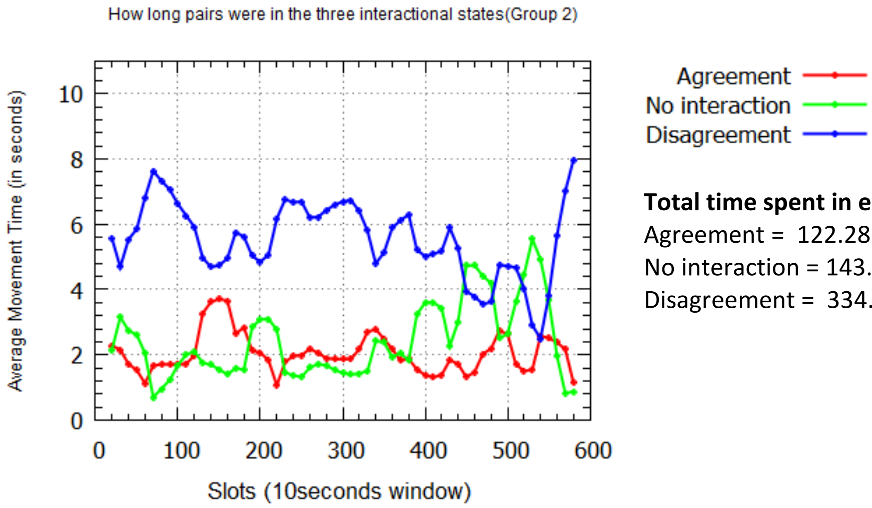
H. Disagreement Percentage Calculation

1d	P1Fire (ms)	P2Fire (ms)	P1Left (ms)	P2Left (ms)	P1Right (ms)	P2Right (ms)	total Key presses (ms)	Disagreement (ms)	Ratio of Disgreement to keypress	Disgreement percentage
1	292505	231873	16871	44980	125110	150127	861466	371186	0.430877	43.09
2	227571	258082	38857	52308	33768	72391	682977	334529	0.48981	48.98
3	242378	221951	51028	98544	83457	48992	746350	371740	0.498077	49.81
4	216209	286272	19932	47408	62545	55343	687709	341332	0.496332	49.63
5	221884	229266	43765	13123	15466	44507	568011	340376	0.599242	59.92
6	166972	204642	50181	37524	51936	77749	589004	318305	0.540412	54.04
7	277084	328174	108728	120713	131292	134088	1100079	313774	0.285229	28.52
8	200145	217276	63424	110346	112297	146909	850397	337948	0.3974	39.74
9	180649	204649	30885	60739	60065	63153	600140	327826	0.546249	54.62
10	162639	237295	58413	21132	240596	76728	796803	412926	0.518228	51.82
11	373548	263394	20090	49916	90719	19061	816728	334521	0.409587	40.96
12	256598	237865	4450	1009	13980	3386	517288	275092	0.531797	53.18
13	205898	185586	39798	70182	55710	65640	622814	332892	0.534497	53.45
14	219044	226791	125013	135613	138167	129344	973972	315294	0.32372	32.37
15	307476	305929	63497	43105	58627	28926	807560	321724	0.39839	39.84
16	207330	92850	139585	81670	104837	124549	750821	357439	0.476064	47.61
17	235229	214118	38113	104005	65029	54303	710797	351338	0.494287	49.43
18	247558	242682	20043	36849	61017	21231	629380	324025	0.514832	51.48
19	230639	203017	19100	54970	112638	20840	641204	329645	0.514103	51.41
20	298093	236528	74853	60356	97712	67678	835220	324996	0.389114	38.91
21	216899	266618	8185	14665	58152	17335	581854	305402	0.524877	52.49
22	181091	185666	108385	127152	81208	132512	816014	362360	0.444061	44.41
23	209897	334224	70865	32270	55999	45199	748454	370756	0.495362	49.54
24	403851	259248	155784	176079	138515	142926	1276403	342519	0.268347	26.83
25	137597	181291	82751	149322	87319	65007	703287	346496	0.492681	49.27

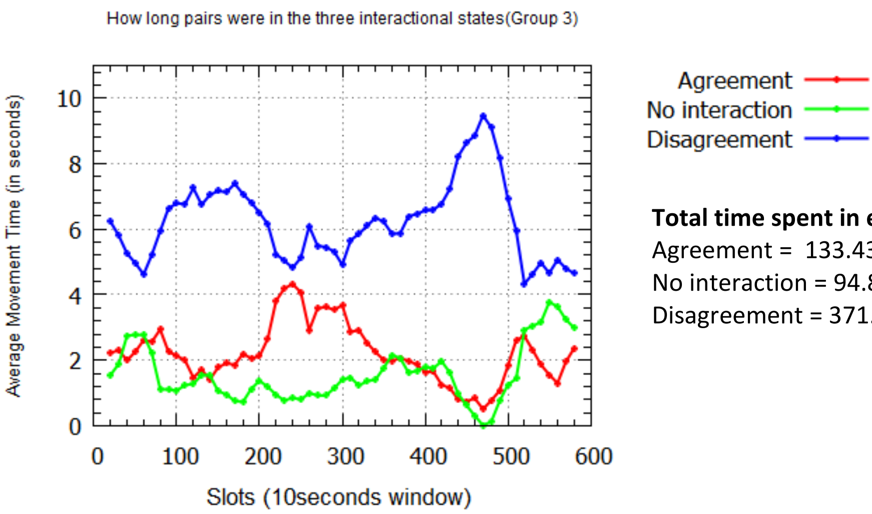
I. Graphs of the Three Interactional States



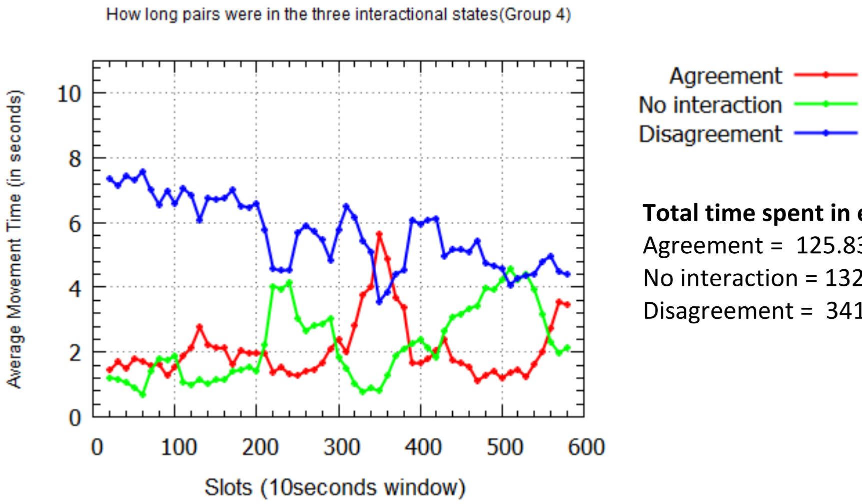
Total time spent in each state (in seconds)
Agreement = 141.132
No interaction = 87.682
Disagreement = 371.186



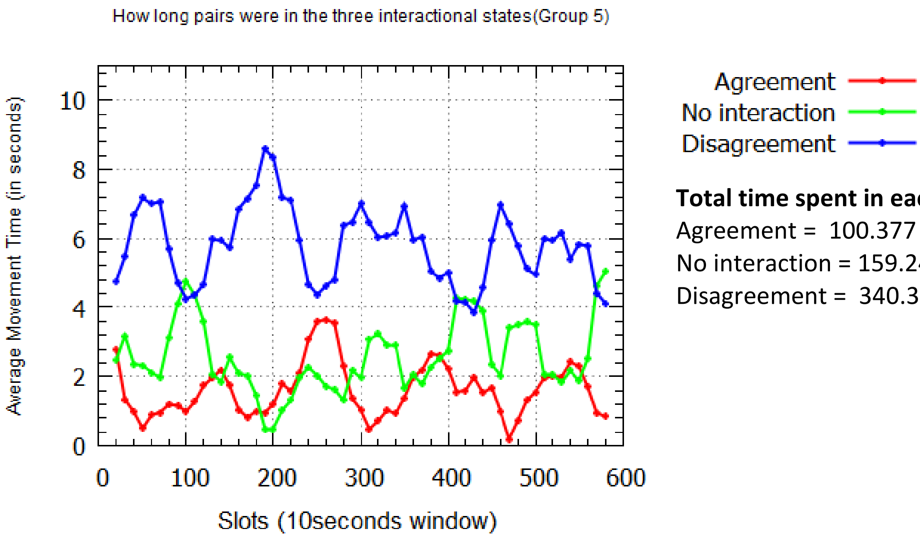
Total time spent in each state (in seconds)
Agreement = 122.28
No interaction = 143.191
Disagreement = 334.529



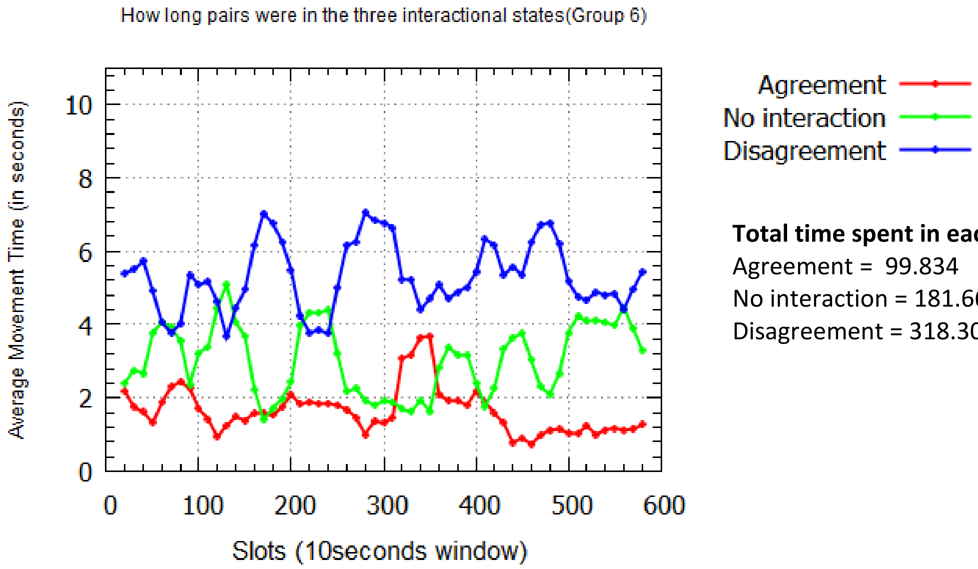
Total time spent in each state (in seconds)
Agreement = 133.43
No interaction = 94.83
Disagreement = 371.74



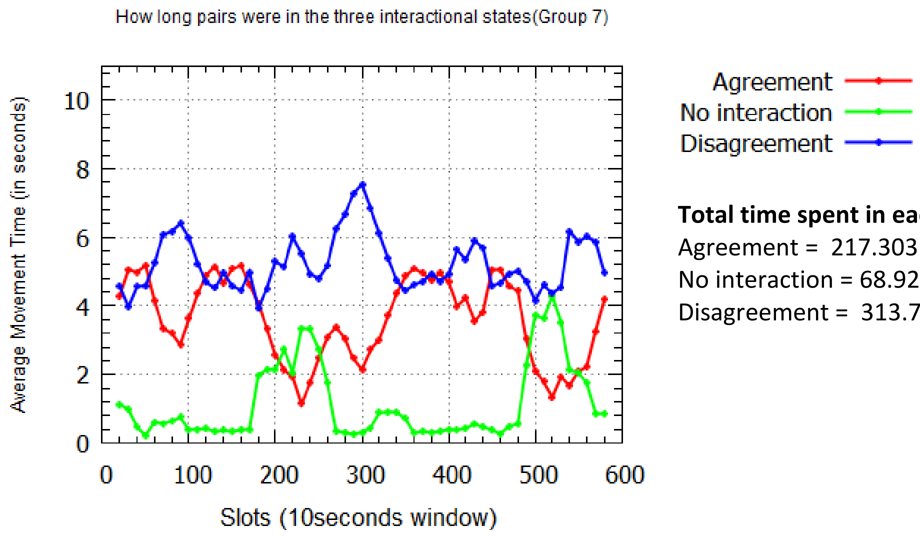
Total time spent in each state (in seconds)
Agreement = 125.831
No interaction = 132.837
Disagreement = 341.332



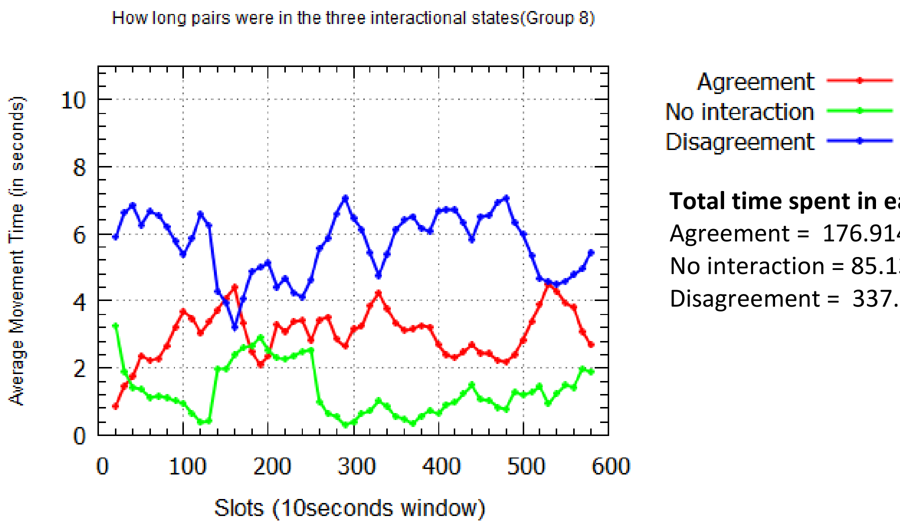
Total time spent in each state (in seconds)
Agreement = 100.377
No interaction = 159.247
Disagreement = 340.376



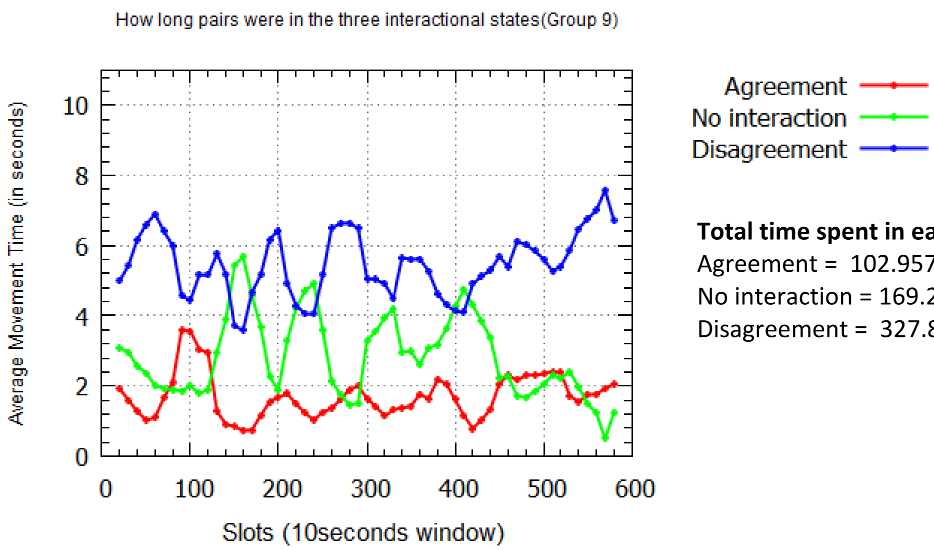
Total time spent in each state (in seconds)
Agreement = 99.834
No interaction = 181.661
Disagreement = 318.305



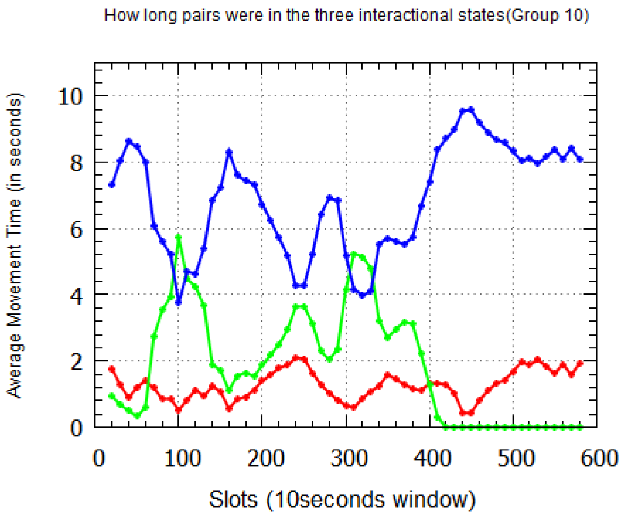
Total time spent in each state (in seconds)
Agreement = 217.303
No interaction = 68.923
Disagreement = 313.774



Total time spent in each state (in seconds)
Agreement = 176.914
No interaction = 85.138
Disagreement = 337.948

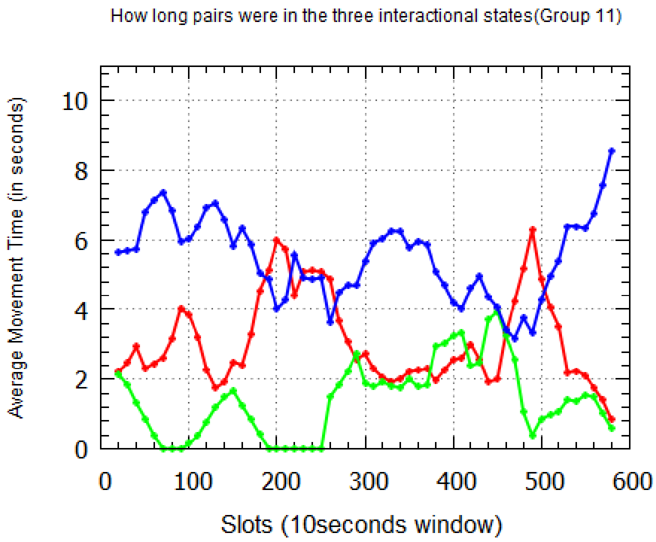


Total time spent in each state (in seconds)
Agreement = 102.957
No interaction = 169.217
Disagreement = 327.826



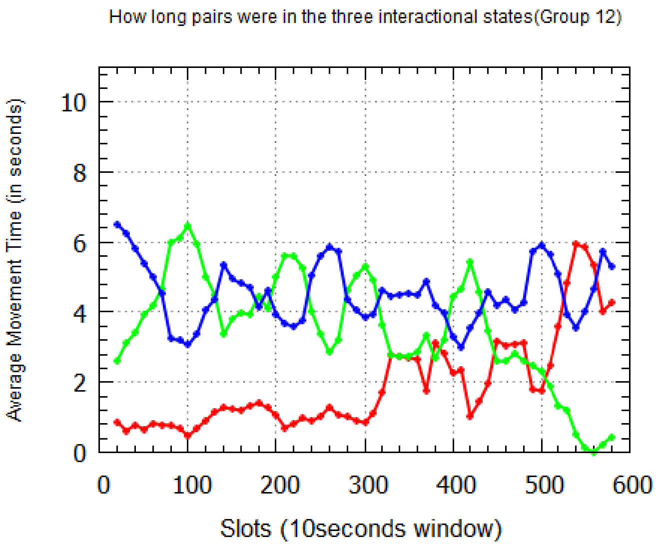
Agreement
No interaction
Disagreement

Total time spent in each state (in seconds)
Agreement = 79.477
No interaction = 107.597
Disagreement = 412.926



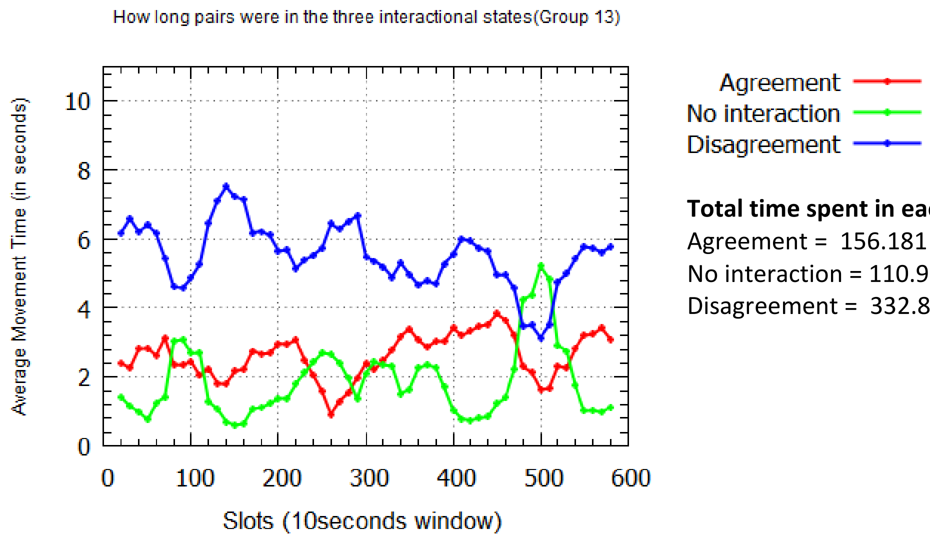
Agreement
No interaction
Disagreement

Total time spent in each state (in seconds)
Agreement = 181.154
No interaction = 84.325
Disagreement = 334.521

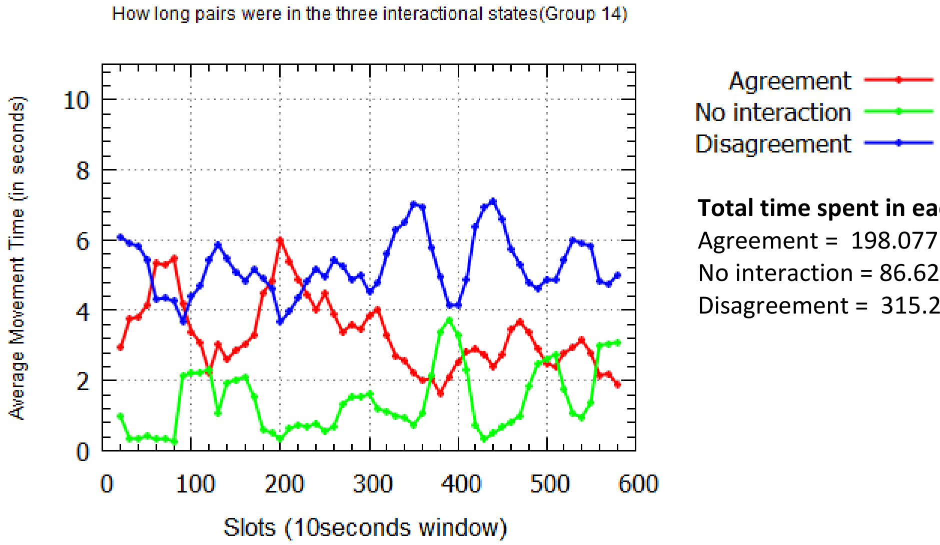


Agreement
No interaction
Disagreement

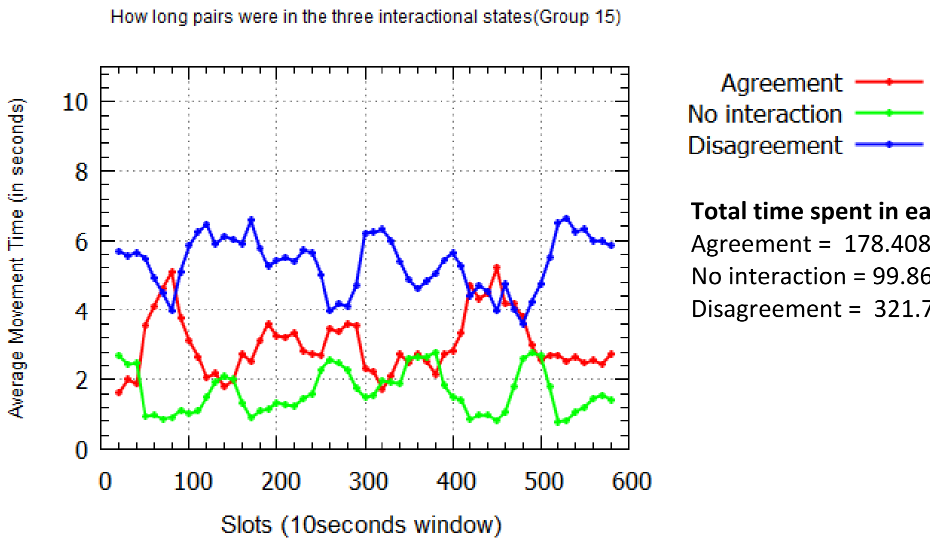
Total time spent in each state (in seconds)
Agreement = 118.749
No interaction = 206.159
Disagreement = 275.092



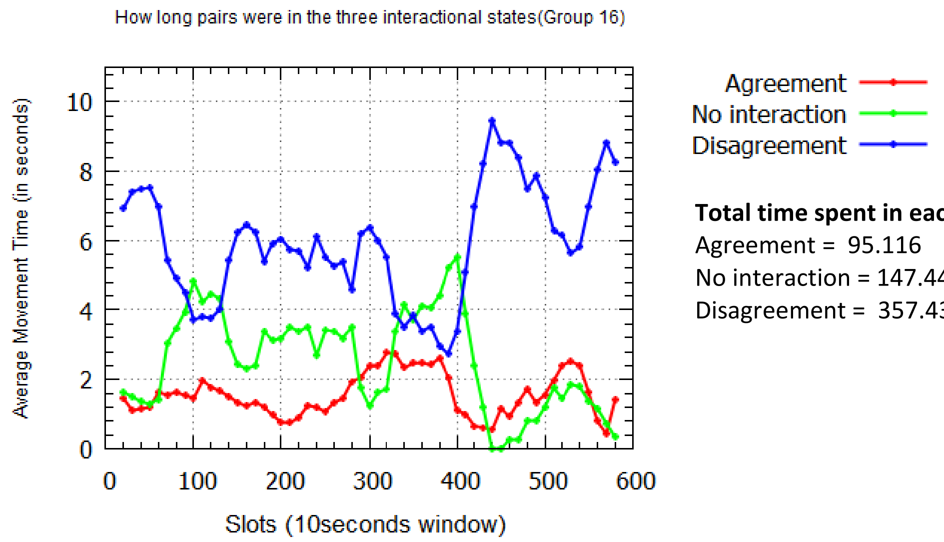
Total time spent in each state (in seconds)
Agreement = 156.181
No interaction = 110.927
Disagreement = 332.892



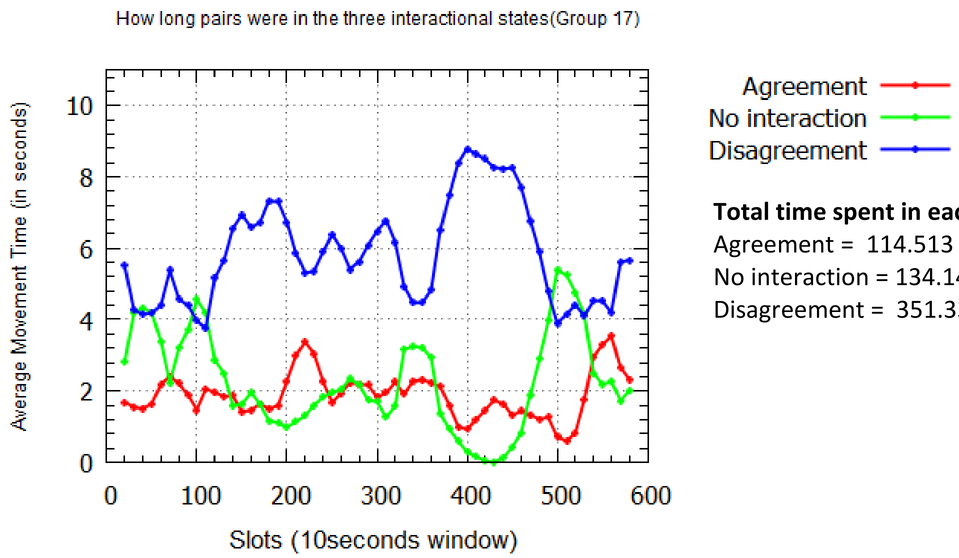
Total time spent in each state (in seconds)
Agreement = 198.077
No interaction = 86.629
Disagreement = 315.294



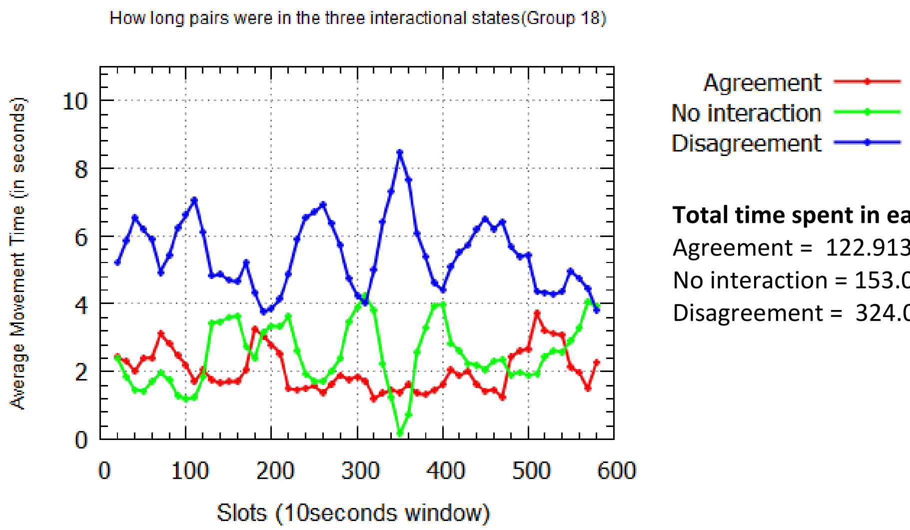
Total time spent in each state (in seconds)
Agreement = 178.408
No interaction = 99.868
Disagreement = 321.724



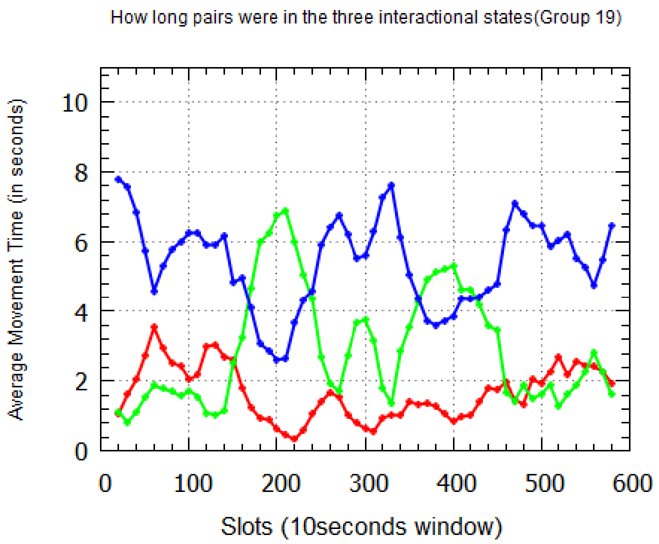
Total time spent in each state (in seconds)
Agreement = 95.116
No interaction = 147.445
Disagreement = 357.439



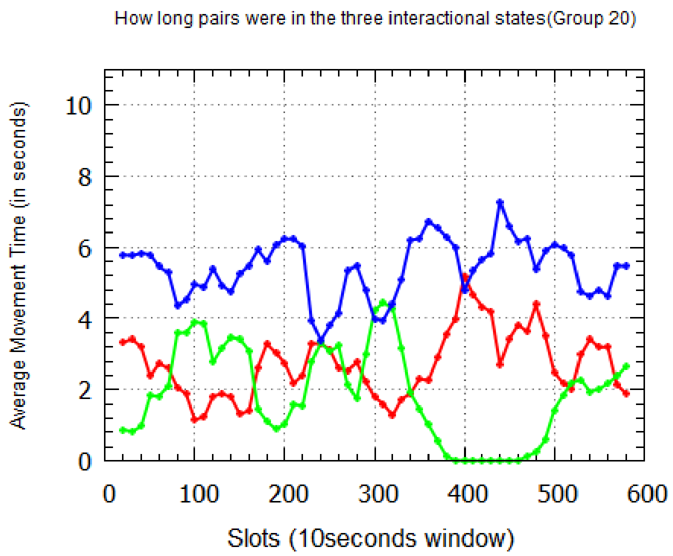
Total time spent in each state (in seconds)
Agreement = 114.513
No interaction = 134.149
Disagreement = 351.338



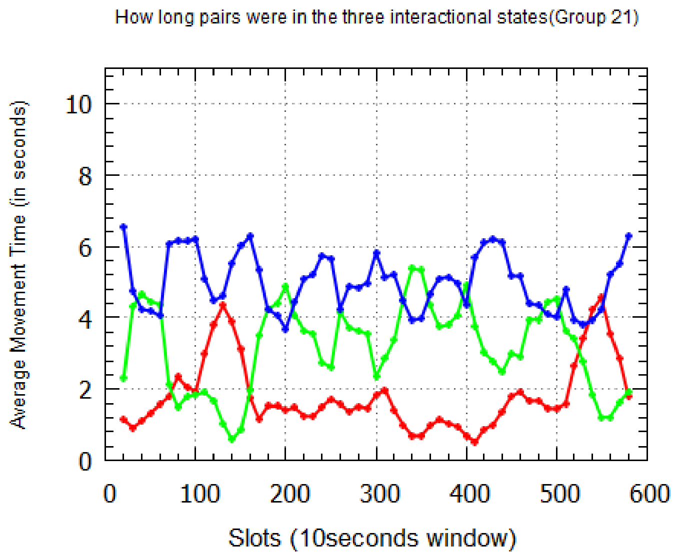
Total time spent in each state (in seconds)
Agreement = 122.913
No interaction = 153.062
Disagreement = 324.025



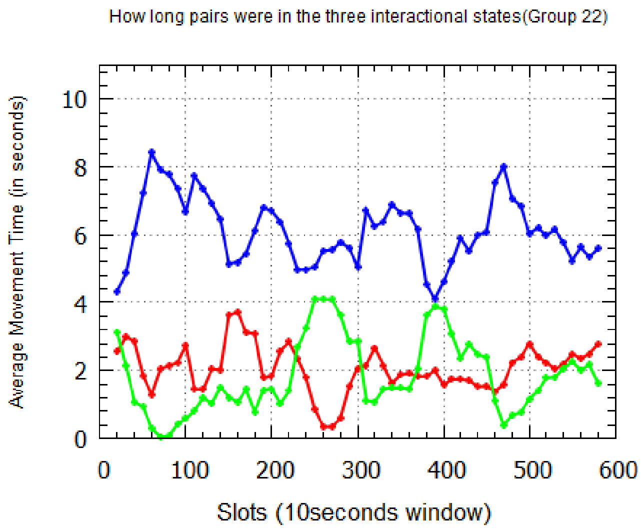
Total time spent in each state (in seconds)
Agreement = 98.774
No interaction = 171.581
Disagreement = 329.645



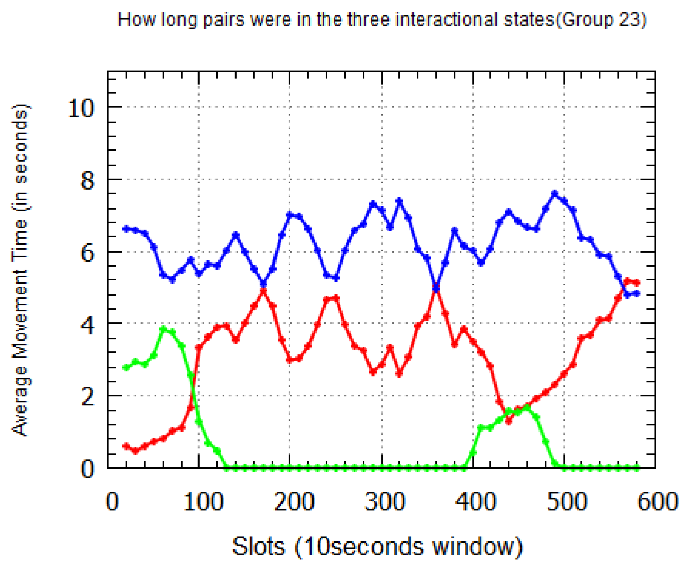
Total time spent in each state (in seconds)
Agreement = 162.083
No interaction = 112.921
Disagreement = 324.996



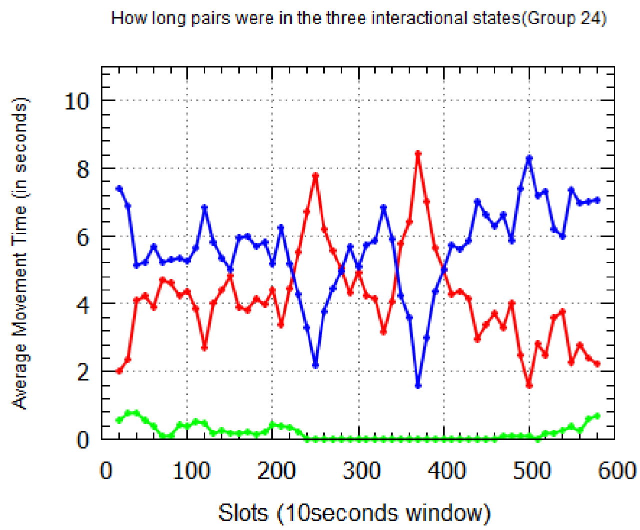
Total time spent in each state (in seconds)
Agreement = 106.799
No interaction = 187.799
Disagreement = 305.402



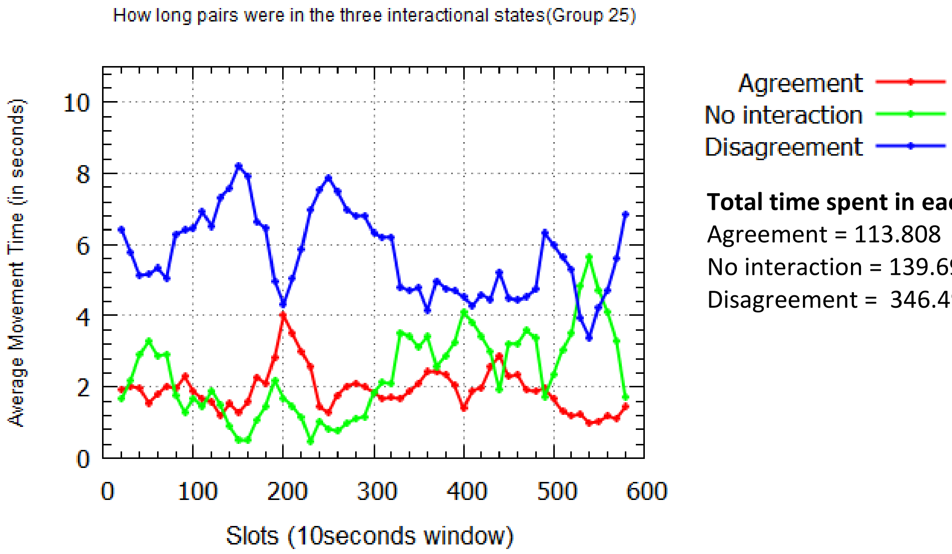
Total time spent in each state (in seconds)
Agreement = 125.179
No interaction = 112.461
Disagreement = 362.360



Total time spent in each state (in seconds)
Agreement = 186.607
No interaction = 42.637
Disagreement = 370.756



Total time spent in each state (in seconds)
Agreement = 244.946
No interaction = 12.535
Disagreement = 342.519



Total time spent in each state (in seconds)

Agreement = 113.808

No interaction = 139.696

Disagreement = 346.496

J. Change in Strategy

CATEGORY 1						
Group	**Before first gameplay**	**First gameplay**	**5 seconds pause after 1st death**	**Second gameplay**	**5 seconds pause 2nd death**	**How strategy changed?**
1	None	Pairs mostly played silently (spoke for only 0.899 seconds). However, P1 gave instruction once to P2. P2 stared at the screen all through while P1 moved her eye gaze intermittently from the screen to her controller and P2's controller	**P1:** "Oh, we moved too soon" **P2:** *[stares at P1]* **P1:** *[stares at P2 and giggles]* **P2:** *[giggles]*	Pairs mostly played silently as well (spoke for ony 0.586 seconds). P2 gave instruction once to P1. P2 stared at the screen all through. P1 stared at the screen but at one point glanced at P2s controller	**P2:** *[makes a sound and looks at the researcher]* **P1:** *[stares at the screen]*	P1 was more focused on the screen after they died the first time.
5	None	One of the pairs accidentally pressed the wrong button following the instruction given by the partner. This is illustrated in the transcript of their talks in the post first/pre second death moment Talk time = 2.316 seconds	**P9:** "What's it?" [stares at P10] **P10:** "I pressed that one" [shows P9 controller] **P9:** "Left!" [shows P10 controller]	Both players focused their gazes on the screen although there were times when they looked at each other's controllers. Talk time = 27.544 seconds P10 (10) gave more instructions than P9 (6). On one occasion P10 touched P9's controller to make the partner do the same thing and P9 did not attempt to stop the partner from touching her controller P10 used pointing gesture to direct the partner on what button to press: "*Go that way*"[pointing to the right] Period of silent play Conflict resolution and non-conflict situations were present. On one occasion, P10 touched P9's controller to show P9 what key to press: **P9:** "*Wait a minute. Don't shoot that way. We need to press left first*" **P10:** "*This is left press*"*[touches P9's controller]*	**P9:** "Wow, hi five!" *[both hi five each other]* **P9:** *[moves close to other group]* "What's your highest we can beat it!"	Both players were more focused and engaged after they died the first time. There was improvement in controller manipulation by P10 considering the fac t that they failed in the first game because of her inability to press the right key. In the second game play, P10 improved to the extent that she is confident enough to show P9 (who was previously teaching her the correct key presses) what key to press. As a result they seemed to be more interactive and enjoy the game.

CATEGORY 1						
Group	**Before first gameplay**	**First gameplay**	**5 seconds pause after 1st death**	**Second gameplay**	**5 seconds pause 2nd death**	**How strategy changed?**
16	**P32:** "You say left, I say right. You say right, I say left" [laughs] **P31:** [laughs]	Both pairs gave instructions to each other (although P31 gave more instruction). They both looked more at the screen and had few instances where they moved their eye gazes to their own controllers and partners controllers. There were also several instances of positive affects like laughing and smiling. Conflict resolution and non-conflict behaviours were observed. Talk time = 28.078 seconds	Both make an aww sound and smiles.	Both pairs gave instructions to each other (although P31 gave more instruction). They both looked more at the screen and had few instances where they moved their eye gazes to their own controllers and partners controllers. There were also several instances of positive affects like laughing and smiling. Conflict resolution and non-conflict behaviours were also observed Talk time = 41.019 seconds	**P31:** *[drops arms and looks at P32]* **P32:** *[makes a sound] "Look at you"* **P31:** *"It's shocking, right?" [smiles]*	Negotiated a strategy before first gameplay. But the strategies adopted in the first and second gameplay did not change. It appeared they understood the strategies they adopted in the first game play worked for them and did not bother to change it. it is evident that they played relatively longer in the first game play than any other group in this category.
18	**P35:** "we gonna do it exactly at the same time. So I say left you say, I will say left right. By the way that's that [points at the left button] and that's that [points at the right button] " **P36:** "Yeah" [stares at P35's controller] **P35:** "and that's shoot" [points at the shoot button] **P36:** "but I've played it…" [smiles] **P35:** "Yeah, I just forgot " [smiles]	Both pairs focused their eye gazes more on the screen although there times they looked at their partners's and own controller, at their partner and at the researcher. Talk time = 18.941 seconds Both pairs participated in giving instructions to each other Conflict resolved, non-conficts and tutoring behaviour (where one pair corrected the other as shown in the transcript) were observed: **P36: "** *…move left "[glanced at P37's controller] "What?"* **P37:** [shows P36 his controller] "*Left!"* **P36:** "*That's right"*	**P35:** "You go that way " [shows P36 controller while staring at his controller] **P36:** *[stares at P35's controller]* "It's really hard" **P35:** "Yeah, I know what to do. I know what to do" [points at the shoot button]	Both pairs focused their eye gazes more on the screen although there times they looked at their partners's and own controller, at their partner and the researcher. Talk time = 25.836 seconds Both pairs participated in giving instructions to each other Negotiating strategy to play game as seen in the following transcript: **P36: "…** Whenever you see a , go a bit left*"* **P37:** "*Whenever you see a bullet press left"* ***P36:*** *"hold left"* **P36:** "*Yeah.*" Non-conflict and onflict resolved were also observed	**P35:** *"What? Did we die?"* **P36:** "How did we die?" **P35:** "How did we die?"	There was evidence of tutoring behaviour during the first game play where one of the participants P36 showed the partner how to use the controller. But this was absent in the second game play which suggests that the participant who was being taught had learned. Furthermore, there was evidence the pairs negotiated a strategy during second game play which did not happen in the first game play.

CATEGORY 1						
Group	**Before first gameplay**	**First gameplay**	**5 seconds pause after 1st death**	**Second gameplay**	**5 seconds pause 2nd death**	**How strategy changed?**
21		One child gave instructions twice to the other. Both pairs focused their gazes more on the screen Talk time = 4.084 seconds	**P41:** "Oh no we weren't firing them" [glanced at P42] **P42:** "When I say move, move!" **P41:** "OK"	They had a conflict which was resolved. Both pairs focused their eye gazes more on the screen although there times they looked at their partners's and own controller and at their partner Same child gave instructions twice to the other Talk time = 14.184 seconds	**P42:** "That's right, that's right ok? *[Points to the right and looks at P41].* That's left, is that left? Right *[points left]*, left *[points right]"* **P41:** "Why are you doing that? *[staring at P42]*"	The pairs seemed to have realized that they strategy used in the first gameplay didn't work and before the start of the second game they negotiated a strategy for the second game
22	None	One child gave instructions twice to the other. P44 gaze was more on the screen while P43 intermitently glanced at P44's controller Talk time = 1.763 seconds	Both children looked at each other and smiled	Both pairs participated in giving instructions. They were more engaged as they focused their eye gazes more on the screen. Although one of the pairs (P43) glanced intermittently at P44's controller to see what P44 was doing. There was an instance of non-conflict situation. Talk time = 20.064 seconds	**P43:** *[makes a sound and drops arm]* **P44:** *[laughs]*"We only got 110"	The children were more engaged during game play with a shift from one child dominating the interaction in the first game play to both children more participatory in interacting with each other
24	None	One child gave instructions once to the other (boy). Mostly played silently. Focused more on the screen with few intermittent glances at partners controllers Talk time = 0.860 seconds	**P48:** *[drops arms]* **P47:** *[stares at P48]* **P48:** "When you want to move go to the right" [stares at P47].	Whle the boy in the group continued to give instructions, the girl attempted to give instruction twice to the boy They looked at the screen all through the period Talk time = 34.100 seconds	Both stares at the screen	Pairs were more enganed in the second game play than in the first
25	**P50:** "Alright, we just say, say fire if you want to fire. Say left if you want to go left and say right if you want to go right". **P49:** "OK".	They looked at the screen and had just an instance of Non-conflict situation Talk time = 2.681 seconds	**P50:** "Left" [shows P49 controller. **P49:** [stares at P50's controller and nods]	Both parties gave instructions to each other. They focused their gazes more on the screen although there were periods where they glanced at individual controllers and thier partners controllers. There were instances of non-conflcit situations Talk time = 34.000 seconds	Both make a sound and raise their arms	They seemed to have realized what made them to fail and an attempt was made to resolve the issue evidenced by the conversation which they had when the first game ended. In the second game play, they became more participatory by interacting more with each other.

CATEGORY 2						
Group	**Before first gameplay**	**First gameplay**	**5 seconds pause after 1st death**	**Second gameplay**	**5 seconds pause 2nd death**	**How strategy changed?**
2	**P3:** "I will tell you what to do, yeah? Let's do this!" **P4:** "Alright, let's try it" **P3:** "We will time it together" **P4:** "OK."	One pair gave instructions to the other. One instance of conflict that was resolved. They gazed at the screen mostly Talk time = 28.002 seconds	**P3:** *[stares at other group]* **P4:** "Oh, oh" **P3:** *[stares at the screen]* "We gonna do it again" **P4:** "So close"	One pair gave instructions to the other. One instance of conflict that was resolved. They gazed at the screen mostly Talk time = 9.363 seconds	**P3:** *[touches his head]* **P4:** *[glanced at own controller]* "Its jamming*" [shows P3 his controller] [Both glanced at each other before staring at the screen]*	Negotiated a strategy before first gameplay. But the strategies adopted in the first and second gameplay did not change. They might have considered that the strategies they adopted in the first game play worked for them and did not bother to change it but rather encouraged each other at the end of the game. P4 mentioned that the controller was unresponsive but the researcher looked at the map on the screen and confirmed that this was not the case. It was probably as a result of not pressing the keys at the same time.
6	None	Both stared at the screen One participant gave instructions Enquiry from partner was observed. Talk time = 22.860 seconds	**P12:** *[drops arm]*	Both pairs mostly stared at the screen but were distracted by the youth leader who nterrupted their interactions and diverted the attention of one participant to his phone. Same participant gave instructions participant gave instructions Talk time = 11.033seconds	none	The pairs were distracted by the youth leader who diverted their attention to his phone.
7	none	Both stared more at the screen. One participant gave instructions to the other Enquiry from partner was obseerved Talk time = 18.309 seconds	**P14:** *[smiles, raises arm up and makes a sound of excitement]*	Both stared more at the screen. Same participant continued to give instructions to the other Enquiry from partner was obseerved Talk time = 6.103 seconds	Both stares at each other and laughs	

CATEGORY 2						
Group	**Before first gameplay**	**First gameplay**	**5 seconds pause after 1st death**	**Second gameplay**	**5 seconds pause 2nd death**	**How strategy changed?**
3	None	Both pairs participated in giving instructions Non-conflict, Conflict resolution, deictic gestures were observed. Tutoring behaviour was also observed as seen in the transcript: **P5**: "Left this way, right this way"[gestures with arm] Both focussed their gazes more on the screen Talk time = 31.505 seconds	**P7:** "oh god!"	Both participated in giving instructions One child encouraged the partner at the beginning of game play connflict resolution was observed Both focused their gazes more on the screen Talk time = 15.204 seconds	*Both made a sound of excitement and jump up.* **P6:** Yes we hit it, yes! *[Both hi five]*	There was tutoring behaviour in the first game play displayed by P5 which did not occur in the second game play rather, there was evidence of encouraging behaviour by the same participant (P5) who tutored the other. This suggests that P5 may have concluded the partner had learned and switched from tutoring to encouragement (discontinued the tutoring early) which may have affected their game play
17	None	One participant gave instructions (P34) They mostly stared at the screen Talk time = 12.798seconds	*Both make sounds of excitement* **P33:** *[jumps up]* **P34:** *[raises hands]* **P34:** "I will say left right"	The same participant (P34) continues to give instructions to the other (P33) They mostly stared at the screen Talk time = 5.665 seconds	Both drop arms and smiles **P34:** "Come on then, you tell me"	They strategized at the end of the first game play which did not seem to have worked for them
19	None	Both participants gave instructions to each other Enquiry from researcher about game, Non-conflict , Deictic, Conflict resolved and tutoring behaviours were observed Both stared at the screen but one participant (P37) also looked several times at his own controller. Talk time = 42.077 seconds	*[Both children drop their arms]* **P37:** "Oh" [glanced at researcher] **P38:** "How did we die?"	Both participants continued to give instructions to each other. Non-conflict and conflict not resolved due to game over observed Mostly looked at the screen and occasionally looked around Talk time = 24.637 seconds	**P37:** *[Sighs] "Oh we died!"* **P38:** "Keep on shooting"	The participants were ocassionally distracted from the game at the second game play

CATEGORY 2						
Group	**Before first gameplay**	**First gameplay**	**5 seconds pause after 1st death**	**Second gameplay**	**5 seconds pause 2nd death**	**How strategy changed?**
4	**P7:** "What do we do now?" **P8:** "Keep on pressing it"	One pair was confused about which game character he is controlling and enquired severally from the parner as seen in the transcript: **P7:** "*Oh quickly they are coming*" **P8:** "*Can't move over*!" **P7:** "*Where am I?*" **P8:** [points at the screen] "*There*! move" **P7:** "*Where am I?*" **P8:** [makes a sound and kicks his left leg in the air]"*It's not moving*" **P7:** "*I don't know* where *I am*" **P8:** [laughs] [researcher intervenes and clarifies how to play game again]. Non-conflict, enquiry with response to enquiry and conflict resolution were observed Talk time = 23.409 Mostly stared at the screen Both players participated in giving instructions	**P7:** [makes an aw sound] **P8:** "what are you doing?" [laughs and hits P7 on the cheeks] **P7:** [laughs and hits P8 back] "Come on!"	Both participated in giving instructions to each other Non-conflict was observed Mostly stared at the screen Talk time = 18.277 seconds	**P8:** "What are you doing?" *[stares at P7]* **P7:** *[stares at P8].* "Oh, chill out!" *[points at the screen]*	P7 did not know what he was doing in the first game play and there is no evidence this changed in the second gameplay as he was asked the same question "What are you doing ?" by P8 after each gameplay.
20	None	Both participants mostly stared at the screen Both gave instructions to each other Non-conflict, giving suggestion and conflict resolution were observed Talk time = 34.168 seconds	**P40:** "Oh, 270?"	Both participants mostly stared at the screen Non-conflict and giving suggestion were observed Talk time = 18.677seconds	**P39:** "Oh we got 150" **P40:** *[makes a sound and raised his hand]*	

CATEGORY 2						
Group	**Before first gameplay**	**First gameplay**	**5 seconds pause after 1st death**	**Second gameplay**	**5 seconds pause 2nd death**	**How strategy changed?**
23	None	One participant gave instruction once to the partner Both participants looked at the screen most of the time Positive affects such as jumping and laughing were observed Conflict not resolved due to gameover was observed Talk time = 22.477 seconds	P45 glanced at P46	Conflict continued but was resolved with the help of the researcher. They did not seem to understand how to play together. Both participants gave instructions to each other Looked at the screen, at the researcher and at each other Talk time = 22.477 seconds	Both stares at each other and laughs	Unresolved conflict from phase one which was carried over to the second game play. They were also distracted

K. Cross Tabulation of Smileyometer and Again-Again results

How much fun was it to play the game on the gamepad? * Would you like to play the game again? Crosstabulation

Count

		Would you like to play the game again?			
		No	Maybe	Yes	Total
How much fun was it to play the game on the gamepad?	Awful	3	0	0	3
	Not very good	2	1	0	3
	Good	1	11	3	15
	Really good	1	2	10	13
	Brilliant	1	2	13	16
Total		8	16	26	50

L. Regression Analysis on Performance Metrics.

Correlations

		Number of deaths	Scores	Level of Agreement	Level of Disagreement
Pearson Correlation	Number of deaths	1.000	-.503	-.484	.029
	Scores	-.503	1.000	.474	.086
	Level of Agreement	-.484	.474	1.000	-.192
	Level of Disagreement	.029	.086	-.192	1.000
Sig. (1-tailed)	Number of deaths	.	.005	.007	.445
	Scores	.005	.	.008	.342
	Level of Agreement	.007	.008	.	.178
	Level of Disagreement	.445	.342	.178	.
N	Number of deaths	25	25	25	25
	Scores	25	25	25	25
	Level of Agreement	25	25	25	25
	Level of Disagreement	25	25	25	25

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Level of Disagreement, Scores, Level of Agreement[b]	.	Enter

a. Dependent Variable: Number of deaths

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.575[a]	.331	.235	2.695

a. Predictors: (Constant), Level of Disagreement, Scores, Level of Agreement

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	75.471	3	25.157	3.464	.035[b]
	Residual	152.529	21	7.263		
	Total	228.000	24			

a. Dependent Variable: Number of deaths

b. Predictors: (Constant), Level of Disagreement, Scores, Level of Agreement

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	29.153	5.165		5.644	.000
	Scores	-.003	.002	-.352	-1.700	.104
	Level of Agreement	-.281	.186	-.318	-1.513	.145
	Level of Disagreement	-.001	.069	-.002	-.009	.993

a. Dependent Variable: Number of deaths

M. Paired t-Test to Compare the means of the Length of First and Second gameplay

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Length of First gameplay	27.96	25	17.996	3.599
	Length of Second gameplay	31.88	25	16.405	3.281

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Length of First gameplay & Length of Second gameplay	25	-.191	.361

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper			
Pair 1	Length of First gameplay - Length of Second gameplay	-3.920	26.564	5.313	-14.885	7.045	-.738	24	.468

N. Paired t-Test to Compare the means of the Length of First and Second gameplay in Groups with Improvement and no Improvement in Strategy.

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Length of First gameplay for groups in category 1	15.15	13	12.435	3.449
	Length of Second gameplay for groups in category 1	41.23	13	12.604	3.496
Pair 2	Length of First gameplayfor groups in category 2	41.83	12	11.582	3.344
	Length of Second gameplay for groups in category 2	20.92	12	12.901	3.724

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Length of First gameplay for groups in category 1 & Length of Second gameplay for groups in category 1	13	.601	.030
Pair 2	Length of First gameplayfor groups in category 2 & Length of Second gameplay for groups in category 2	12	.578	.049

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Length of First gameplay for groups in category 1 - Length of Second gameplay for groups in category 1	-26.077	11.191	3.104	-32.840	-19.314	-8.401	12	.000
Pair 2	Length of First gameplayfor groups in category 2 - Length of Second gameplay for groups in category 2	20.917	11.309	3.265	13.731	28.102	6.407	11	.000

O. Correlation coefficients and the p values for the correlation between each three interactional states with time.

Groups	Agreement and time	No interaction and time	Disagreement and time
G1	r = 0.33, P = 0.401	r = -0.413, P = 0.001	r = 0.356, P = 0.003
G2	r = -0.069, P = 0.301	r = 0.234, P = 0.036	r = -0.187, P = 0.076
G3	r = -0.173, P = 0.093	r = 0.160, P = 0.111	r =0.015, P = 0.455
G4	r = 0171, P = 0.096	r = 0.391, P = 0.001	r = -0.551, P = 0.001
G5	r = -0.055, P = 0.338	r = 0.178, P = 0.087	r = -0.136, P = 0.150
G6	r = -0.230, P = 0.038	r = 0.037, P = 0.391	r =0.111, P = 0.199
G7	r = -0.132, P = 0.158	r = 0.144, P = 0.136	r = -0.006, P = 0.482
G8	r = 0.191, P = 0.072	r = -0.190, P = 0.073	r = 0.029, P = 0.413
G9	r = 0.054, P = 0.342	r = -0.170, P = 0.097	r = 0.148, P = 0.130
G10	r = 0.132, P = 0.157	r = -0.362, P = 0.002	r = 0.312, P = 0.008
G11	r = -0.098, P = 0.228	r = 0.187, P = 0.077	r = -0.057, P = 0.334
G12	r = -0.605, P = 0.001	r = -0.486, P = 0.001	r = -0.089, P = 0.249
G13	r = 0.227, P = 0.041	r = 0.140, P = 0.143	r = -0.327, P = 0.005
G14	r =-0.343, P = 0.004	r = 0.206, P = 0.057	r = 0.119, P = 0.183
G15	r = 0.081, P = 0.269	r = -0.035, P = 0.395	r = -0.055, P = 0.339
G16	r = 0.072, P = 0.291	r = -0.278, P = 0.016	r = 0.211, P = 0.053
G17	r = 0.010, P = 0.469	r = -0.100, P = 0.223	r = 0.094, P = 0.238
G18	r = 0.010, P = 0.470	r = 0.144, P = 0.136	r = -0.142, P = 0.139
G19	r = -0.032, P = 0.404	r = 0.010, P = 0.470	r = 0.007, P = 0.479
G20	r = 0.128, P = 0.165	r = -0.171, P = 0.095	r = 0.070, P = 0.298
G21	r = 0.071, P = 0.296	r = 0.023, P = 0.429	r = -0.082, P = 0.267
G22	r = -0.005, P = 0.485	r = 0.064, P = 0.313	r = -0.061, P = 0.322
G23	r = 0.312, P = 0.008	r = -0.456, P = 0.001	r = 0.031, P = 0.407
G24	r = -0.084, P = 0.262	r = -0.151, P = 0.124	r = 0.109, P = 0.204
G25	r =-0.112, P = 0.197	r = 0.357, P = 0.003	r =-0.297, P = 0.011

11.6 Appendix6: Chapter 8 Documents

A. Thematic Analysis of Interview Responses

Pn represent each child's responses
R represents the researcher's questions

Group	Transcription	Codes
1	**R:** This is a chart of your key presses during gameplay. The chart shows that you were not mostly in agreement whilst pressing the right and left buttons. So, what was it that happened? What happened while you were playing the game that made you to be mostly in agreement whilst pressing the fire button but for the left button you were mostly not in agreement and the right button presses as well. What really happened? **P1:** [1]we were just pressing the button and [2]we just looked at the corner to and saw what each other was pressing. **R:** so you used the stuff at the corner to know what key to press. Was that what you used all throughout to play the game? **P1:** Yeah **R:** Ok, thank you.	[1]Random interaction [2]Use of interaction Map
2 and 3	**R:** So these are charts of how you guys fared during gameplay. This is yours and that's for two of you. You were in agreement for most of the time but there were times when you were not in agreement. Same as yours, yeah? So how did you guys manage to be in agreement? What happened? **P3:** [3]I told him I was the leader and I told him when to move and shoot. **R:** Anything else? **P4:** [1]We were just pressing every button at a time (laughs) **P5:** [4]We took turns and to like tell each other what to do. **R:** was there anything else? **P3:** [1]we weren't scared of pressing the B button, pressing it all the time (laughs). **P5:** [1]Cos I'm no good so I was going that way and that way **R:** Ok thank you very much.	[3]Giving Instructions [1]Random interaction [4]Verbal communication [1]Random interaction [1]Random interaction
4	**R:** This is a chart of how you fared during gameplay. It actually shows what keys you pressed, at what time and how long you were in agreement for. It shows that you were mainly in agreement whilst pressing the fire button but not the case for the left and right buttons. So, what happened? **P7:** [1]we were just pressing the buttons [2]and then we looked up and saw what each other was pressing **R:** Ok thank you very much for participating	[1]Random interaction [2]Use of interaction map
5	**R:** So, this is a chart of how you fared during gameplay. You can see this is right, left and fire. You could tell you guys pressed the fire button mostly and were in agreement for most of the time. So what happened? **C9:** [4]we were communicating a lot. We were just saying which way we wanted to go [5]and what we thought would be the best direction. **R:** Ok, was there anything else? **C9:** [6]it was fun how we got err both have to do the same move to make it work. Some people are used to single player controller but when you do it collaborative like we did, it kind of bring extra factor to the game. **R:** Thank you very much.	[4]Verbal Communication [5]Gameplay judgement [6]Collaboration (fun to collaborate)

Group	Transcription	Codes
6	**R:** So this is a chart of how you fared during gameplay. Looking at it, you can tell that you were in agreement for most of the time so how did you manage to reach agreement? **P11:** [4]Just like talking to each other **R:** was there anything else? **P11:** no **R:** Ok thank you very much	[4]Verbal communication
7 and 8	**R:** this is a chart of how you fared during gameplay. It shows the keys you pressed and how much you were in agreement for. Same as you guys. You can see that you were in agreement for most of the time, How did you do that? **P13:** [7]We both just started using the same thing at the same time without realizing how to interact with it. But then we got into it… **P15:** We learn from it **R:** was it the same for you guys **R:** was there anything else? **P15:** No.	[7]Harmonious game play
9	**R:** Ok, this is a chart of how you fared during gameplay. You can see here that these are your key presses – right, shoot and left and when you were doing the same thing at the same time. You can see that you were mostly in agreement whilst pressing the shoot button. So what made you stay in agreement? **P17:** [8]Just looking at what the other person was doing. And then doing the same just to shoot properly **R:** Do you mean looking at someone's controller? **P17:** [8]Yeah, **P18:** [8]Yeah, I know. just like looking at how they try to do it the same **P17:** [8]yeah, to do it at the same time pressing it at the same time. **R:** was there anything else? **P18:** [9]You know the little bombs, the red ones we are trying to shoot (inaudible) looking to choose what side to go to **R:** Ok, thank you very much	[8]Copying from one another [9]Strategized using bomb position
11	**R:** This actually a chart of how you fared during gameplay. It shows the keys you pressed and how much you were in agreement for. You can see that you were in agreement for most of the time, so how did you manage to do that? **P21:** [4]We were just talking to each other **R:** was there anything else? **P21:** No **R:** Thanks	[4] Verbal communication
12	**R:** This is a chart of how you guys fared during gameplay. It shows that you guys mainly pressed the shoot button and were in agreement for most of the time. So how did you do that? **P23:** [3]By telling him to do it at the same time. **R:** so you guys communicated? **P23 and P24:** [4]Yeah, we communicated **R:** So was there anything else? **P23:** [9]you just see and know where the bombs were going and you know not to go there. **R:** Ok, thank you very much	[3]Giving instruction [4] Verbal communication [9]Strategized using bomb position

Group	Transcription	Codes
13	**R**: This chart shows what you were doing during game play. This is the right key press, fire and left key presses as well as when you were in agreement. In this chart you can see that you were in agreement for most of the time. So how did you do that? How did you manage to be in agreement? **P25**: [4]we just communicated. Like tell each other what to do **R:** Ok, was there anything else? **P26:** [5]it's like we just know what way we want to go. [4]We were just communicating **R:** Ok. So did you enjoy the game? **P26:** It was a good game, we liked it. **R:** So doing it together, what do you think about that? **P26:** I like it together cos it's more of a challenge. **R:** It was more of a challenge? **P25:** Yeah, it's more challenging cos you have to communicate and like say where you are actually going. It's more fun **R:** Ok, thank you very much	[4]Verbal communication [5]Gameplay judgement
14	**R:** So, this chart shows what you were doing during gameplay. You can see that you were mostly in agreement, how did you manage to do that? **P27:** [4]We communicated. Talking. **R:** Was there anything else? **P28:** [4]we got a system working where we were pressing it at the same time. So, I say press it now, press it now and we both did it at the same time. **R:** Ok, thank you.	[4] Verbal communication [4]Verbal communication
15	**R:** So, this chart shows what you were doing during gameplay. You can see that you were mostly in agreement, how did you manage to do that? **P29:** [4]we said left and right and we did it at the same time. **P30:** [4]We talked. Like say 'go left' and we both press it. Talking about where we wanted to go. **R:** was there anything else? **P30**: [4]Just a lot of communication **P29:**[10] Err, we did it as well without talking- [5]we both knew what to do. **R:** Ok, Thank you very much	[4] Verbal communication [10]Non verbal communication [5]Gameplay judgement
16	**R:** This is a chart of how you fared during gameplay. It shows what keys you pressed, how long the key were pressed for and when you were in agreement and for how long. So you can tell from this chart that you were in agreement for most of the time, how did it happen? **P31:** [4]Erm, cos we were sort of saying 'go left' 'go right'. Whenever we said that in the game then we were ok. [3]Every now and then one of us will shout left and we both pressed left, right and shoot. But we don't do that every round. **R:** So what made you not to be in agreement, like the times when you were not in agreement? **P31:** [5]Erm, well cos sometimes I though the bullet was coming down and it looked like it was gonna hit me but Sam didn't think it was, so I just pressed it. **R:** Was there anything else? **P31:** Erm, not really	[4] Verbal communication [3]Giving instruction [5]Gameplay judgement

Group	Transcription	Codes
17	**R:** This is a chart of how you fared during game play. So you can see you were mostly in agreement but there were times when you were not in agreement, so what happened? **P33:** [11]We were talking to each other like say go right! Cos if like shout at them, they won't do it! **P34:** laughs **P33:** and if we did wrong, we were not shouting at them, we were just saying try to do it next time and like helping each other. **P34:** [2]and also the thing in the corner helped us as well. **P33:** [2]yeah, it showed us which way to go. **P34:** [4]and we said let's and get this one and we got it. And that's how we got all the penguins! **R:** ok, so what about times when you were not in agreement, what happened? **P34:** [4]let's say I was going that way and he is going that way **P33:** and then we say let's go right and then… not doing right **P34:** yeah **P34:** and we are like changing over. **R:** Ok, was there anything else **P34:** No **R:** Thank you so much.	[11] Helping each other [2]Use of interaction map [4] Verbal communication [4]Verbal Communication
18	**R:** This is a chart of how you fared during game play. So you can see that there were times when you in agreement and times when you were not in agreement, so what happened? **P35:** [9]we kind of kept pressing B and occasionally when the rockets came down we pressed left. **P36:** [1]we thought of this idea where say jack has his controller jack could you hold your controller quickly). Now If B is for shoot, we could pick to press shoot. If I am pressing B all the time when jack wants to press B cos I am pressing B randomly, and jack presses it just once it will come up once. And the same with me, he will have to keep pressing moving so I can move anytime I like. **R:** Ok, Thanks for your time.	[9]Strategy using bomb position [1]Random interaction
19	**R:** So, this is a chart of how you fared during gameplay. You can tell that you were not always in agreement for the right and left button but were in agreement mostly while pressing the fire button. So what happened? How did you guys manage to be in agreement? **P37:** [4]Just say what was happening and then just try and talking to each other[5]. **R:** Was there anything else? **P37:** No **R:** Ok, thanks	[4] Verbal communication
20	**R:** This is a chart of how you fared during game play. It shows the keys you pressed what time you pressed them and when you were in agreement. So you can see that there were times when you in agreement and times when you were not in agreement, so what happened? **P39**: [4]saying the buttons that you press **R:** was there anything else? **P40:** Sometimes we were pressing left and then we were pressing right and we couldn't go each way **R:** sorry I didn't get that **P39:** Basically, she was pressing left and I was pressing right and we could go each way **P40:** so we ended up staying the same	[4] Verbal communication

Group	Transcription	Codes
21	**R:** So this chart shows what you were doing during game play. This is the right key press, fire and left key presses as well as when you were in agreement. In this chart you can see that you were in agreement for most of the time especially for the shoot button. So how did you do that? How did you manage to be in agreement? **P41:** [4]we told each other what to do. We told each other when to play at the same time **P42:** [6]we worked together **R:** What about times when you were not in agreement, what happened? **P41:** [12]somebody didn't press it or [13]we did not press it at the same time. **P42:** it was an accident and we got really excited	[4] Verbal communication [6]Collaboration [12]No interaction [13] Accidental disagreement
22	**R:** So this chart shows what you were doing during game play. This is the right key press, fire and left key presses as well as when you were in agreement. In this chart you can see that you were in agreement for most of the time especially for the shoot button. So how did you do that? How did you manage to be in agreement? **P43:** [2]we used the top right corner thingy to know what we were doing. So if we went left we look at the top right corner to go left. **P44:** [3]One person is leader and [2]then Kimberly would look at the top if she saw where the yellow thing she would go left or right **R:** Thank you so much	[2]Use of interaction map [3]Giving instruction [2]Use of interaction map
24	**R:** So, this is a chart of how you guys fared during gameplay, the keys you were pressing, what time you pressed the keys, when you were in agreement and at what time. The chart shows that you did really well. You were in agreement for most of the time. So how did you manage to do that? **P48:** [4]We were just talking to each other. So we say go left, go right **R:** Was there anything else? **P48:** No **R:** Ok, thanks for participating	[4] Verbal communication
25	**R:** This chart shows what you were doing during game play. This is the right key press, fire and left key presses as well as when you were in agreement. In this chart you can see that you were in agreement for most of the time. So how did you do that? How did you manage to be in agreement? **P49:** [14]what we did, err at the beginning we said when we want to shoot say shoot, when we want to move right say right, and when we want to move left say left before we started to play the game. **R:** so what about when you were not in agreement, what happened? **P50:** [3]well, I said move, move and he said where, where, where and I was like right, right and I am like ok (gestures). **P49:** [13]Sometimes in the game we were like, err just standing still **P50:** [3]like shoot, shoot, no go left, go left, no right, right **P49:** [13]sometimes we were just staying at a place and shooting **R:** Ok, thank you so much	[14]Strategized before game play [3]Giving instruction [13]Gameplay strategy [3]Giving instruction [13]Gameplay strategy

First Level Code	Second Level Code
Strategized using bomb position **(G9, G12, G18)**	Strategy
Strategized using interaction map **(G1, G4, G17, G22)**	
Strategized before game play **(G25)**	
Gameplay strategy **(G25)**	
Giving instruction **(G2, G12, G16, G22, G25)**	
Random interaction **(G1, G2, G3, G4, G18)**	
Copying from one another **(G9)**	
Verbal communication **(G3, G5, G6, G11, G12, G13, G14, G15, G16, G17, G19, G20, G21, G24)**	
Non-verbal communication **(G15)**	
Gameplay judgement **(G5, G13, G15, G16)**	
Helping each other **(G17)**	
Accidental Button press **(G21)**	Accidental interactions
No interaction **(G21)**	
Harmonious gameplay **(G7)**	
Collaboration **(G5, G21)**	

For illustration purpose, G9 means group 9