A Hero's Journey:

Using co-design to develop a fine motor skills video game with and for children with Developmental Coordination Disorder (DCD).

George Greaves
MSc by Research

University of York
Theatre, Film, Television and Interactive Media
June 2022

Abstract

Developmental Coordination Disorder (DCD), is a neurological disorder that among other things affects fine and gross motor coordination in around 5-6% of school-aged children worldwide. Despite research indicating the effectiveness of digital technology in supporting children with DCD, digital tools such as video games have not yet broken into mainstream DCD support. This project developed a video game-based support for children with DCD through a co-design process. This co-design process had two facets, firstly I worked with adult expert participants to develop ideas for how video games could be used as support for children with DCD, conducting a series of interviews with experts in supporting children with DCD, secondly I worked with 5 children with DCD to co-design key elements of a video game, including character, story and user interfaces, as a way to ensure that the developed game developed is not only effective but something that children with DCD would want to use and enjoy. Using this process, a game was developed to challenge and improve fine motor skills through a series of different interactions. The game was evaluated by 8 teachers, who reported that the game was effective, valuable and something they could use in schools.

Declaration

I declare that this thesis is a presentation of original work and I am the sole author. This work has not previously been presented for an award at this, or any other, University. All sources are acknowledged as references.

Acknowledgements

I'd like to thank a number of people for their support during this research project.

Firstly I would like to thank all of the participants in the research, from the experts, to the co-designers, to the testers. Without their input, ideas and designs, this project would not have been possible. I have thoroughly enjoyed working with all of them.

I'd also like to thank my supervisor Dr Debbie Maxwell, who first encouraged me to take on this project and then supported me throughout. This was not an easy project and I could not have asked for a better supervisor. I'd also like to thank all of the other Interactive Media, and wider TFTI staff, who supported me throughout my undergraduate and postgraduate degrees.

Finally I would like to thank my parents, siblings and Molly. Their patience, reassurance and support helped steady me and allowed me to produce my best work.

Table of Contents

Abstract **1**

Declaration **2**

Acknowledgements **3**

Table of Contents **4**

List of Figures **7**

Chapter 1- Introduction **8**
1.2 Previous Work 9

Chapter 2- Literature Review **10**
2.1 Developmental Coordination Disorder (DCD) 10
2.2 DCD Interventions and Support 12
2.2.1 Traditional DCD Interventions and Support 12
2.2.2 Technology in DCD Support 14
2.3 Storytelling in Education 16
2.3.1 Digital and Interactive Storytelling 17
2.4 Conclusion 18

Chapter 3 - Expert Interviews **19**
3,1 Approach 19
3.2 Ethics 20
3.3 Method 20
3.4 Analysis 21
3.5 Conclusions 23

Chapter 4 Co-design Workshops **26**
4.2.1 Design Workshop 1: Individual Introductory Session 27
Activity 1: A day of Play! 27
Activity 2: Game Features 29
Activity 3: My Dream Game 31
Summary of Design Workshop 1 32
4.2.2 Design Packs 34
4.2.3 Design Workshop 2: Character Designing 34
Character Designing Activity 35
Teacher, Parent, Student 36
Post-workshop 36
4.2.4 Design Workshop 3: Story Creation 39
4.2.5 Design Workshop 4: User Interface Design 41

Chapter 5 Second Expert Interviews and Final Game **45**
5,1 Second Interviews 45

5.1.2 Feedback 46
5.1.3 Conclusions 46
5.2 Final Game 47
5.2.1 Interaction 1- Following a Path 47
5.2.2 Interaction 2- Finger Tapping Game 48
5.2.3 Interaction 3- Dual Action Game 49
5.2.4 Interaction 4- Shape Tracing 49
5.2.5 Other Features 50
5.2.5.1 Character Customisation 50
5.2.5.2 Backgrounds 51
5.2.5.3 Rewards 51
5.2.5.4 Audio 51

Chapter 6- Playtesting With Teachers 52
6.1 Introduction and Methods 52
6.2 Results 53
6.2.1 Observations 53
6.2.2 Questionnaire 54
6.2.3 Discussion Questions 55
6.3 Conclusions 56

Chapter 7- Reflections 56
7.1 Goals 56
7.2 Limitations of Work 58
7.3 Future Work 59

Appendix 59

References 107

List of Figures

Page

Figure 1: Diagram of Co-design Process **10**

Figure 2: Screenshot of game mechanic **25**

Figure 3: Screenshot of game mechanic **26**

Figure 4: Participant 1's Mural of Dream Game Activity from Workshop **33**

Figure 5-8: Images of Design Packs **36**

Figure 9: Blank Mural of Character Design Activity from Workshop 2 **37**

Figure 10: Group 1's Character Designs from Workshop 2 **38**

Figure 11-17: Group 1 and 2's Character Designs from Workshop 2 **39-40**

Figure 18: Section of Participant 1's Storyboard from Workshop 3 **42**

Figure 19: Wireframe shown to participants in Workshop 4 **45**

Figure 20-23: Early game show to experts in follow up interviews **48**

Figure 24: Screenshot of game mechanic **50**

Figure 25: Screenshot of game mechanic **51**

Figure 26-29: First interaction of the final game **52**

Figure 29-32: Second Interaction of the final game **53**

Figure 33-34: Third Interaction of the final game **54**

Figure 34-37: Fourth interaction of the final game **54**

Figure 38: Character Customising Menu from final game **55**

Figure 39-41: Reward System from final game **56**

Figure 42: Screenshot of an arrow which participants struggle with. **59**

Chapter 1- Introduction

Developmental Coordination Disorder (DCD), also known as Dyspraxia, is a neurological disorder that has a wide range of impacts. The best known and most prevalent impacts are: difficulties with fine motor skills, the ability to make small precise movements (U.S. National Library of Medicine, 2021); and gross motor skills, the ability to make large general movements and sensory processing (U.S. National Library of Medicine, 2021). While these may be the most prevalent and best known impacts of DCD they are by no means the only ones, see section 2.1.

Technology such as video games have been explored as a potential means of supporting people with DCD and have shown some promising results in their effectiveness. While there has been research into the possible application of video games to support poor gross motor skills and balance, as explored by Hickman et al. (2017), Smits-Engelsman et al. (2018) and Mentiplay et al. (2019). there has been no research into the possible uses of video games in supporting other significant issues such as poor fine motor skills As section 2.2 explores, similar disorders such as Dyslexia, a specific learning difficulty which causes problems with reading, writing and spelling, has a wide range of video game support, which can be used in both home and school. However, and despite this, no such alternatives appear to exist to support children with DCD, see section 2.2.

The research question this project seeks to explore is *how can co-designed video games be used to help support children with Developmental Coordination Disorder (DCD)?* This was done by initially researching the literature around DCD and b educational video games and then working with those who have the most direct experience of supporting DCD such as class teachers, special needs teachers, occupational therapists and people with DCD, to design and develop a game which could be used a means of support for children with DCD. I worked with 5 children aged 10-12 as co-designers, allowing them to be directly involved in key design decision making, i.e. co-design, or participatory design (Szebeko and Tan, 2010).

Chapter 2's literature review explores DCD as a condition, its impacts, current research, and methods intervention and support. It also looks at the current state of e-learning and the use of video games in the support of children with DCD. Finally I analyse current literature on the use of storytelling and digital storytelling in mainstream and special education and exploring its potential to improve current means of support for children with DCD.

Chapter 3 explores and explains the series initial interviews which were conducted with experts in supporting children with DCD, explaining and justifying the methods, as well as exploring results and conclusions gathered from these interviews.

The main body of this thesis, Chapter 4, explores and describes the design and research workshops with children with DCD. In these workshops I worked with children with DCD to design a video game which could be used to support them. This process was divided

up into four different workshops, each exploring different ideas and designing possible elements for the game. A diagram which explains the design process can be seen below, as *figure 1*.

Following this, the thesis describes the second round of interviews with experts and explores in detail the game that was developed and designed by participants in the previous stage. Chapter 5 explains the key elements of the game, and justifies their inclusion as a means to help support children with DCD.

Chapter 6 then describes the testing process in which I once again worked with teachers to test the usability of the game by having participants play the game and give feedback. The testing process also explored whether the games developed in this project could be valuable in schools and/or at home. In the final chapter, chapter 7 I reflect on the process, successes and limitations, and areas for future research and development.

This thesis has a supporting video which shows a playthrough of the game designed and developed in this project which can be viewed here: *https://youtu.be/6PDgdmpCHyQ*

1.2 Previous Work

Prior to taking part in this project, I worked on an undergraduate project which sought to develop a video game handwriting tool and fine motor skills trainer for children with DCD. As part of that project, I interviewed teachers and special needs teachers to develop ideas for these handwriting tools. Elements of the final game for this MSc project builds on work from the undergraduate project, although none of the same development code or designs were used. The undergraduate work also supported this project, as I was able to resume contact with some of the original teachers from the undergraduate project in the initial interviews and evaluation. In addition, these contacts were invaluable in recruiting participants for the co-design process.

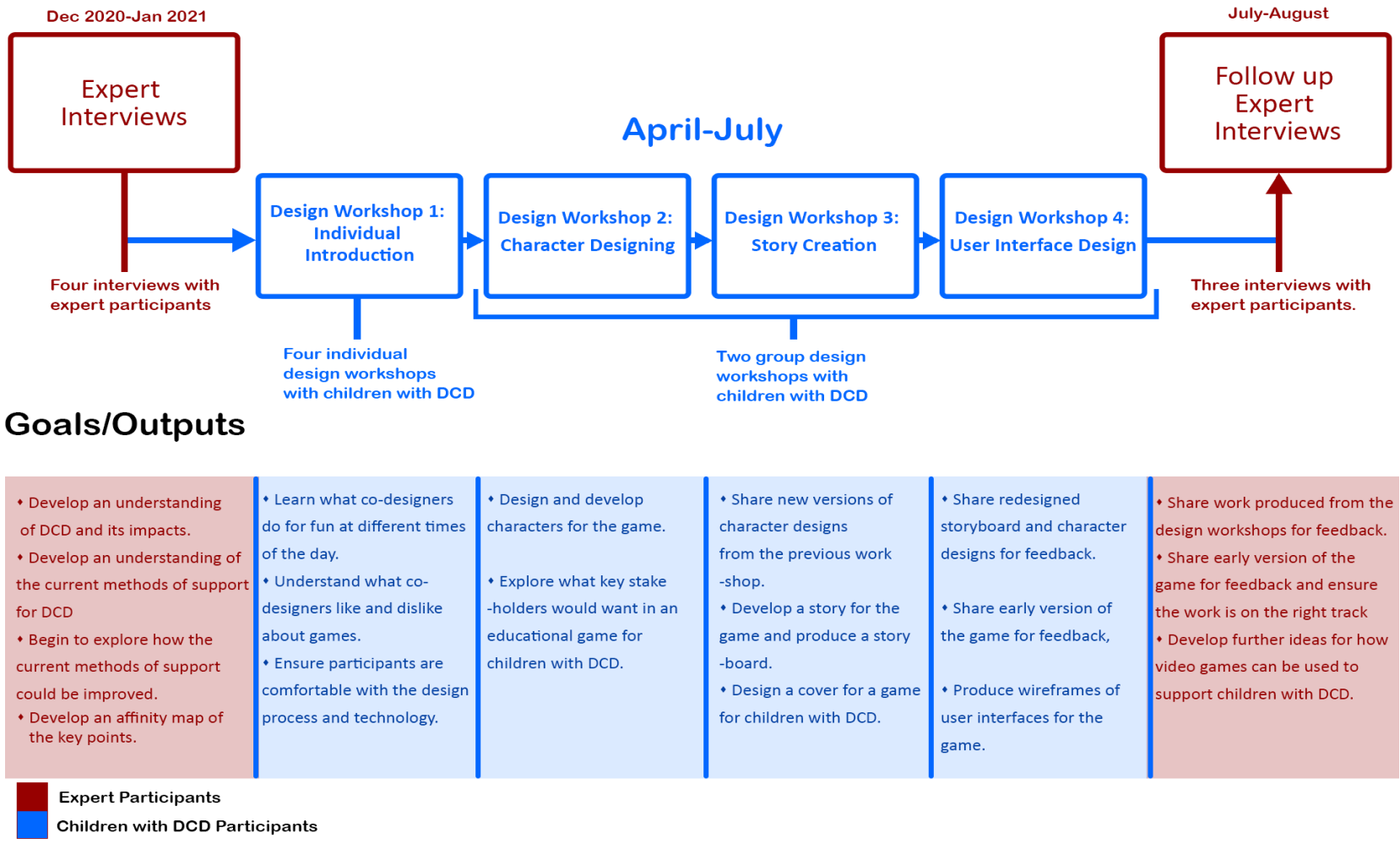


Figure 1: Diagram displaying the design process.

Chapter 2- Literature Review

This literature aims to explore and understand DCD by looking at its significant impacts, and the current methods of support used to help with these impacts. Furthermore it attempts to explore the potential for technology to be used in supporting DCD, by looking at how it has been used this far, as well as how technology has been used to support other similar disorders such as dyslexia. And finally it explores how storytelling has and can be used to support children with DCD.

2.1 Developmental Coordination Disorder (DCD)

The reports of the prevalence of DCD does vary from source to source, some estimates have the figure as high as 10% (Gibbs, Appleton and Appleton, 2007; Walker et al. 2018; Faught et al. 2005), however, most sources indicate it is more likely to be around 5-6% of school-aged children world wide (Caçola and Lage, 2019; Karras et al. 2019; Smits-Engelsman et al. 2018; Tal Saban and Kirby, 2019; Zwicker et al. 2012). Despite the popular belief that DCD only affects children and that children with the disorder will simply grow out of it, DCD continues to affect a vast number of those well into their adult life, with some estimating the figure to be as high as 70% people diagnosed with DCD as a child continuing to have difficulty into adulthood (Biotteau et al. 2019). Nevertheless it is worthwhile focussing on childhood DCD, as it is believed that DCD should be diagnosed, addressed and treated as early as possible and to reduce its impacts in later life. Earlier treatments are more effective and may allow the children to overcome some of their difficulties or adapt effective strategies to make their lives manageable (Gibbs et al. 2007).

Even though research into DCD has existed for over 100 years, being first described in 1900 as "congenital maladroitness", as cited by Stafford (2000), there are many different definitions and understandings of DCD. One way that DCD is often understood is not as a specific medical condition, but rather situations in which motor skills are not at the level they should be and are beginning to impact the lives of the person with the disorder. Caçola and Lage (2019) and Gibbs et al. (2007) explored different definitions of DCD claiming it is often simply used as a “catch all term to describe symptoms of poor coordination, clumsiness or awkwardness” (Gibbs et al. 2007). However they also suggest some are critical of this definition believing that it does not go far enough to cover DCD, and believe that DCD may have a specific origin (ibid). One such origin that Gibbs et al. offer comes from a psychological definition of DCD which suggests that the motor difficulties that people with DCD have are due to difficulties with sensory processing and perceptual problems (ibid).

Despite this lack of consensus about the underlying medical origins of DCD there is universal agreement about much of the difficulties that DCD causes. It is generally understood that DCD is something that affects everyday life, leading to general “clumsiness” causing “difficulty using everyday objects”(Walker et al. 2018). These difficulties include

“dressing”, “walking” and “poor ball skills” (Gibbs et al. 2007). Furthermore, DCD can also have a serious impact on education, due to the structure and nature of classroom learning. It is estimated that even with the availability of modern digital technology “42% of time during the school day is spent on paper-and-pencil task” and children with DCD often have difficulty “mastering these activities”, which in turn leads to children with DCD appearing more difficult and “the false notion that children with DCD are not compliant as other children” (Caçola and Lage, 2019).

On top of the issues that children struggle with in classroom settings, it is also believed that DCD can cause problems with the social, emotional, and mental health of those coping with the disorder. DCD is often associated with a higher risk of anxiety and depression (Tal Saban and Kirby, 2019, Caçola and Lage, 2019) and DCD has also been associated with “mental health problems in later life” (Caçola and Lage, 2019). Similarly, it has been suggested that people diagnosed with DCD may struggle to interact with their peers, and “are more likely to experience several interpersonal difficulties” (Tal Saban and Kirby, 2019). These social difficulties and mental health problems are often a result of a reduced level of engagement in social and physical activities that their peers will engage in more readily, and more successfully. In one study, the parents of 10 children with DCD, aged 7-12, were interviewed in depth about how the disorder affects their children’s participation in activities. The parents described difficulties such as “playing tag games”, “climbing ropes” and riding bikes (Mandich et al, 2003) and stated that their children’s inability and often failure to complete these activities as well their peers would have significant emotional impacts on their children. The parents state that often their children will “feel a sense of failure” and that their failure will make them “feel stupid”, additionally some parents even stated that their children were “left out, teased, or bullied” (ibid).

Finally, this study also suggested that the failure and alienation children with DCD often feel when participating in sport or games with their peers often leads to them wanting to no longer try or participate at all (Mandich et al. 2003; Karras et al. 2019). Research suggests that this not only impacts their mental health and socio-emotional development (Tal Saban and Kirby, 2019) but also their physical health. One study suggested that DCD is a “fundamental cause of inactivity”, which in turn increases the “the risk of obesity and poor fitness” (Cairney and Veldhuizen, 2013). Faught et al. (2005) went further than this and suggested that there is evidence of DCD and the inactivity related to it can even lead to increased risk of cardiovascular disease.

On top of the better-known difficulties associated with DCD, such as poor fine and gross motor skills, there is also a range of lesser known difficulties. DCD is known to affect the speech and language skills of people with the disorder (Gibbs, Appleton and Appleton, 2007, Tal Saban and Kirby, 2019). It has even been found that children with DCD perform similarly to children with specific language impairments (SLI) in tasks related to language and speech performance (Archibald and Alloway, 2008). As well as language, research has also suggested that DCD can affect a whole range of development traits. It has been

suggested that children with DCD are at higher risk of struggling with “attention, social skills, reading, and spelling” (Lingam et al. 2010).

Finally one key aspect of DCD that appears in much of the literature, is that while the child may have significant delays in motor skills, language and other developmental areas, their intelligence should be within the expected range for their age. For a diagnosis of DCD, the motor difficulties cannot be “better explained by intellectual delay” (Caçola and Lage, 2019). Despite often poorer performance in school, children with DCD often have average to high intelligence levels (Zwicker et al. 2012).

2.2 DCD Interventions and Support

2.2.1 Traditional DCD Interventions and Support

The majority of interventions for DCD can fall into two main categories 1) process-based interventions and, 2) task-based interventions. Process-based interventions attempt to address the underlying problem behind the difficulty in a specific task (Gibbs et al. 2007; Smits-Engelsman et al. 2018) and use training to improve bodily functions such as sensory integration (Morin, 2019), muscle strength and balance as means of improving motor performance of children with DCD in tasks they may find difficult (Smits-Engelsman et al. 2013). For example, in process-based interventions, if a child was having difficulty catching a ball, then the treatments would attempt to address the underlying issues that are causing this difficulty. This could include the sensory integration required to feel the ball in their hand, or the hand strength to grasp the ball. An occupational therapist would then develop a programme to improve the child's sensory processing and hand strength, which in turn would hopefully improve the child's ability to catch a ball.

Task-based interventions focus on the improvement of specific tasks through repeated practice of the task, (Gibbs et al. 2007; Smits-Engelsman et al. 2018; Miyahara et al. 2017). Task-based approaches such as Neuromotor Task Training attempt to analyse a task a child is having difficulty with, identify why they are having difficulty with that task and then practice the task at increasing levels of difficulty until they no longer have difficulty with the task (Neuromotor Task Training, 2018; Smits-Engelsman et al. 2018). In task-based interventions if a child was having difficulty catching a ball, then the treatments would have the child practice catching a ball at increasing levels of difficulty, such as increasing the distance from the thrower or speed of the ball, with a particular focus on what element of catching the ball they are struggling with.

Although some argue there are benefits to both approaches, task-based interventions have been proven several times to be a very effective and useful means of helping children with DCD (Galea, 2020,Schoemaker et al. 2003,Schoemaker and Smits-Engelsman, 2015). However, there has been very little evidence to prove effectiveness of process-based interventions (Schoemaker et al. 2003; Schoemaker and Smits-Engelsman, 2015 ; Offor et al

2016). Furthermore, when the two are compared directly, task-based interventions are significantly more effective than process-based interventions. Smith-Engelsman showed that task-based interventions have a strong impact on improving the motor skills of children with DCD, whereas process-based interventions have shown a weak impact (Smits-Engelsman et al. 2013). However, despite their lack of effectiveness, process-based interventions have been around much longer than task-based interventions and remain popular (Schoemaker and Smits-Engelsman, 2015; Schoemaker et al. 2003; Sugden, 2007).

While it is not clear why task-based interventions are more effective than process-based interventions, there are benefits of the former that are not as apparent in the latter. Task-based interventions are often more relevant to daily activity than process-based interventions and allow children to practice activities that they can relate to and understand the potential benefits of. It is believed that because of this task-based interventions encourage participation and practice in activities that will challenge their motor skills and in turn improve them (Smits-Engelsman et al. 2013). Through the repeated practice of a task which children understand, task-based interventions allow the child to reflect on their performance and how it can be improved, promoting problem-solving (Schoemaker and Smits-Engelsman, 2015). This may also add to the effectiveness of task-based interventions over process-based interventions.

Despite much of the research indicating that there are only two types of interventions for DCD, some argue that there is a third type of intervention, physical and occupational therapy training. Physical and Occupational therapy training attempt to address the underlying and most important motor skills required for normal functioning, and try to improve them through direct skill training. In this sense, it can be considered somewhat of a hybrid of task and process-based interventions (Smits-Engelsman et al. 2013). Physical therapy for people with DCD can include several different approaches, from traditional techniques such as strength training using weight machines or resistance bands to more novel or modern approaches such as aqua therapy using water and rebound therapy using trampolines. Physical therapy has even involved technology, specifically video games, through the use of active video games (AVG's) (Offor, Williamson and Caçola, 2016). Much like task-based intervention, physical and occupational therapy techniques have proven themselves to be effective means of helping children with DCD, with evidence showing strong treatment effects (Smits-Engelsman et al. 2013; Offor, Williamson and Caçola, 2016).

One important thing to acknowledge is the availability of these means of support. In the UK, while some support can be accessed through the NHS, typically 4-6 occupational therapy sessions, this is believed by many to be insufficient, and people often have to pay for additional support, which restricts access for the wider impacted community. One study from 2020 explored the cost of DCD on affected families in the UK, through a questionnaire with parents and guardians of children with DCD (Cleaton, Lorgelly and Kirby, 2020). The results of this study showed significant barriers to access means of support, with only half of those polled stating that they have received health care support, such as access to an occupational therapist. Some participants went as far to say that there is "no free ongoing support" and there is "no money in the system", suggesting significant issues with access. This leads many

to turn to private support, such as private physiotherapy and occupational therapy, which in 2020 had a mean cost of £756 for 6 months of support and management (Ibid.) . As well as the cost of therapy and management, over half of those polled reported having bought additional specialist equipment. All of this suggests there is work to be done to make support for children with DCD more accessible.

2.2.2 Technology in DCD Support

As well as the traditional methods, technology has begun to be explored as possible means of supporting children with DCD. Active video games (AVGs), are video games which use physical movement and full-body activity to interact with and play the game (Williams and Ayres, 2020). They have existed for several years in a variety of forms, such as Nintendo's Wii platform and Microsoft's Xbox Kinect. Currently there are several platforms available to buy which contain active video games elements, such as Nintendo's Switch system and virtual reality systems like the HTC Vive, the Oculus Rift, or Sony's Playstation VR. These systems, along with others, have been proposed and used as a means of supporting children with DCD, by using the physical movement and exertion required for the games as therapy (Hickman et al. 2017; Smits-Engelsman et al. 2018; Mentiplay et al. 2019).

AVG's have been used in several different ways, attempting to address different aspects of DCD. AVGs have been described as "a useful adjunct" to conventional therapies (Smits-Engelsman et al. 2018), as well as a "viable avenue to provide the practice levels required for motor improvement" (Hickman et al. 2017). One study analysed the effects of the use of an AVG on balance in children with poor motor performance by asking children to use a Wii balance board with the game 'Wii Fit Plus' and balance activities in the game such as "ski-jump, segway circuit, obstacle course and skateboarding" as an intervention (Mombarg et al. 2013). The children used the balance board three times a week for six weeks for a total of 30 minutes a week. Children were assessed on their balance skills using the 'Movement Assessed Battery for children (M-ABC-2)' and the 'Bruininks–Oseretsky test of motor proficiency (BOT-2)' both before and after using the intervention and showed significant improvements after using intervention (Mombarg, Jelsma and Hartman, 2013).

As well as the better-known difficulties felt by children with DCD, such as balance and motor proficiency, AVGs have also been used to address some of the less direct and lesser-known impacts of DCD, such as lack of interaction in physical activity. One such study attempted to use Wii training as a means of increasing adolescents with DCD levels of engagement in physical activity and in turn improving their physical fitness. After participants had used the wii fit system for 14 weeks participants showed significant improvements in aerobic and anaerobic fitness (Bonney et al. 2018). Similarly another study attempted to compare the efficacy of AVG's as a task-based intervention (Wii Fit), with a more traditional task-based intervention, in helping improve a variety of areas of difficulty for children with DCD. There were significant improvements in anaerobic performance after the children had used the Wii Fit interventions, whereas the more traditional neuromotor task

training showed no improvements in anaerobic fitness. However when comparing the improvements in motor performance and balance, while there were improvements when using the Wii Fit programme there was not a significant difference between before and after using the Wii-Fit, whereas there was for the neuromotor task training programme. Nevertheless it is worth noting that the children in the neuromotor task training group spent more time on their program, with 18, hour-long sessions over 10 weeks compared to the 18 half-hour-long sessions over six weeks, in the WiiFit programme. This difference in time spent on each programme could have influenced the results and casts doubt over conclusions of this study (Ferguson et al. 2013).

AVGs offer several unique benefits over traditional means of support and allow for combining the positive elements of traditional means of support with novel modern ideas and technologies. For DCD treatments to be effective, it is believed that they must be delivered at a high and constant rate (Hickman et al. 2017) While approaches, such as Neuromotor Task Training and Cognitive Orientation to Daily Occupational Performance approach (CO–OP), requires weekly 30-60 minute sessions (Kraversky, 2020), these also need to be supplemented by daily exercises at home (Brookes, 2007). I believe that active video games would allow treatments to be delivered at the high volume required for success (Hickman et al. 2017) by creating informed home training (Smits-Engelsman et al. 2018; Bonney et al. 2018). Although it is possible to create rigorous home exercise without the help of active video games, these programs can often, eventually become chores to the children (Hickman et al. 2017). However active video games, such as the ones using the Wii system in the studies by Mentiplay et al. (2019) and Bonney et al. (2018), have shown to have extremely positive effects on enjoyment and adherence to the activities of children with DCD and prevent monotony and boredom (Smits-Engelsman et al. 2018).

Nevertheless despite the positivity, not all of the research suggests AVGs are successful in supporting children with DCD. As stated earlier, Ferguson et al. (2013) found when comparing AVGs with more traditional forms of support while AVGs can significantly improve anaerobic performance, the more traditional method of intervention, neuromotor task training (NTT), leads to better results in motor proficiency, cardiorespiratory fitness and functional strength. Similarly, a systematic review of DCD video game interventions by Mentiplay et al. (2019) found mixed results, with "conflicting results shown across studies." (ibid, p.14). This systematic review also suggested much of the current research and studies were not strong enough to draw serious conclusions from, with small sample sizes and "low to moderate methodological quality" (ibid, p.14). Furthermore it has been suggested that the use of AVG's in DCD support has some promise but may not be significantly more effective than traditional methods. Whilst AVG support may be useful as part of a wider "comprehensive home plan", AVGs are not recommended as a stand-alone intervention as alone they are not capable of "creating permanent neuromotor improvements" (Hickman et al. 2017). Finally it has been suggested by several papers that further high-quality research is required into the efficacy of AVG DCD interventions, such as studies with larger sample sizes (Mentiplay et al. 2019; Smits-Engelsman et al. 2018; Hickman et al. 2017) and in the case of

the study by Smits-Engelsman et al. (2018) a study including control groups could lead to more accurate results.

Additionally while the aforementioned studies into the effects of e-learning and AVGs on DCD do address some of the most significant impacts of DCD, such as balance, gross motor skills and lack of engagement in physical activity, there are many of the other impacts of DCD which are not addressed as much by these AVG interventions. Difficulties like poor fine motor control could potentially benefit from AVG support however this has not been developed, or researched. One more possible limitation of AVG interventions are the technological requirements for many of them. Although it has been suggested that AVG may have high levels of availability due to the limited amount of time needed to be spent with a professional, many of the AVG interventions referenced earlier require expensive specialist equipment, such as games consoles or VR equipment (Mentiplay et al. 2019; EbrahimiSani et al. 2020) Schools or parents may not be able to afford such pieces of equipment and therefore will not be able to access potentially life-changing interventions. VR has been described as "too expensive" for higher education (Radianti et al. 2020) and it has been suggested that for the educational sectors to adopt VR technology, they need to be made more available (Elmqaddem, 2019).

Overall however video games and e-learning offer significant promise and opportunity to help children with DCD. They offer very promising results in improving areas of difficulty for children with DCD, as well as other benefits such as enjoyment and accessibility. However it is worth noting that one study highlighted limitations to enjoyment levels of educational games, with them being described as "not as fun as children expect" and "more educational than video games" (Padilla-Zea et al. 2014).

2.3 Storytelling in Education

As well as using technology, storytelling can and often is used as means to support education and therapy, such as physically acting out popular stories or using digital interactive stories in video games. This section will explore the potential benefits of storytelling and how it has been used and could potentially be used more to help children with DCD, improving and supporting the current means of support. Storytelling "shapes our ways of communicating with each other and our ways of experiencing the world" (Bruner, 2010). In education it has been used as a means of delivering information which would normally be considered complex or confusing in a way that is meaningful and easy to digest (Anon, 2015,Sharda, 2007; Hibbin, 2016). Storytelling has also been used as a means of improving communication skills, with significant success (Mokhtar et al. 2011). Storytelling has been described as having "considerable benefits to the socio-emotional development of children, (Hibbin, 2016)

Storytelling has also been used as a means to improve motor skills and motor competence, by combining movement activities with storytelling activities. In one study

children aged 3-4 engaged in a program of activities in which they would act out elements of 'The Gruffalo' story through the use of basic body movements such as jumping, skipping, throwing and catching (Duncan et al. 2019). At the same time other groups engaged in a program of either movement or storytelling activities. The results suggested that the combination of storytelling and movement were more effective in improving motor and language skills than either of the two alone, with the combined intervention being shown to "accelerate motor competence and language ability". It is theorised that this may be because embedding storytelling into movement exercises may make the exercises more engaging and enjoyable, encouraging participation (Duncan et al 2019; Eyre et al. 2020).

Traditional storytelling methods offer some significant benefits in education. I argue that when combined with techniques used to help support children with DCD storytelling offers serious potential as a means of support for DCD.

2.3.1 Digital and Interactive Storytelling

Digital storytelling is the combination of traditional storytelling with multimedia elements using computer software (Robin, 2016). Like traditional storytelling, it allows complex ideas and messages to be meaningfully integrated into learning environments and create exciting and engaging learning outcomes for children (Smeda et al. 2014). It allows for children to take a more active role in their learning in what is known as a 'constructivist' approach (Robin, 2016; Smeda et al. 2014), by having control over their education. The interactivity of digital storytelling can allow the user to control the flow of the story and the rate at which information is delivered, and while some may be more interactive than others, any form of interactivity offers the user some degree of control. Digital storytelling leads to high engagement and enjoyment of children. A 2014 study from Smeda et al, suggested that incorporating digital storytelling into education creates an exciting and engaging learning environment (Smeda et al. 2014). Similarly Padilla-Zea et al. (2014) suggests that incorporating storytelling into educational video games can change the way that students engage with educational video games and in turn improve their educational ability. Storytelling in video games plays a key role in motivating the user to play further and enjoy the game they are playing. It is therefore suggested by Padilla-Zea et al. that incorporating more storytelling elements into educational video games would create a product which not only provides the necessary information to the user but also serves as an enjoyable engaging game which users want to play (Ibid.).

These are not the only benefits and uses of digital storytelling in education, with the literature offering a plethora of others. For example, digital storytelling can improve computer literacy and teach users computer programming skills (Papadimitriou, 2003; Yuksel et al. 2011), improve children's knowledge of the wider world and understand information in a global context (Yuksel et al. 2011), and even help children learn a second or foreign language (Van Gils, 2005). Furthermore, digital storytelling can improve children's ability to work collaboratively and enhance their teamwork (Robin, 2016; Botturi et al. 2014; Yuksel et al. 2011). Digital storytelling is even said to help with more traditional areas of education such as writing, organisational, problem solving and assessment skills (Yuksel et al. 2011).

This is not an exhaustive list of uses and benefits of digital storytelling, but simply demonstrates the breadth of potential applications in education.

While digital storytelling does not appear to have been used to explicitly help children with DCD, methods have been developed for using digital storytelling to help children with other learning difficulties and disabilities. For example Bratitsis and Ziannas (2015) used digital storytelling as means of improving social empathy and reducing the social exclusion of children with social difficulties, such ASD (Autism Spectrum Disorder), by having children engage with a digital interactive story, titled. This proved to be a success, with the study indicating that digital storytelling is a possible means to enhance empathy in children with special educational needs. Similarly another study investigated the potential to use digital storytelling as means of improving the communication and social skills of at-risk children, such as children with disabilities. This paper also suggested that digital storytelling was successful, stating that it can be used to aid the communication skills of children with specific learning disabilities (Botturi et al. 2014). Furthermore, both papers suggest that the digital storytelling techniques explored and developed by them have the potential to help other children with specific learning disabilities.

Storytelling (including digital storytelling) offers significant benefits and impacts on children's learning from increased enjoyment to allowing children to take a more active role in their education. The evidence suggests by combining these proven storytelling methods with established techniques used to help children with DCD one could develop a tool which offers significant benefits to help people with DCD while also benefiting from the affordances of digital storytelling. As stated earlier, AVG's and e-learning have shown significant potential in helping children with DCD and the inclusion of digital storytelling in these tools could only serve to improve their efficacy.

2.4 Conclusion

To conclude, DCD is a disorder with a wide range of impacts affecting many areas of life with varying degrees of severity. The majority of treatments for DCD can be divided into two main categories, task-based interventions, and process-based interventions, and it is clear from the literature that task-based are the significantly more effective of the two. Technology, such as video games, have begun to be explored in the support of children with DCD and show significant promise for their efficacy and ability to mimic the traditional, effective approaches. It is clear that much of this work is in its infancy and there are limitations, with some suggesting that technological approaches may not be necessarily more effective than traditional approaches. Furthermore there are limitations around the availability and pricing of much of the equipment needed to use these tools. Nevertheless video game technology has the potential to be an extremely useful tool in the support of children with DCD. Similarly storytelling and specifically digital storytelling, while not necessarily currently used to help children with DCD, has shown significant promise in helping children

with or without specific learning difficulties, helping teach computer literacy, languages, as well as helping children with ASD improve their empathy and communication skills. I believe the promise and benefits shown by digital storytelling, when applied to DCD, could improve current methods of support and create new ones. This project will attempt to take the most effective elements of traditional DCD support and combine them with the promise shown by video games technologies and digital storytelling to create an effective, enjoyable and accessible tool to help support children with DCD.

Chapter 3- Expert Interviews

3.1 Approach

My approach to the research for this project had two distinct elements. First, I saw this as an opportunity to work with experts who had first-hand, relevant experience of DCD and its impacts. The second element was to work with children with DCD to collaboratively design and develop key elements of a video game which could be used as a support, developing a tool which children with DCD would hopefully want to use. An overall view of this approach can be seen in the diagram labelled *figure 1.* This chapter will explore, describe and justify the work undertaken in the first approach in which I worked with experts, to develop a deeper understanding of DCD and the current approaches used to support it used in the UK. Expert interviews are a technique commonly used in human-computer interaction (HCI) research and are often used at the start of a research project to give guidance for the next stage of research (Blandford et al 2016). Expert interviews are a flexible tool that can be used in any HCI, from research into the current development of AR and VR technologies (Speicher et al. 2019), to research into the users needs for post knee replacement e-textile (Byrner et al. 2013), to an analysis of the divide between technical and humanities disciplines in games research (Melcer and Isbister, 2017).

Expert interviews were a suitable method in the first design stage of the project as the goal was to gather as much information about DCD, its impacts, and its treatments. By interviewing experts I was able to draw upon their professional experiences of DCD and supporting children with it (Hannibal, 2021). While it would be possible to gather similar information about the impacts of DCD through other methods such as interviewing children with DCD, or their parents/guardians, these interviews would require a significantly larger sample size to gather a similar quality of data when compared to expert interviews. This is because expert interviews would be able to draw upon multiple individual experiences of DCD. Furthermore, using expert interviews allowed me to work with participants who I would continue to work with throughout the project. Later in the project, after I had worked with children, I returned to the same experts, sharing some of the findings from my work with the children, as well as my ideas for the game. The experts were able to give me feedback and further guide the project in the right direction.

3.2 Ethics

When working with any participants, it is essential to ensure that all ethics procedures and guidelines are adhered to. If guidelines and procedures are not adhered to, the research may not be safe and the data not valid. In the initial interviews stage I was working with adults who were not vulnerable, and while this meant there were less ethical considerations, there were still many key issues that needed to be kept in mind. One such important consideration was acquiring informed consent and providing the participants enough information to give that consent, which was achieved through consent forms and information sheets, *see Appendix 8.1-8.2*. These forms were submitted as part of the ethics application. Similarly, all data gathered at this stage of the project was to be stored securely on the

University Google Drive to ensure the safety and security of their data. Additionally participants were treated anonymously, and all the information gathered could not be associated back to them. Participants were also made aware that if they wanted to no longer be involved in the project at any point they could say so and we could stop and all their data would be deleted.

3.3 Method

Four expert interviews were conducted, lasting about 40 minutes to an hour. All the interviews took place over Zoom. Participants were gathered through personal connections, and were first contacted over email, with the project being explained to them and then I asked if they would be interested in taking part. Following this, if they said yes, a date and time was organised for the interview and participants were provided with an information sheet and consent form *see appendix 8.2-8.3*. Attempting to gather a range of perspectives when doing expert interviews is an important part of ensuring one gathers valuable data (Prpa et al. 2020). In my case, of the four experts interviewed, two were special educational needs coordinators (SENCO), one was a private occupational therapist and one was a mainstream classroom teacher. Each of these experts had their own experiences with working with children with DCD and its impacts. These expert participants will be referred to in this analysis by a code, OT1 (occupational therapist), PS1 (primary school teacher) SN1 and SN2 (special needs teachers). The interviews were semi-structured, meaning that while I wanted the interviews to be a free flowing conversation and allow the interviewees expertise to dictate the flow of the conversation, I still used some prepared questions to begin the conversations. Six questions were asked in the interviews, they were;

1. Could you tell me about your work?
2. In your opinion what are the biggest challenges and impacts on the children of DCD?
3. In your opinion what are the biggest challenges and impacts on the parents and teachers of people with DCD?
4. What are the techniques used to help children with DCD?
5. In your opinion what is good about the current techniques and tools used to help support children with DCD.
6. In your opinion is there anything missing in the current techniques and tools used to help support children with DCD

The interviews were recorded and then transcribed. Following this the transcriptions were analysed through open coded tagging process (Bengtsson, 2016), in which categories, or tags were found in the data, and the data was then divided throughout these. The tagging process was done by using Taguette (Rampin and Rampin n.d.), *see sample in Appendix 8.3.* I then developed an affinity map (fig 1, appendix 8.4) of the key points raised in the interviews. Affinity mapping (Lucero, 2015) is a technique in which pieces of data are written on post it notes before being sorted into different categories and groups. This process allows a researcher to iteratively sort through large amounts of data and identify themes and patterns

arising from the data. For the affinity map, I used the online collaborative whiteboard tool Mural (Anon, 2021)). As I followed a design-centred approach with mixed methods, as opposed to a social science approach, the tagging and affinity mapping process was deemed to be a sufficient approach to interview analysis and there was no need for more in-depth qualitative analysis.

3.4 Analysis

The goal of these interviews was to develop an understanding of impacts of DCD and the nature of current treatments in order to develop ideas of how video games could be used as a means of support for children with DCD. These interviews allowed me to explore what areas of difficulty for children with DCD as well as develop ideas for game mechanics which would be used in the game developed in the project, which address key issues with DCD, inspired by the current means of support.

Fine and gross motor skills were the most common difficulty mentioned by experts, when asked what are the biggest challenges and impacts of DCD on children. This came as no surprise as these are arguably the most known and largest impacts of DCD. Almost all participants mentioned these as a major issue with them also highlighting more specific difficulties caused by poor fine and gross movement. For fine motor skills, participants highlighted handwriting as a specific difficulty. Two participants also highlighted the specific ways handwriting is affected, with SN1 mentioning Letter formation and “keeping on a line” and PS raising “handwriting speed” and “quality”. In regards to specific gross motor skills, OT1 highlighted “riding a bike” and PS1 mentioned “getting dressed for PE”. One thing that did surprise however was how significant the behavioural and emotional problems were, with one participant (OT1) going as far to say that it was either the biggest impact or at least the most neglected. OT1 stated that children with DCD often struggle with poor self-esteem and confidence and PS2 stated that they are “aware they are clumsy” and can “feel singled out”. Participants suggested that children with fine and gross difficulties can have a significant impact on their social and emotional well being, a point that is supported by some of the literature which was explored in the literature review (Mandich et al, 2003).

The focus on fine motor skills here led me to decide to focus the game on improving fine motor skills, as this was something that clearly had a significant impact on the children with DCD, with all of the game mechanics developed being focused around improving fine motor skills. Similarly the focus on handwriting and children with DCD inability to “Keep on a line”, as stated by SN1 led me to focus the design of some of the game mechanics around tracing shapes and following a controlled path.

When discussing the current methods of support and interventions several key techniques for successful support came up. The most popular of these were making the activities fun, by using play as means of support, embedding the activities in daily life with plenty of repetition and practising very basic movements. All participants stated they use play

and fun when helping children with DCD in order to make the activities more engaging and enjoyable for children with DCD. Similarly all bar one participants (SN1, OT1, PS) stated that they design activities, which can be integrated into everyday life, to allow for repetition and daily practice. Participants highlighted some more specific ways in which they attempted to support children such as using Dot to Dot puzzles, mentioned by SN1 and using keyboard/typing activities,mentioned by SN1 and SN2. SN2 went further and specifically highlighted the BBC programme Dance Mat Typing (BBC, 2019), this method is supported by literature which suggests that typing exercises can be an effective means of improving fine motor skills (McGlashan et al. 2017). This discussion again heavily inspired the game mechanics developed later in this project, with all of the mechanics developed focussing on the repetition of basic fine skills movement. The mention of Dot to Dot puzzles further inspired me to focus on developing a game mechanic which has users use their fine motor skills to follow a controlled path, similar to how they would when using a dot to dot puzzle. Additionally the references to typing activity inspired me to focus on developing a mechanic which has users tap on the screen in a certain place with each finger, mimicking the movements which would be done in the keyboard/typing activities mentioned by participants. In general, while participants use a range of specific means to support children with DCD, there were few key emergent ways in which support is made effective, by making support fun, with daily practice and repetition and by practising basic movements.

Some of the most interesting points raised by participants came from our discussions about what is missing from current methods of supporting children with DCD and problems with the current education system for children with DCD. All Participants highlighted a lack of funding and resources meaning that regular work with specialist and specialist equipment is not always possible and while the impact of this could be reduced if children were able access a programme which could be done at home, participants also highlighted that to their knowledge, these either do not exist or are not very good. This suggests that there is a fairly large gap in the support of children with DCD and that the development of effective informed tools could significantly improve the lives of children with DCD, reducing the impact that low funding and capacity of support services has on them. Similarly, participants suggested that without the support of experts, like occupational therapists and SENCOs, parents and teachers are often unable to effectively support children with DCD due to a lack of knowledge and understanding, as well as an already incredibly demanding curriculum in the case of the teacher. This all supported the hypothesis that an interactive media system which could be used in homes and schools would be a very effective and worthwhile way to help children with DCD. While it would not be able to replace the treatment and support of occupational therapists and SENCOs, it could go some way to fill in where this treatment and support may not be available. Finally, participants suggested that while e-learning and video games tools for children with DCD exist, OT1 stated that existing tools can “be boring” or are “not up to date”. Similarly all participants suggested that while technology has been used it has not gone anywhere enough. Overall, participants suggested that while effective support does exist, from SENCOs and occupational therapists, it can often be difficult to get this support to children, for a range of reason, from lack of funding and availability, to the lack of

knowledge and understanding of DCD from teachers and parent, to a busy school curriculum and a lack of for DCD support.

3.5 Conclusions

As stated above the goal of these interviews was to develop a deeper understanding of impacts of DCD and the nature of current treatments; together with information gathered in the literature these interviews allowed me to develop the core ideas for the game mechanics which would appear in the final game

Participants highlighting handwriting activities and dot to dot puzzles encouraged as means for improving fine motor control (Northumbria Healthcare NHS, 2018), inspired the game mechanic which can be seen in *figure 1*, in which players trace along a simple path and are encouraged to follow it as carefully as possible. This interaction was also inspired by the Teodorescu Handwriting Program which attempts to improve handwriting and fine motor skills by having children trace simple shapes and paths (Teodorescu et al. 1996).

Figure 2; Path following game mechanic from final game inspired by initial interviews/ Players move the character across the touch screen using their finger to trace the path as accurately and quickly as possible, with their players health falling as if they stray off the path, if their health falls to 0, they will have to try again.

Similarly, participants highlighting typing activities inspired another core mechanic of the game in which participants tap on a designated area of the screen, using individual fingers for different spaces. This too was also inspired by literature, finger tapping is a common activity used by occupational therapists as a way of improving the finger isolation, the dexterity of individual fingers. Finger isolation exercises often consist of tapping individual

fingers to the thumb or tapping loudly on a desk at varying speeds (NHS, 2021; Keinan, Bar-Shalita and Portnoy, 2020). This mechanic can be seen in *figure 2.*

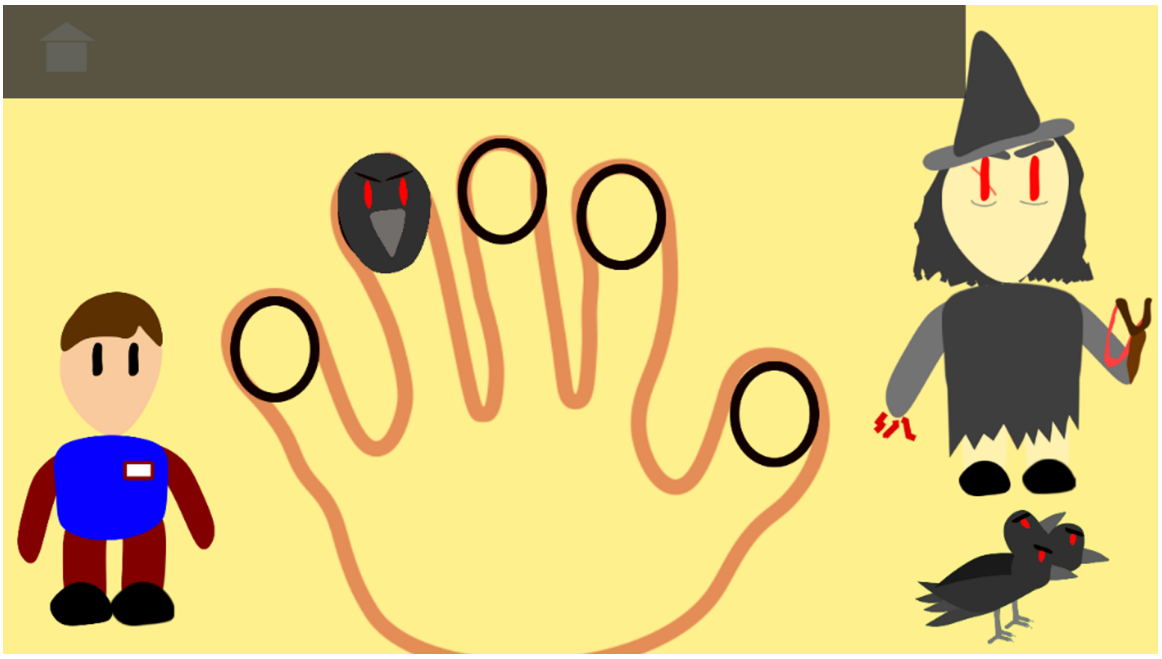


Figure 3; Typing game mechanic from final game inspired by initial interviews. Players, first using their right hand, then their left, attempt to tap the crows as they appear in the different spaces for each individual finger; if they fail to tap the crow before they disappear their score falls.

Overall the initial interviews with experts and subsequent affinity mapping process allowed me to better understand the most significant impacts of DCD, the most effective ways to support children with DCD, and issues with the current means of support for children with DCD. This process allowed me to form the core ideas for the game mechanics which would be used to support children with DCD. These ideas would be built on in the next stage of the design process, where other key elements of the game such as the character design, narrative, and user interface of the game, would be developed.

Chapter 4 Co-design Workshops

4.1 Approach

Following my initial interviews with experts, in which the core ideas and mechanics were developed, the next stage of the project was to begin the co-design process in which I worked with children with DCD to come up with ideas and begin to design tools/games, which we could eventually develop into high fidelity prototypes. There were four workshops in this section. The first was an introductory workshop, with each participant individually. The next three workshops were run as group workshops in which participants would work collaboratively to come up with characters, stories, and user interfaces. The activities in workshops allowed participants to draw characters, storyboards and user interfaces in the main activities of the sessions. This was done as it allowed children to express themselves through media familiar to them and related to their level of skill (Vaajakallio et al. 2009; Frauenberger et al. 2015). Some of the participants knew each other prior to engaging in the workshops, these participants were put in the same groups as a way to hopefully help participants engage with the group activities more easily.

We held the meetings over Zoom and used Mural to describe the activities and to document our ideas/discussion. All participants joined the zoom calls on laptops from their homes. The online nature of these workshops, while necessary due to lockdown restrictions caused by the COVID-19 pandemic, did come with potential difficulties. The tiring nature of long online conferencing (Fauville et al. 2021) could have had a serious impact on the engagement levels on the co-design workshops. To reduce this I kept sessions relatively short, never going beyond an hour, and breaking up workshops into different activities with different types of engagement, such as drawing (Kennedy et al. 2021). Access to technology and computer literacy could also cause difficulties. Participants may not have access to the same technology as others participants, or not be as able to as use them as well as others. It was therefore decided that participants would only use technology to join the Zoom call and all of their engagement with the co-design sessions was done on pen and paper. There were five participants in the workshops, aged 10-12, and were all male. The lack of diversity of co-designers was certainly a limitation and a more diverse group would have been ideal, however due to limited time a second round of recruitment was not possible. The first sessions took place throughout April and May and the second, third and fourth workshops took place over six weeks from June to July, see *figure 1 for overview of the codesign process,* Participants will be referred to by a code in this section P1 (Participant 1) to P5. Participants were recruited through the expert participants in the previous stage of the design process. Expert participants contacted the parents/guardians of children they thought would be suitable for the project and explained the project using a description I provided them with. These parents/guardians were then provided with my email and were told to contact me if they were interested. When parents/guardians contacted me I provided them with more information about the project and if they were still interested they were provided with an information sheet and two consent forms, one for the parents/guardians and one for the child

(see section 4.1.2). Participants were provided with a design pack containing materials for the project, this is explained in more detail further on.

It is worth noting that in a traditional co-design process, co-designers would not only design key elements but would be actively involved in implementing these designs (Trischler et al. 2018). While ideally, I would have liked to have participants physically involved in the development, the remote nature of these workshops would have made developing the game alongside participants too difficult to organise and run. It was decided therefore that I would develop the game myself using the ideas and designs produced in the co-design workshops. To negate the impact of this reduced engagement with participants, the game was shared at various stages of development with participants during the co-design workshops, ensuring that participants contributed to the development process as much as possible.

As these workshops were a collaborative effort, between all 5 co-designers and me, not all of the co-designers' ideas and responses could be worked into the game and therefore I had to decide which of their ideas were included and which were not. This was done by selecting the ideas that were most popular with the co-designers and therefore suggested by more than multiple co-designers. It was explained to them that this was a collaborative effort and therefore not all of their ideas could be included, to ensure a coherent aesthetic and narrative but I ensured that something from each of the co-designers was included in the game. Similarly there were some ideas that would not be possible given the scope of the project. This was communicated to participants by stating that while the ideas are strong, it may not be possible in the time available. Ultimately the power over decision making within the design process was with me, however all the ideas ultimately came from participants and as was said above, the decisions were based on what was most popular with participants. While the designs, such as the character design were made by me, they were based on the designs that participants created. *See appendix 8.27 which sets out the key design decisions and elements and who made them.*

4.1.2 Ethics

As stated above, in these workshops I worked with participants that would be considered potentially vulnerable, as they were under 18 and had DCD. This meant there were several serious ethical considerations which needed to be taken into account when working at this phase of the project, on top of the usual ethical considerations when working with participants. One such consideration was the potential to cause upset or harm. As I was working with children with DCD, discussion about their disorder and its impacts does have the potential to cause upset or harm, potentially reminding them of difficulties they have had in school or at home. To avoid this being an issue a decision was made not to discuss DCD and its impacts in the interviews and to steer the conversation away from this topic if it came up. Furthermore, as the participants were under 18, I could not meet with the participants alone and I required their parents/guardians to sit in the workshop. Similarly as the participants were under 18 they alone could not give informed consent to take part in the

project and therefore I provided consent forms and information sheets to both the parents and the children. These forms and sheets contained largely the same information although presented slightly differently. The purpose of these forms provided to the children, while they would not necessarily affect their ability to engage with and take part in the research, was to allow the children to fully understand their participation in the project and make an informed decision as valued participants. Allowing children the opportunity to decide to take part in a project, while not necessary in terms of formal institutional ethics requirements, may encourage better understanding of the project on the side of the children as well as potentially more engaged participation (Field et al. 2004). *See Appendix 8.5-8.8*.

4.2.1 Design Workshop 1: Individual Introductory Session

In the first workshop, participants took part in three activities, in which I attempted to understand what they liked and disliked about games, as well as how they spend their free time and what they do for fun. Additionally this session was intended to make sure participants were comfortable with me, the design process and the technology before we moved on to the group sessions.

Activity 1: A day of Play!

The first activity of the initial design workshops participants were asked what they do for fun, at different times of the day, before school, during school, after school, and at weekends and holidays. Here, the participants and I were able to explore where tools designed to support children with DCD could fit into their lives, while also beginning to explore what activities participants enjoy and do not enjoy.

Before School

Participants referenced a number of different activities which they do before school. Almost all participants mentioned watching some kind of video content, whether that be Netflix, YouTube or television. These were either watched using a television or a tablet, such as an iPad. Two participants mentioned playing video games in the morning, on both tablets and consoles. Other participants however made it clear they do not, or do not often, play games in the morning. One participant stated it is rare that they will play on their Playstation in the morning and another stated that they "don't have time for anything in the mornings". Similarly, two participants stated that they are not allowed on several devices before school, such as iPads, Playstations and PCs highlighting the limited time in the mornings. However it is worth noting that while some of the stated participants are not allowed to play video games in the morning, I believe it may be different if these were educational games.

During School

Digital interactive activities make up the majority of what participants do for fun in school, with every participant mentioning them in some form. Many of the participants highlighted educational video games, such as 'Times Table Rockstars', 'Mathletics', and the Nessy apps. This suggests that there could not only be space for a game designed to support their DCD but it also suggests there would be an interest. While most of the participants stated they enjoy at least some of these games, their thoughts on educational video games was not wholly positive, with most of the participants mentioning that they did not enjoy at least one educational video game. When asked why they did not like these games, most participants simply stated that they were either "not fun", or "boring". One participant did state that they found Times Table Rockstars stressful due to the timer. This emphasises the need to make any games I developed to not only be useful but also fun and engaging.

After School

Much like during school, digital interactive activities were the most popular after-school fun activity. Every participant stated they play video games after school, with participants referencing a range of games, from first-person shooters', to sport simulation games. Console video games were not the only digital interactive activities referenced here with participants also highlighting using iPads and PCs.

During weekends and holidays

The activities mentioned in this section were mostly the same as the ones as after school, with participants again highlighting digital interactive activities such as playing on the games console or iPad. Participants also highlighted physical activity here, such as team sports and going for walks.

Activity 2: Game Features

In the second activity, we discussed features of video games and how important they are to the participant, ranking them on a bullseye with the most important features going in the centre, less important outside of that, and the least important on the outside of that. This was inspired by the icebreaking children's activity 'Identity Circles'(The Linking Network, 2017), in which participants rank the things which are most important to them. A list of 15 options consisting of video game genres (Vince et al. 2018), mechanics (Kramarzewski and De Nucci), platforms (Stuart, 2015) and additional features (Clement, 2021) was provided to the participants and they were asked to rank them on importance, with spaces were left for the participants to come up with their own features.The goal of this activity was to begin to develop ideas for what could be included in the game we designed by asking participants which features are most important to them (fig 4). While there was some confusion around some of the features listed, they were all explained to the participants.

Overall this activity did reveal some interesting conclusions about which features were most important to participants. On average the most important feature was story, with all but two participants placing this in the most important category. P3 stated that story is important to keeping a player engaged in the game, and this idea was also echoed by P2. This suggested that story was a feature that must be included in the game we develop. However, P1, who did not place it in the most important category, remarked that the story is "very important but it's not the only thing that I want to do". Story was closely followed by humour, character customisation, and avatar creation, these features were also very popular with participants and only narrowly less important than story. P4 highlighted the importance of humour, stating that it "makes a game fun". Similarly, P4 and 5 emphasised the importance of character customization and avatar creation, with both suggesting they enjoy it as it gives them more creative freedom.

Following the most important features, the next most popular ones were Action, multiplayer, trophies, the ability to play anywhere, easy and hard difficulty and motion control. While these features were not overall as popular as the ones mentioned above, some of these were placed in the most important category by participants and given the small sample size, it is important to consider these features. There seemed to be some consensus

with multiplayer games; P1, 2, 4 and 5 all suggested that while they do enjoy multiplayer games they also enjoy playing on their own and do not want to play online all the time. For trophies the response was more varied, P4 placed it in the most important category and stated it is important to help them see progress. This was supported by P5 who suggested that it is important to show progress but also reward players. Other participants' responses were less enthusiastic, with P2 stating it is “quite important” and two of the other participants placing it in the middle category and the other placing in the least important category.

The session also highlighted the least important features to participants, those being realistic graphics, scores, and the ability to share your score with others. While it was not explicitly stated, it seemed that the participants' lack of interest in scores and the ability to share your score was reminiscent of points raised in the expert interviews. As stated above in the initial interview, experts stated that children with DCD often suffer from poor self esteem, confidence and “feeling singled out”. It could be therefore stated that the participants' lack of interest were an extension of this difficulty, participants may not want a score and the ability to share it with others as they may worry about being embarrassed about their scores and may not want others to see it. P1 supported this by stating that they do not like scores as people may get too competitive. This further highlights the importance of making the game a safe and comfortable experience for players.

Activity 3: My Dream Game

In the final activity we discussed the participants' dream game by considering four different attributes of games; How it's played (what platform?), what type of game (what genre?), What the tone of the game is, and how it looks (fig 5). Much like the previous activity, participants were provided with a few different examples for each category but were also asked to contribute any of their own. The goal of this activity was to again develop ideas for what could be included in the game we designed by asking participants which features are most important to them.

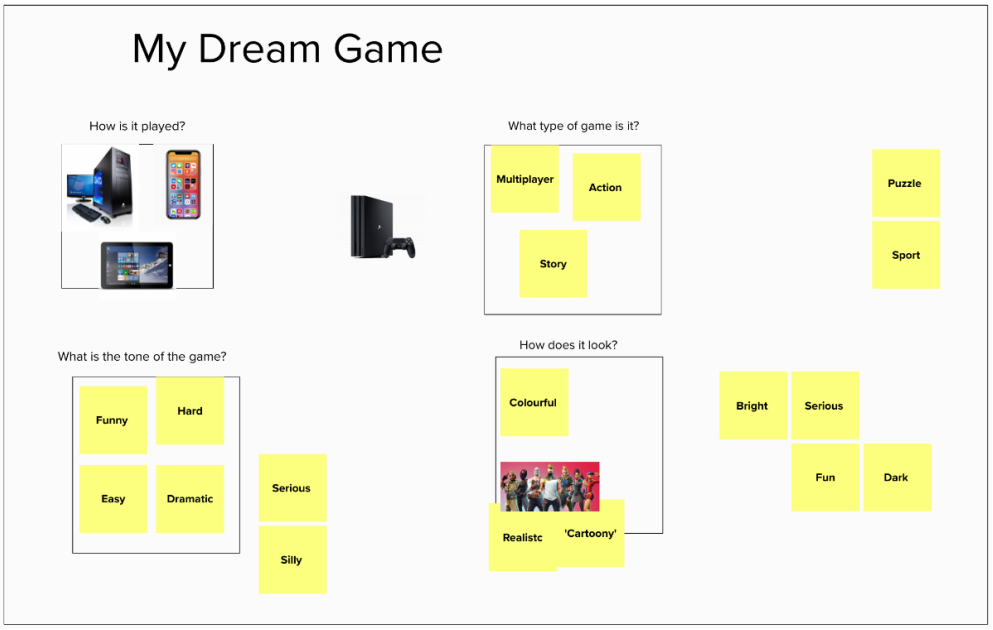


Figure 4: P1 My Dream Game Mural

When discussing how their dream game would be played, wide availability was the most important issue to the participants, with all of the participants acknowledging this in some way. P2, 3, and 4 stated that they wanted to make the game available to as many participants as possible and selected a range of platforms to play it on. This was further supported by P1 who felt it should be available to play both in school and at home, stating "you could do it at school for ICT and home". This along with some of the points raised in the first activity informed the decision to build the game for use on a tablet. This is explored more in subsequent chapters.

Once again Story was popular, with all bar one participants including this in the 'What type of game is it?' section, further highlighting its importance to participants as something participants would want in the game designed in this project. Multiplayer was also very popular in this activity, again with all bar one participants including this in the 'What type of game is it?' section. While it is clear that multiplayer is an important feature to participants, I decided that this was unrealistic in the timeframes for development and therefore excluded it from the final game. Nevertheless, I felt it is worthwhile to acknowledge

this as an important feature to participants and could be something that could be implemented in the future iterations if I was to continue to develop the project.

Similarly ‘Funny’ was selected in ‘ What is the tone of the game?’ section by all bar one participant, echoing the selection of humour in the previous activity as an important feature of video games. This was the only choice in this category that more than one participant selected.

In the final category ‘How does it look?’ there was very little consensus between participants with the most popular choices being ‘bright’ and ‘realistic’, which were selected by 3 of the 5 participants. Realistic being selected by so many participants was somewhat surprising given how unimportant it was in the previous activity, being one of the least important options. P1 selected ‘realistic’ as well as ‘cartoony’ and stated their dream game would be a mixture of them both, giving the game Fortnite as an example of this.

Summary of Design Workshop 1

Overall the first session was extremely useful for the research project, supporting the subsequent design workshops and informing several design choices for the final game. One of the main goals of the first session was simply to get to know the participants and have them feel comfortable working with me, and on this project, before the subsequent group sessions. Although participants were able to share with me and engage with the activities in the first session, their engagement certainly improved as the session progressed and as they got to know me and the project. I felt it was important to have this before we moved on to group sessions, as it would be more difficult to do this in a group of two or three. The decision to use the first session to introduce the participants to the design project as well as to the researcher was inspired by similar work, as this is a common technique when using co-design with children (Van Mechelen et al. 2019, 2018; Vaajakallio, Lee and Mattelmäki, 2009).

Despite this being the first of four workshops, several key design choices were made due to information gathered in this workshop. One such design choice was the decision to use a tablet to build the game. From the first activity it was made clear just how much participants engage with interactive media not only at homes but also at school, and just how much of that is done using tablets. Every participant mentioned at least one educational video game they play in school using a tablet, such as Times Table Rockstars, Nessy, Purple Mash, and Matheltics. This, combined with their use of tablets at home, indicated that a game designed to support children with DCD built on tablets could fit into the lives of children with DCD. This point was made more clear in the third activity as participants suggested that their dream game would be available to as many participants as possible. While building for multiple platforms would provide the greatest reach and be the best way to do this, given the limited timeframe for development in this Masters by Research, it would not be possible. It was therefore decided that tablets would be the most suitable platform given that in 2021 86% of schools in the UK have access to at least one tablet per teacher with 69% of schools

having access to one device for four children (Department For Education, 2021) . Furthermore, in 2020 over 50% of UK households had a tablet (Alsop, 2020). These workshops also led to the decision to include a story, humour, as well as an ability to have players create characters, all due to the popularity of these features with participants in the second and third activities of the workshops. *See appendix 8.9-8.11 for full data from these workshops.*

4.2.2 Design Packs

Following the introduction workshops, I put together and sent design packages for the participants that contained, paper, pens, pencils, and other items of stationery that could be used in the workshops to write down, draw and engage in the activities of the subsequent design workshops (fig 6- 9). While some of the participants may already have some of these items, the design packages could increase engagement and allow the participants to feel more involved in the project. Participants were asked if they wanted a design pack and all accepted.

Figure 5-8: (Top left: squared paper and a plastic wallet,Top right: Coloured paper,Bottom left: All the items which were sent to participants including a pencil case containing a pen, pencils, colored pencils, a rubber, and pencil sharpener,Bottom Left: two packaged design packs with the participants named blurred out.)

4.2.3 Design Workshop 2: Character Designing

In the next phase of the design process, we began to work in small groups to design key elements of the game. In this workshop, I asked the participants to design characters for the game by exploring the core element of what makes a video game character. As well as this, we explored what the key three stakeholders (parents, teachers, and children) would want from an educational game that can be played in school and at home. Here there were two workshops with two groups, Group 1 (P1 and P2) and Group 2 (P3, P4, and P5).

Character Designing Activity

The first activity in these workshops was to design video game characters. Once again I used Mural to explain and run this activity (fig 10), however unlike the activities in previous workshops, participants were asked to write and draw on the paper provided to them in their design packs, and then share their designs by holding them to the camera.

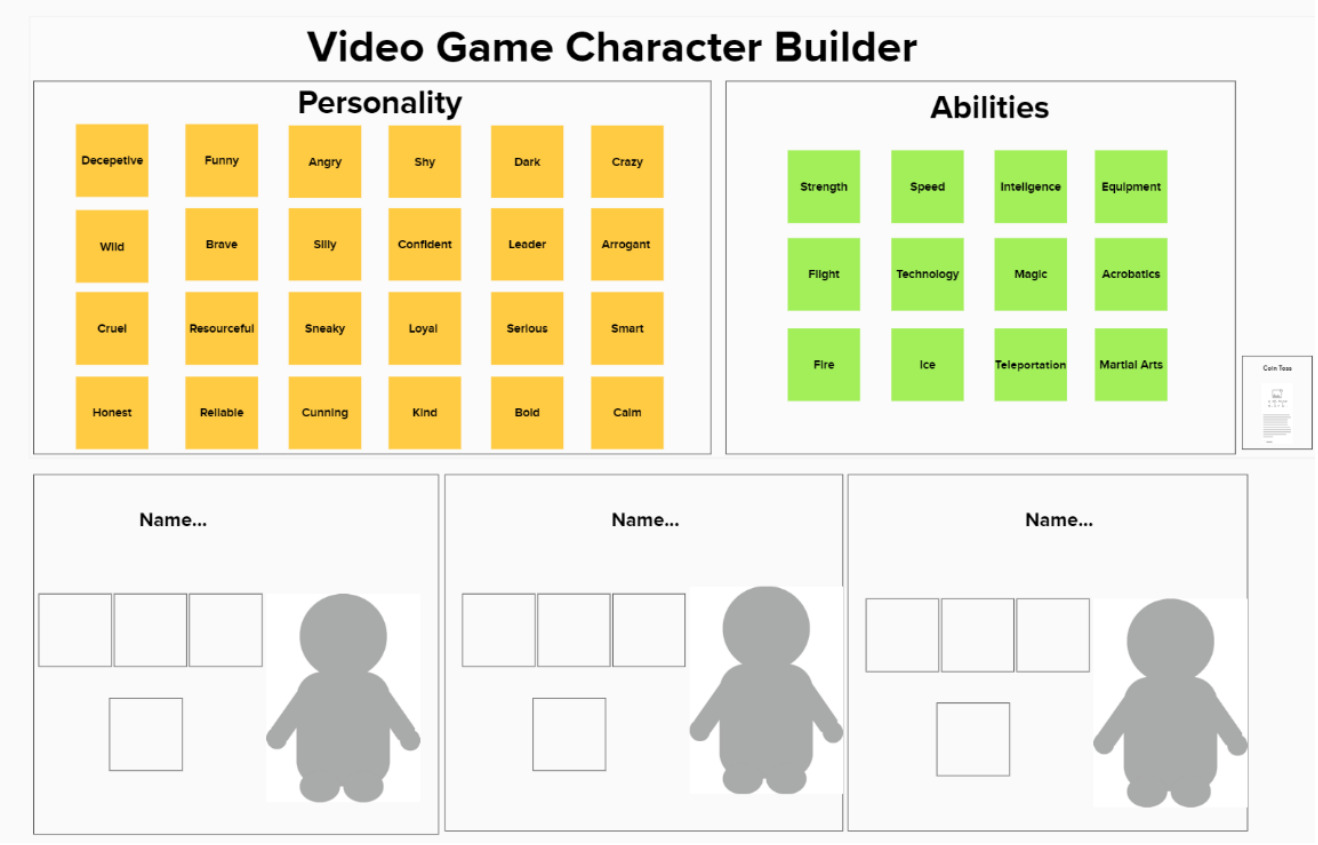


Figure 9: Blank character designing Mural

The activity broke video game characters into three key elements; personality, abilities, and design. Participants took it in turns to select three personality traits and one ability from the ones provided and then name and design their character based on the traits and abilities selected. We then shared and discussed the designs with each other. This was inspired by the common school activity of creating characters and drew much of its specific inspiration from one activity created by the BBC (BBC, 2021).

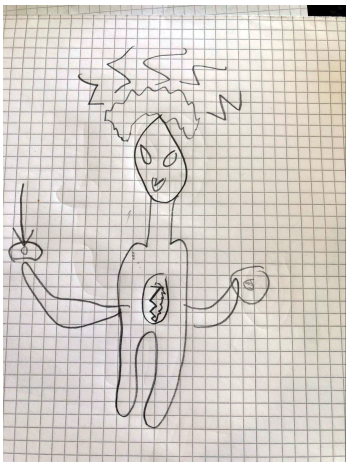


Figure 10: Group 1's character drawings.

Teacher, Parent, Student

In this activity the participants were asked to imagine themselves as each of these three groups one at a time and asked what each of them would want from a game designed for children with DCD. As participants stated what they thought each group would want from such a game I wrote these ideas down on the Mural. This was inspired by the co-design activity customer, employee, shareholder (Gray, 2011), in which co-designers are divided into three groups and asked to imagine what each of these would want from a business or product. For both groups, most of the discussions were about the needs of the students. They both raised many of the same points from previous workshops, such as in the inclusion of customisable characters from Group 2 and not including leaderboards to prevent people from getting too competitive from Group 1. The two groups also raised some of the same points, with both of them highlighting a reward system with trophies as being a want/need of students. Both groups also stated that parents would want the game to be 'not too addictive' or 'not allow people to play for too long'.

Post-workshop

Following the workshops, I took the participants' character designs (fig 11) and developed them into a uniform style (fig 12-16), using Adobe illustrator. The uniform style of the characters was inspired by the simple character designs which can be seen in the games Minecraft (Mojang, 2021) and Roblox (Roblox Corporation, 2021), both of which were games the participants liked and played. While it would have been ideal to have the characters be wholly designed by participants, the resources and skill required to create character sprites to be used in a video game would have been asking too much of the participants.. *See appendix 8.12-8.21 for more images of character designs.*

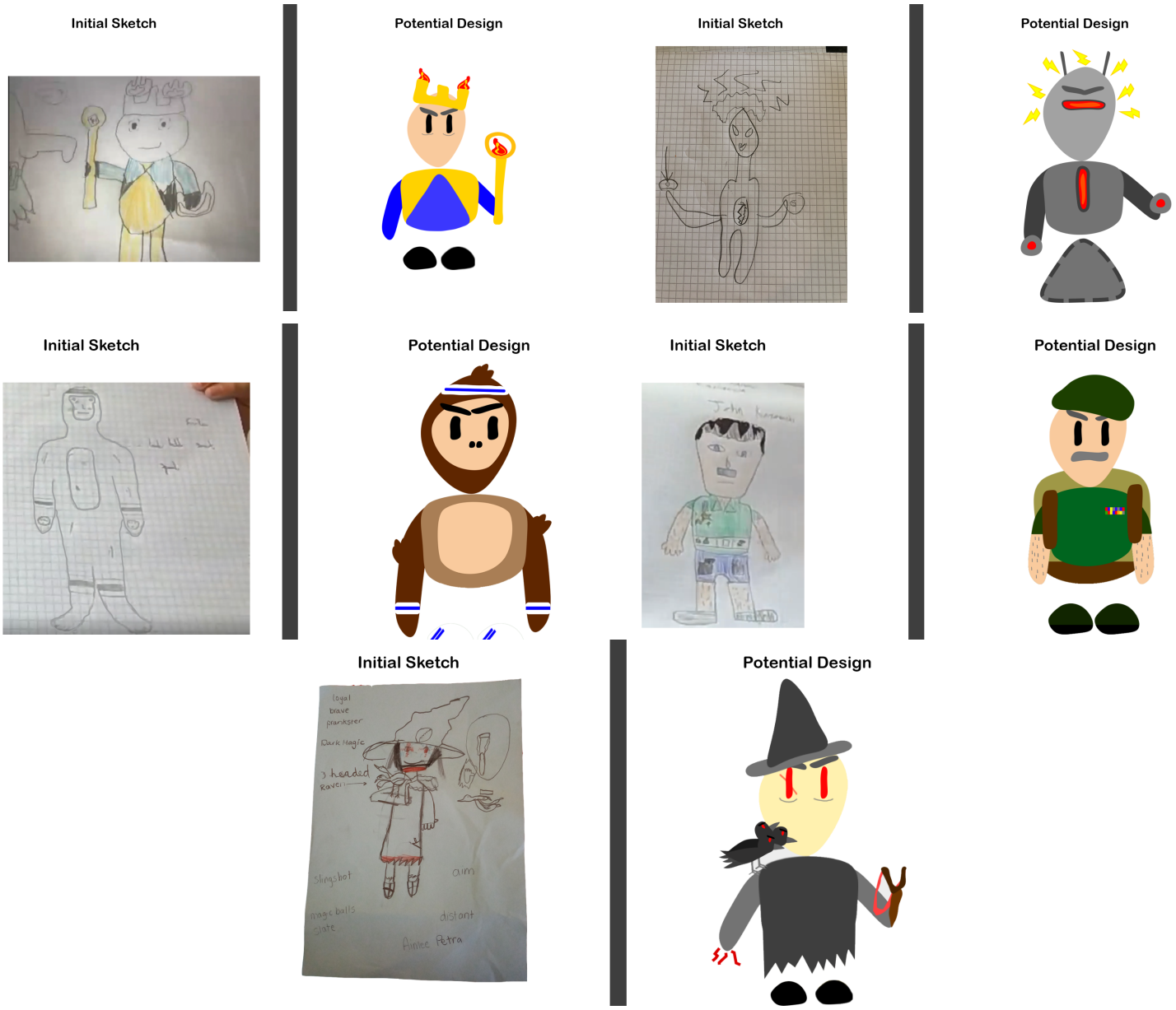


Figure 11-15: Character Designs from Group 1 and 2

Summary of Second Workshop

The second workshop furthered the design process significantly and allowed the design concepts to begin to take a clearer shape. The most significant advancement from this session was the development of characters for the game, with each participant creating characters in the workshops. The characters allowed the game to begin to take shape in several ways. First of all, despite the participants' drawings and ideas having very different styles, in attempting to create a style which unified the designs, the game's aesthetic and style began to take shape. The aesthetic took elements from each of the participants' designs and was designed to allow for the key elements of their characters to be present and obvious. It informed the designs of the levels as well as other characters who would appear in the game.

This style, despite being a combination of multiple participants designs, still attempted to appear recognizable as the participants designs. Secondly the characters developed in these workshops allowed the story of the game to begin to take shape, by creating the characters that would be involved. The main goal of the subsequent sessions (workshop 3) was to develop a story and participants used the characters developed here as the characters in these stories. The characters created here therefore allowed the participants to begin to think about the story for the game and what it would look like.

In the activity, participants also gave their characters names, personality traits, and an ability which like the designs would be shared with participants in the subsequent session to create the stories. As can be in *figure 17,* one of the participants named their character King Ember and was described as 'cruel' and a 'leader' and therefore in the subsequent design sessions was chosen to be a villain. Similarly as can be seen below, one participant named their character Major John Kazowski and described them as 'loyal' and 'brave' and was chosen to be a friend and support of the main hero in the stories created in the next design session.

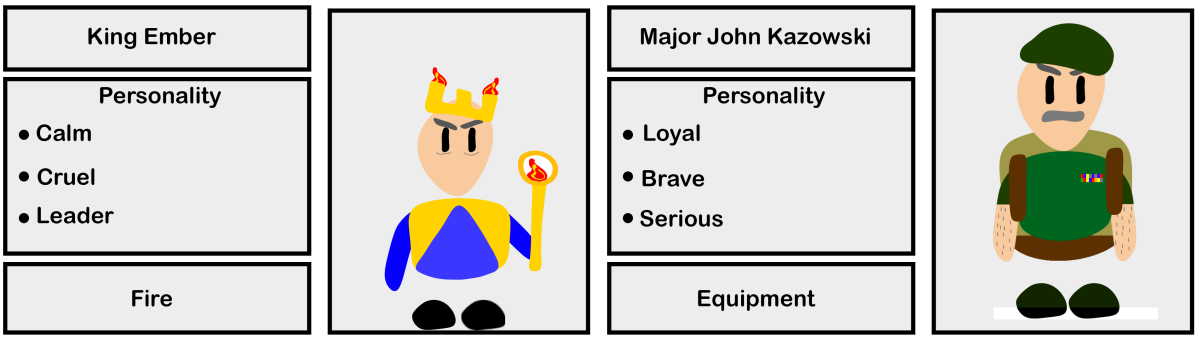


Figure 16-17 Character sheets from design sessions.

The second workshop also allowed the game to take shape by reaffirming the decisions, from workshop 1, to include certain features in the game. Once again the ability to create custom characters was something discussed by participants as a feature they would want in the game we are designing. Although I had decided to include this based on the input in the first session, this only further confirmed that idea that it should be included in the game. Similarly a reward system, distinct from scores, for the game was something that was discussed and was popular with participants in the previous session and appeared here too, suggesting that it too should be included in the final game.

These workshops were significant as they were the first to take place in small groups. I had some concerns that the group dynamics would be difficult to manage and the engagement with participants would not be as good as in the first individual workshop. I was concerned that some participants may find it difficult to share in a group setting and end up being quiet. However this was not the case and the groups worked well together. This was partially due to the most of the participants being familiar with each other already, with both

P1 and 2, of group 1, and P3 and 4 of group 2, knowing each other already. It was only P4 that was not familiar with the other participants however they were able to easily share and engage in the session. As stated earlier the groups were curated to allow participants best share and engage the session, by putting participants who already knew each other together.

4.2.4 Design Workshop 3: Story Creation

In the third workshop, we continued developing key elements of the game, this time focusing on the video game's story. In this workshop we also reviewed the redesigns of their characters to see if the participants had any recommendations. These workshops featured the same groups as the previous workshop.

Presenting the characters

The first activity of the workshop was sharing my redesigns of the participants' characters to see if they felt I had accurately captured their design. Most of the participants were happy with the designs however there were some recommendations. P1, who designed a teleporting robot, wanted it to look "wilder", P2, 3, and 4, while they liked most of the designs, didn't like that I had chosen to not give them legs and so this was changed too. This design decision was made as a way of keeping the character designs simple, inspired by the simple character designs seen in Minecraft (Mojang, 2021) and Roblox (Roblox Corporation, 2021). However, since the participants didn't like it, it was changed.

Hero's Journey Storyboarding

Following a warm-up exercise based on the game Tall Tales (Nath, 2017), which helped participants to start to think about creating stories by taking turns to tell part of a story,e moved onto the main activity of this workshop, which was to develop storyboards using a simplified version of the hero's journey (Campbell, 2003). The hero's journey is an archetypal narrative arc, in which a hero goes on an adventure, faces challenges, achieves their goal and returns as a changed person. The most famous version of the hero's journey by Joseph Campbell contains three acts and 17 stages. The hero's journey story structure was chosen as it could be easily divided into sections and shared between participants to allow for each participant to contribute equally and collaboratively to the story. As stated above, in this session we used a simplified version of the hero's journey which divided it up into four sections.

1. Status Quo and Call to adventure: Establishing where the hero is at the start of the story and the reason for their adventure.
2. Departure and Trials: The beginning of their adventure and any difficulties they encounter along the way.
3. Crisis and Treasure: The main challenge of the heroes adventure and the reward for it.

4. Return and the changed world: The heroes return journey and the heroes' new status quo.

Each participant was made the lead on their section which meant they decided on the content and designed the storyboard(s) for that section. Following a discussion about each section, participants were asked to draw a storyboard of their section (fig 18). These storyboards contained drawings and text. Participants were asked to use all the characters we had developed in the previous workshops, not just their own, as the characters in their stories with these characters serving as the inspiration behind the ideas. After they had drawn their storyboard, participants held their drawings to the camera and as the sessions were recorded, I was able to get screenshots of these after, and following these workshops I used their drawings to develop a storyboard. Participants were also asked to take a picture of their drawing and send it via email. The stories developed in this activity made up the story used in the game, with different elements being taken from both stories created by participants. In combining two stories there would be a risk of plot inconsistencies or participants not being happy with the final result due to the combination of their stories. Participants were therefore allowed to review the story in the next workshop and give feedback.

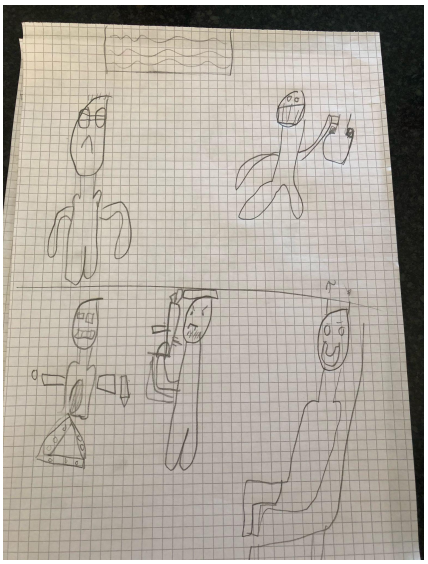


Figure 18: Section of P1's storyboard

Participants seemed to enjoy this workshop and had fun developing their storyboards. Additionally, the stories developed by the participants were varied and creative, seemingly drawing their inspiration from a range of genres, from fantasy to sci-fi. Following the sessions I was able to create a story that was solely made up of ideas from participants. While I did have to make some changes from their proposed stories in order to merge the stories, all of these changes were still heavily inspired by ideas from the participants. *See appendix 8.22-8.24, for the two storyboards and the combined storyboard.*

Designing the Box

In the final activity of the workshop, we began to think about what would be the appeal of an educational game which they would play in school. We did this by looking at what may be written on the box/cover of such an education game. Participants were asked using their pen and paper to draw the box/cover of a game complete with slogans, titles, designs. Following the drawing, I asked the participants to present their drawings and we talked through them.

The main takeaway from this activity was the participants' focus on the "fun" of the game. While this was not surprising it did emphasise what may be lacking from the current crop of educational games, once again echoing the references made in earlier workshops to games like 'SumDog', in which participants described it as not being fun, and suggested any game we make should not be like it.

Summary of Third Workshop

As stated above the main goal of this workshop was to develop a story for the game and this was achieved by developing two separate stories in both sessions and combining them following the workshops. All participants used the characters developed in the previous workshops and therefore there were some similarities between the two stories and this made combining the stories a lot easier. This workshop progressed the project significantly and allowed me to begin to design prototypes and begin to build the final game.

Although I had already developed ideas about the gameplay and had begun to build the key mechanics using input from the previous sessions, the story developed in these sessions allowed me to begin to think about what mechanics and interactions could fit in where. It was following this workshop that the game was able to firmly take shape, and I was able to present the participants a very early version of the game in the following session. This activity was a key point in the design process and can be seen as the point in the project in which development on the final game was able to fully begin.

The design of the box activity, while interesting with participants emphasising fun, was not surprising and did not advance the project as significantly as the other activities in the sessions and other activities in previous workshops. This activity contained similar questions

to the final activity in the previous workshop 'Teacher, Parent, Student' and therefore it may have impacted how much this activity advanced the project.

4.2.5 Design Workshop 4: User Interface Design

In the fourth workshop, we explored the purpose and importance of user interfaces by designing wireframes of a main menu for the game. The goal of this session was to continue to think about what sort of features participants would want to see in an educational game. Additionally, we explored the work produced so far and I asked the participants for feedback on this work. Unfortunately for this workshop, P5 was not available.

Characters

Following feedback in the previous session, I made the changes which participants recommended to their characters. The new updated characters were shared with the participants to see if the changes were what they wanted. Participants were happy with the changes and no additional changes were suggested.

Storyboards

The storyboards were also shared with the participants, and once again participants were happy and did not feel any changes were necessary. Three storyboards were shared with the groups, the storyboard from their group, the storyboard from the other group and a combination of the two. This storyboard, despite being a mixture of two distinct ideas, contained the character designs which participants were already familiar and happy with, and used their direct quotes from the workshops and therefore they still felt represented by the story and could see their ideas and voice within it.

Feedback on early game

At this point in the project I had managed to develop some elements of the game, and was able to share this with the participants, through screen sharing. The game was developed using the game engine Unity, which I chose for two reasons. Firstly it allows for cross platform development meaning that the final game could be published on a range of platforms, such as android tablet, iPad, or WebGL, this meant that it would allow for the most freedom when it comes to sharing the game with participants for testing and beyond. Secondly Unity is a platform I am familiar with and have used many times before. While there was not too much to comment on and I was not able to have the participants play the game at this phase, they were not able to make any suggestions on the game play, which consisted of the first two levels and two different game mechanics, as well as the first two story cutscenes. However, a few changes were suggested on the user interface and user

experience. P1 and 2 stated the on screen text and text box could be improved by making it more ‘colourful’ and ‘fun’, highlighting the importance of creating engaging user interfaces. P4 was confused slightly by some of the word choices in the in game text and felt that certain things could be made clearer. They were confused by which character was saying what and wanted additional character names before the dialogue. Similarly they felt like some lines of dialogue could be changed, changing “get ’em ravens” to “get them ravens”.

User Interfaces

The main activity of this workshop was designing user interfaces, or UI, and in this activity participants designed a main menu. The purpose of this activity was not only to see how participants would design a menu but also to see what features they believe would be important to be included in a game. This can be seen as an extension of the activity in the design workshop one, ‘Game Features’ once again exploring which features of video games would be important to participants. We began by looking at some existing menus before participants were shown Figure 19, a simple wireframe of a main menu which contained three components, the title, the options and designs. Participants were asked to design their menus using these three components.

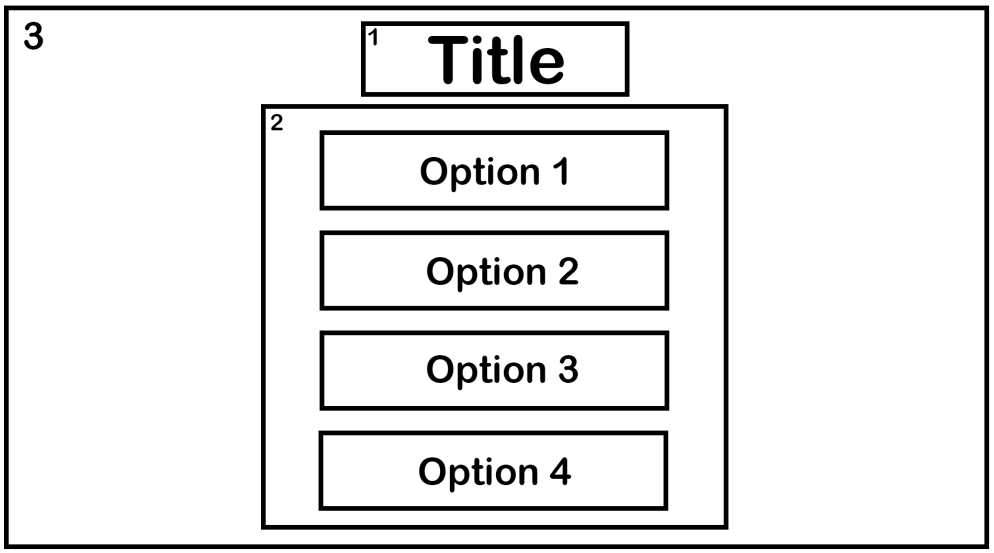


Figure 19: Simple wireframe template shown to participants.

In this activity participants included many of the same features in their designs; three of the four participants included character customization, further highlighting its popularity from the first workshop, furthermore two participants gave the option to give the character a name. Similarly every participant included an option for a story, wanting the game to have a playable narrative, although at this point it was clear what the story would be in this game due to the previous workshop. Two participants included the option to change the background in their designs, this was not a feature I had given any thought to but could be easily implemented. As well as features, the same design choices for the menus could be seen through the four designs, with three of the participants including an image of the player's

custom character on the main menu. Following this activity, I used the participants' menu designs to inform both the layout and content of the games menus. *See appendix 8.25 for participant menu designs.*

Summary of fourth worksop

In summary the fourth and final workshop once again, continued to advance the project significantly, and did so in two distinct ways. First this workshop allowed participants to see all the work we have produced so far. In the workshop participants were shown the character designs and storyboards which we had produced and on the whole were very happy with the designs. It seemed here that participants felt represented by them despite small changes that may have happened when either adapting their character designs to match the overall style, or when merging the two stories. I felt therefore I could continue with the development of the game, confident that it was not straying too far from participants' input. Similarly, I was able to share a very early version of the game, the first two levels, with some of the story, via screen sharing. Participants were able to provide some vital feedback and ideas here and their input informed key design decisions for the game going forward. It was clear from participants that the user interfaces, both in game and menus, needed to be more engaging and eye-catching, and this was changed following the design sessions. One participant highlighted difficulties they had understanding some of the language used in the story text, not understanding "get'em" as a colloquial use for "get them". This made it clear it was necessary to keep the language as easy to understand as possible, to limit confusion and make the game as readable and usable as possible. Except for these small issues, participants seemed pleased with the game, although they may have been more excited had they been able to play it, which was not possible due to covid.

The second way this design workshop advanced the project was through the main activity in which participants designed a main menu for the game. As stated above these designs informed both content and the design of the menu used in the final game. In regard to content, character customization was once again popular, with all participants including this as an option in their menus, although I had decided that it would be included already, this only served to further highlight its importance. Similarly two participants suggested the option to change the background of the main menu, a feature that I was able to include. In this activity participants also highlighted features which were not necessarily feasible given the time and scale of the project. Participants suggested features such as a store with an ingame currency, which players could purchase items for the character to wear. This feature while interesting was not possible, given time available for development but was something that could be considered at a later date. As stated above the design and layout of the menu was also informed by designs in this activity. Three of the four participants included an image of the player's custom character on the main menu. I felt this was an interesting design choice and again something that could be easily implemented.

4.3 Summary of Design Workshops

Overall the co-design was a key step in the process of developing and designing a video game for children with DCD. Through these workshops the co-designers and I attempted to build a game that could not only be effective in supporting children with DCD but also enjoyable to use. And although the focus of these workshops was on design of the game and we were not able to discuss DCD itself, key findings related to DCD did appear.

In the first workshop we discussed generally what participants did for fun, and what they liked in the games they played. The key findings of this workshop were around the platform the game would be built on a tablet, due to participants highlighting their extensive use of tablets in both home and at school. These workshops also led to some key findings about what the content of the game would be with participants highlighting both humour and story as some of their favourite elements of the game. One interesting finding was participants dislike and lack of interest in competitive elements such as the high score and the ability to share your scores with other, this is reminiscent of some of the literature, which suggested that children are aware of their difficulties and their clumsiness (Mandich et al, 2003), and initial interviews where participants stated that children can feel singled out and suffer from low esteem and therefore many not want to have to compete with others. In the second worksop, we focussed on character designs and were able to design 5 characters for the game. In this workshop we also once again discussed features of the game, with participants highlighting their want for a character customisation feature, something that was popular in the first workshop and a reward system. The idea of a reward system was interesting, as while they did not want to have scores and compete with others, possibly because of reasons discussed above, they did want to receive rewards for performing well in the game. In the third workshop, we focused on story and by creating two stories in the two groups and combining them, we were able to create a story for our game. This workshop focussed on story and we were not able to explore many other elements of the game. In the fourth and final workshop we focused on the user interface of the game and once again, participants highlighted key features they wanted in the game such as character customisation and the ability to customise the background and look of the menu, both features I was able to implement. The co-designers also highlighted features I would not be able to implement such as an in game store to further customise their character.

Chapter 5 Second Expert Interviews and Final Game

Chapter 5 has two main sections, the first explores the second round of expert interviews in which I shared the work done up to that point for feedback as well as used it as an opportunity to gather additional ideas for game mechanics. The second section describes the game itself, the core mechanics and additional features.

5,1 Second Interviews

Once the fourth and final workshop was completed, the next task was to complete developing the game which had been designed in the workshops. However, before completing this development, I felt the project would be best served by having another meeting with the experts I had spoken to in the initial expert interviews, to share what had been produced so far and discuss other ideas for a video game designed to help children with DCD. The experts were able to give feedback on whether they felt the ideas I had developed were appropriate and useful and give recommendations to other ideas which could be developed. I conducted three follow up interviews with the Occupational Therapist (OT1) and the two special needs teachers (SN1 and SN2), who I spoke to in the initial expert interviews. Experts were first shown the work that had been produced so far, through screen sharing while the game was played, before being asked if they felt it was valuable, how it could be improved and other ways in which video games could be used to support children with DCD.

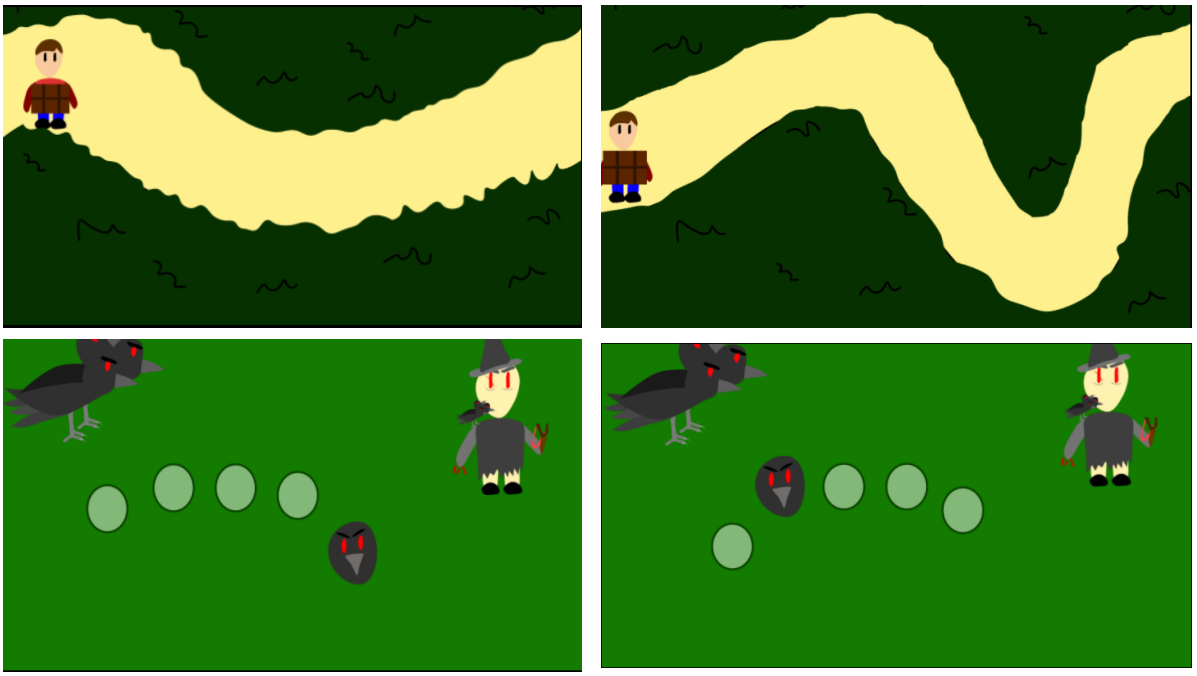


Figure 20-23: Top right and left: Early version of first level, Bottom Left and Right: Early version of the second level.

In these discussions participants were presented with early versions of two levels of the game (fig 20-23). In the first level, the player was required to drag a character along a path and, in the second level the player was required to tap items on a screen, using a different finger for each element.

5.1.2 Feedback

Overall, the experts felt the work produced to this point was valuable and had the potential to be used as means of support for children with DCD. SN1 remarked that the first level reminded them of handwriting training they have used to support children with DCD, referencing the Teodorescu handwriting programme. Similarly SN2 stated that the second level reminded them of activities they have done with children with DCD to help develop their fine motor skill and finger dexterity. They referenced an activity in which they would have children tap each finger to their thumb.

When asked about how these levels could be improved, participants did offer some key recommendations. SN2 stated that while the idea behind the second level is strong, there is no guarantee that children would use it in the way it was intended, and rather than using a different finger each time, they may simply just use the index finger. To avoid this SN2 recommended using a handprint to remind players they are supposed to use a different finger and have multiple items appear at the same time to make sure they don't use one finger.

As well as ways the current levels could be improved, experts offered ways the game could be expanded and other ways this game could be used to support children with DCD. SN1 stated that while they liked the handwriting programme elements they felt these could be strengthened by having another level in which participants not only follow a path but also draw simple shapes. OT1 also offered another level stating there should be a level in which players have to do two different things with each arm, as an attempt to improve bilateral integration. They also stated that a level in which participants trace over shapes would be a valuable expansion of the levels shown to them.

5.1.3 Conclusions

The information gathered in these follow up interviews, much like the initial interviews helped form the core ideas for the game mechanics while also providing feedback on the mechanics already created. The feedback in these interviews, combined with information from the literature led to the ideas for two additional game mechanics for the game.

Participants stating that a level in which players complete two actions at one point time, with each hand doing a different action, as a way to challenge bilateral integration inspired the game mechanic which can be seen in *figure 24.* This mechanic was also inspired by literature, which states that bilateral integration or bilateral coordination, the ability to coordinate both sides of the body at once, is something that people with DCD struggle with (Biotteau et al. 2019).

Figure 24; Bilateral Integration mechanic inspired by the second interviews. Players with one hand move the screwdriver in a circle and with the second hand tap the highlighted buttons which light up and the screwdriver moves.

Similarly, participants stating that handwriting activities in the game could be strengthened by having participants trace over shapes as well as following paths inspired the game mechanic which can be seen at *figure 25.* This was again inspired by fine motor skills and handwriting exercises such as the Teodorescu Handwriting Program (Teodorescu et al. 1996).

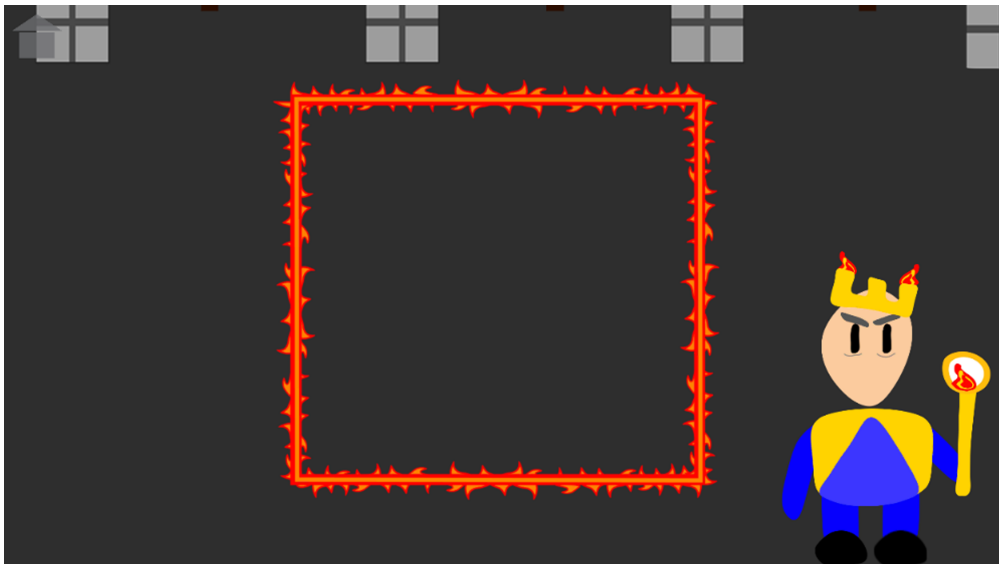


Figure 25; shape drawing mechanic inspired by the second interviews. Players trace over three different shapes with the accuracy measured. If they are not accurate enogh they have to try again.

5.2 Final Game

As is described in section 4.2 the game's characters, story, user interfaces and features were thought of and designed by children with DCD, while the game's mechanics were designed and created based on the input of experts such as special needs teachers and occupational therapists. The game has four different interactions, all of which attempt to challenge and improve the user's fine motor skills in different ways. As stated in the introduction, some of this work builds on work from an undergraduate project in which prototypes of games for children with DCD were developed with input from experts. The sound effects used in this game were obtained from https://www.zapsplat.com.

As stated in the introduction, the game can be viewed at;
https://youtu.be/6PDgdmpCHyQ

5.2.1 Narrative and Characters

The game's narrative and characters are designed by the child co-designers, the game features 6 characters, the hero, who is design using the character customisation feature discussed in 5.2.5.1, an evil witch who the player must defeat early in the game, a military general who takes the hero on an adventure, an evil fire king, the king's monster guards who the player must sneak past and the king's robot guard who the player must also defeat. Designs for the characters can be seen in appendix 8.12-8.21. The game's narrative has the player initially travel through the woods to make a delivery, where they encounter the evil witch who they must defeat, they then return to their village to find it has been destroyed by

the evil king and they must travel with the military general to defeat the evil king. The player must then sneak into the castle past the king's guards, before having the battle between the king and the king's robot; the storyboards developed by participants can be seen in the appendix 8.22-8.24.

5.2.1 Interaction 1- Following a Path

The first interaction that the player encounters has the player drag a character with their finger across a narrow path. This attempts to challenge their fine motor control by asking them to follow a narrow path without deviating from it. If they deviate from the path, their health will fall and if their health falls to zero they will have to start again.This interaction appears throughout the game with slight changes. The second time this interaction appears the player must move the character from right to left, instead of left to right in the first level. The next time this interaction appears the player now has to drag two characters across the map, increasing the difficulty.. The final time it appears the player now has to avoid moving objects introducing timing as an element in the game (fig 26-29).

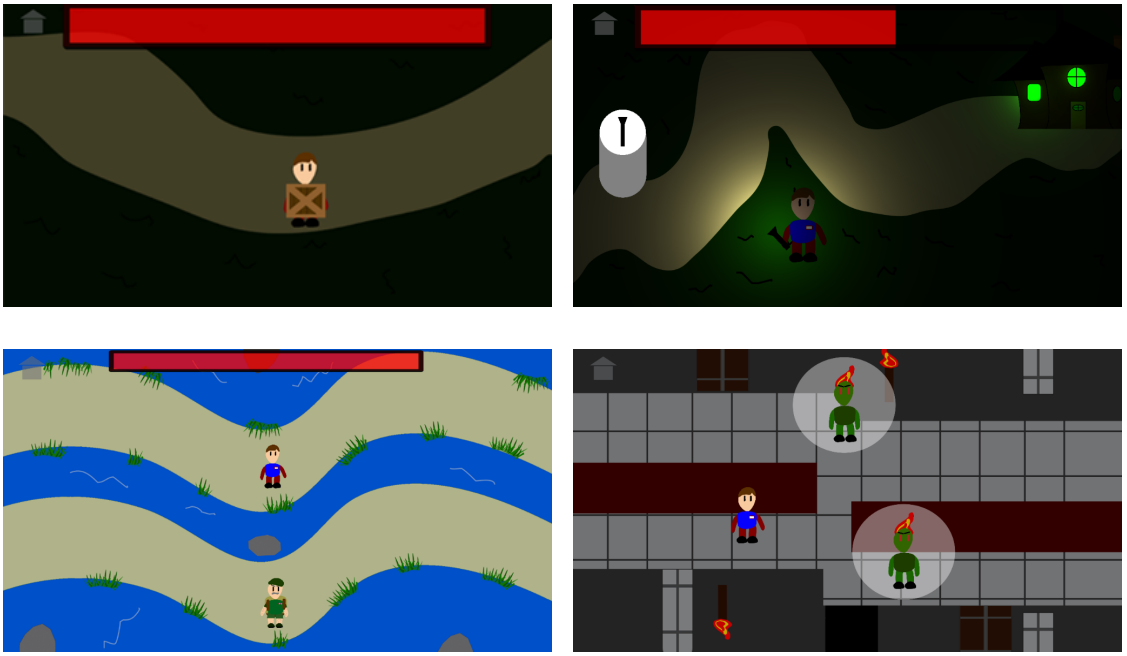


Figure 26-29: Examples of the first interaction.

5.2.2 Interaction 2- Finger Tapping Game

The second interaction of the game has participants tap on objects on screen as they appear, encouraging them to use all of their fingers. This interaction builds on work from my undergraduate project, referenced in the introduction, however it has been expanded further and does not use any of the code from that project. *See appendix 8.31.* The activity has participants first use their right hand, tapping an enemy as they appear in a space designated for each several finger. The enemy appears on screen for at first two seconds before it

disappears and another enemy in a different finger space appears. If the player taps the enemy before those two seconds are up they will hit the enemy, they will gain a point, and the enemy will be destroyed a sound plays here to make it clear to the player that they hit the enemy. If the player does not hit an enemy within two seconds their score will go down. The player does this for ten seconds before switching hands. If their score is high enough after using both hands they will progress to the next sub-level. The levels with the interaction are broken into three different sublevels with varying degrees of difficulty. In the second sub-level the player will now have to tap two enemies at the same time forcing them to use more than one finger at the same time. In the third sub-level, again two enemies will appear at the same time however now the enemies reappear and disappear in less time. This interaction appears twice in the game (fig 29-32).

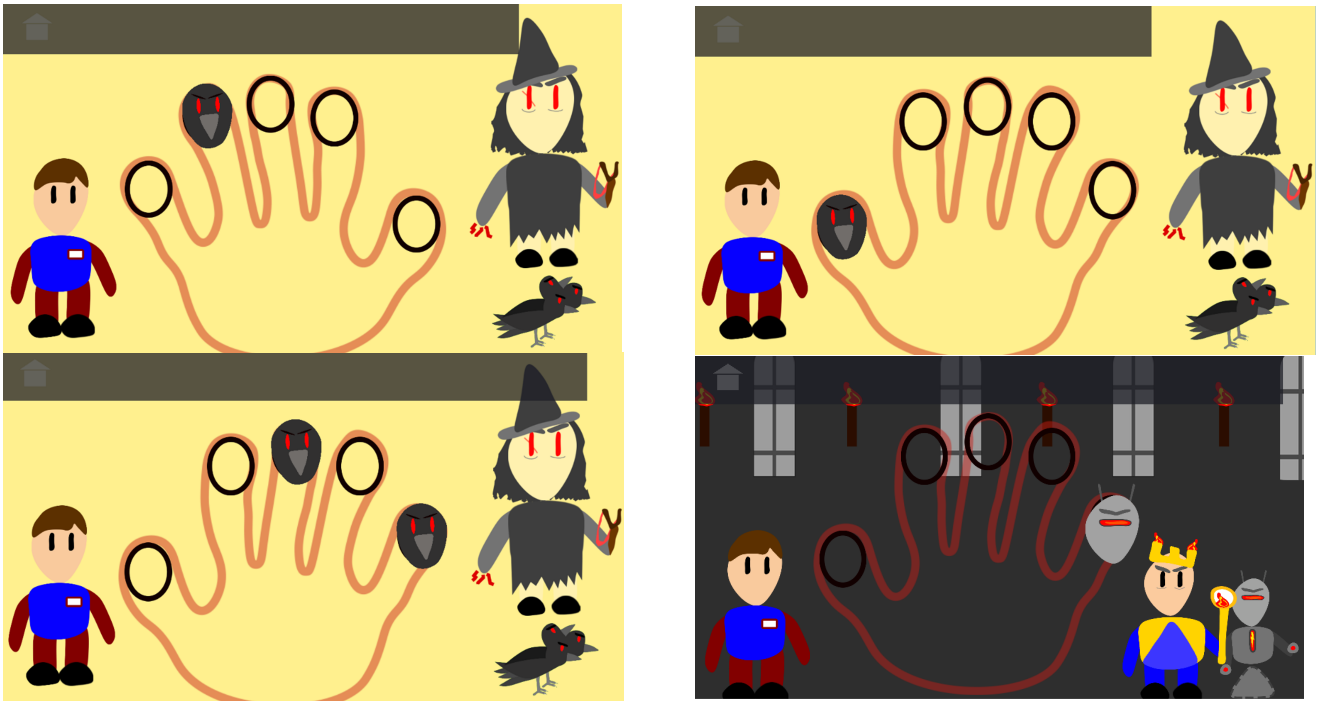


Figure 29-32: Example of second interaction.

5.2.3 Interaction 3- Dual Action Game

In this activity the player with one hand has to spin a screwdriver around in a circle while tapping certain buttons with their other hand, to enter a code, there are four codes, each four digits in length, if they enter four codes successfully the door is unlocked. As they turn the screwdriver the button they are supposed to enter is highlighted, once they stop turning

the screwdriver, they will not be able to enter the code. If they are unable to enter the code they will be allowed to try again. This interaction only appears once in the game (fig 33-34).

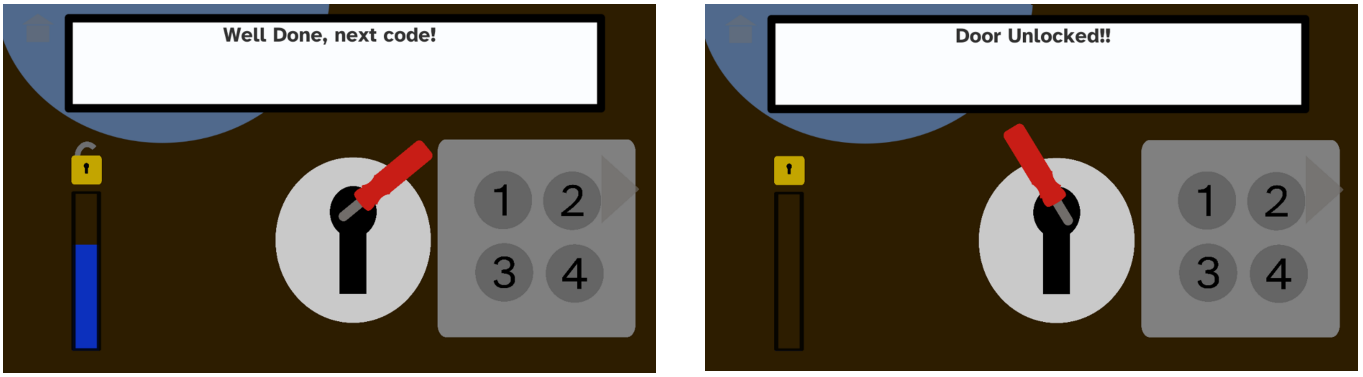


Figure 33-34: Examples of third interaction

5.2.4 Interaction 4- Shape Tracing

The fourth interaction of the game has participants trace over shapes while measuring the accuracy of their drawings. In this activity the player has to trace three shapes, first a square, then a triangle, then a circle. If they do not draw the shape accurately enough they will be made to try again. Much like the first interaction this activity challenges the user's fine motor control. Again, this interaction builds on work from my undergraduate project. Once again it has been expanded further and does not use any of the code from that project. *See appendix 8.32.*

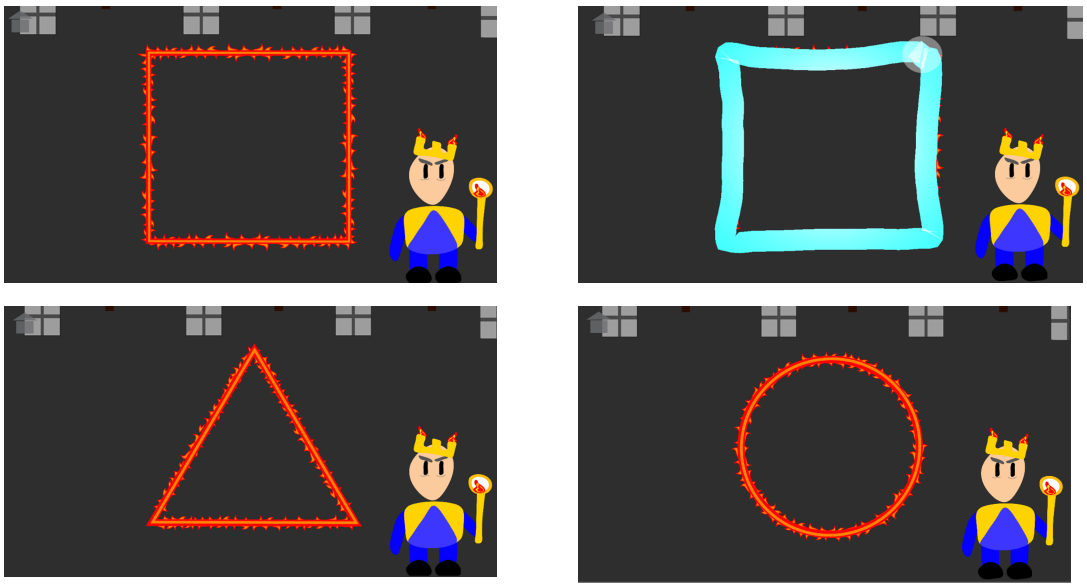


Figure 34-37. Examples of fourth interaction

5.2.5 Other Features

As well as characters and story, participants contributed ideas for a number of other features that were implemented into the game.

5.2.5.1 Character Customisation

The ability to create custom characters was very popular with participants in the design workshops and is a feature I was able to implement into the final game. In the game participants can customise the main character to look as though they would like them to look. Players can change the characters head and hair, torso, arms, and legs, they can also give the character a name. I created the options here, and they were designed with the diversity of the game in mind. The options attempt to represent different ethnicities and genders to make sure all different players feel represented in the game (fig 38).

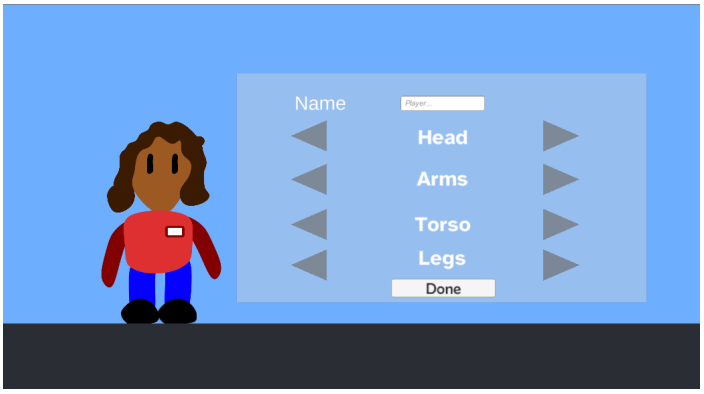


Figure 38: Character Customisation Screen

5.2.5.2 Backgrounds

The ability to select different backgrounds for the main menu was an additional feature that was implemented by request of the co-designers. Players can choose between five different backgrounds, each of which represent a different level in the game. The background menu can be accessed from the 'Backgrounds' button on the main menu.

5.2.5.3 Rewards

Another feature of the game, repeatedly suggested by participants in the design sessions, was a reward system which would reward the player based on how well they complete each level of the game. The rewards take the form of a bronze, silver, and gold medal. These are given at the end of each level and represent how well the players have completed the levels. The medals the player collects are displayed next to the level they achieved it in in one of the game menus (fig 39-41).

Figure 39-41: Example of reward system

5.2.5.4 Audio

Audio was used in a limited capacity in the game, with two interactions using audio feedback to make it clear that a button had been pressed, this was in interaction 2, the finger tapping game and interaction 3, dual action game. Sound effects played when participants pressed the enemies in the finger tapping game and the buttons in the dual action games. Audio was not discussed with participants and therefore these sound effects were added by me as audio feedback to make button presses and some screen presses clearer, audio was something that could have been explored further in the project both with the expert and co-designers, this is discussed further in 7.3.

Chapter 6- Playtesting With Teachers

6.1 Introduction and Methods

Once development was complete and the game was finished, I felt the game needed to be tested to see if they would have potential to be used as support for children with DCD. Evaluative testing was conducted with eight primary school teachers in individual 30-40 minute sessions. The goal of these sessions was to test the usability of the games, as well as explore whether they could see the potential of something like this being used as a means of supporting children with DCD. I decided here to test with teachers as I felt they would be able to draw on their experience of how children learn in school and provide feedback on how usable this game would be in a classroom setting and whether it would fit into the school day. The teachers here all stated they had some experience of working with children with DCD, or similar fine motor difficulties.

Unlike the previous stages of the design process, the testing took place face to face, as opposed to online. This happened for two main reasons. First, with the pandemic situation beginning to improve, the university allowed face-to-face research to be conducted (subject to risk assessments and department sign off). Second, as I was testing the usability of the game, it was necessary to have testers to play it. While this could be possible online, it would be extremely difficult and complicated to execute. As stated in 4.1, online research requires participants to have access to certain elements of technology, both hardware and software, as well as a good understanding of how to use it (Kennedy et al. 2021; Orvokki Nygren et al. 2021). Although this was manageable in the previous stages as the only technology required was a computer and access to the internet, to play the game for playtesting purposes, all testers would need to have access to an android tablet, as well as the ability to install and run an android executable file (apk). While this could have been solved by providing testers with an android tablet with the game installed, I felt this would be simply too difficult to organise and time-consuming. Based on this, despite some advantages of online research, such as the ability to recruit and work with a large number of participants easily and quickly (Kennedy et al. 2021; Orvokki Nygren et al. 2021), I concluded that face-to-face research would be significantly less complicated and difficult to run.

The playtesting sessions consisted of three main activities, all of which attempted to address the goals of the sessions in different ways. Before the activities began testers were provided with an information sheet and consent form *(appendix 8.26-8.27)*. Additionally I briefly explained the work and the process of working with children as co-designers, who developed the characters and story. It is worth noting that this may have biassed the feedback and focus on elements such as character and story. In the first activity testers were observed while they played the game produced in this project. While they did this observations and notes were made about how they found the game, such as what they found difficult, confusing, or easy and what they liked or disliked. Observations are a common technique in user research and can be a strong source of usability information (Rosenbaum, 1989). They are considered to be one of the strongest methods for usability testing (Diah et al. 2010).

In the second activity testers were given a questionnaire about the usability of the game, featuring slightly amended questions from the system usability questionnaire scale (Brooke et al. 1996). I chose to use the SUS as it is considered to be a valid means of measuring the usability of the system and can effectively distinguish between usable and unusable systems (Brooke, 2013). The questionnaire features 10 questions, and as stated earlier, some minor changes were made to make the questionnaire more appropriate for use here, questions can be seen in the appendix at 8.29 They answered these questions by saying how strongly they agree or disagree with the statements. They rated their responses out of five, with one being strongly disagree and five being strongly agree.

The sessions ended with a short interview in which testers were asked five questions about the game, exploring what they felt worked, what didn't work and what they would improve, questions can be seen in the appendix at 8.30 The answers to these questions were made note of on paper while testers spoke. I chose to end with an interview as it would allow them to share some more detailed information on their experience with the game. While the SUS can provide valuable feedback on how usable the system is, it does not provide diagnostic information, such as explaining why participants are responding in the way they are (Ibid). By including these discussion questions testers are allowed to explain what specific elements worked and what did not. Testers will be referred to by a code in this section T1 (Tester 1) to T8.

6.2 Results

6.2.1 Observations

As stated above, I began the playtesting by observing testers playing the game. During this activity several interesting points about the game were noticed. First there was some confusion and difficulty with the user interface elements. Every tester had some difficulty with knowing what was a button and when they should press it. This would happen at start when they are supposed to press an arrow to continue to the next set text. Once the button was pointed out to them testers didn't continue to have this difficulty. Nevertheless it highlighted how the user experience could be improved by making user interface elements clear (fig 42).

Figure 42: Arrow which testers had difficulty (right)

T7 remarked that they felt the font may not be the correct font to use with young children as the letter 'a' is different from the one they are taught in school. Rather than a double storied letter 'a' I should have been using a single storied letter 'ɑ', such as the one used there. While I had considered fonts using 'Atkinson Hyper Legible, a type face specifically designed for those with visual impairment (Crook, 2020), I had not explored the correct font to use for young school-aged children. This again is something that could be explored and improved with further work.

In regard to the gameplay, the observation activity implied that testers enjoyed the game, however this was specifically explored in the third activity, the discussion questions. They particularly seemed to enjoy the levels in which they used the finger tapping interaction. T5 and 6 found gameplay quite hard, although they seemed to know what to do initially, but after a few attempts, they grasped the mechanic and were able to progress.

6.2.2 Questionnaire

In the second activity, testers filled in a questionnaire using the System Usability Scale (SUS). The game received an average score of 89.375. Any score above 80.3 is considered excellent and within the top tenth percentile (Anon, 2017). While this was certainly not a rigorous quantitative study and I was not intending to use it as clear evidence for the effectiveness of the game, the questionnaire suggests the game is usable and has potential to be used as support. The questionnaire also allowed testers to begin to think how they felt about the game before moving on to the discussion questions. By allowing testers an opportunity to reflect on the experience of the game before asking them some more detailed questions it gave the best opportunity for thought-provoking points in the discussion questions. *For a full table of results see Appendix 8.30.*

6.2.3 Discussion Questions

In the third and final activity, I conducted short interviews with the testers in which they were asked five questions about their experience of the game, exploring which elements worked well, what could be improved, and what should be explored further. *See appendix 8.29 for these questions*

When asked what worked best about the game testers gave a range of answers, with some more common than others. One of the most popular answers here was the story, with six of the eight testers stating they felt this was one of the best features, with T4 stating it was key to “holding [the children's] interest” and T2 and 5 stating it is good for engagement. Testers also highlighted that they felt the levels worked well. Four of the eight participants highlighted the second interaction, the finger tapping game, as being useful and enjoyable, T4 stated that it was challenging but could be very rewarding when helping children with DCD. Similarly, T1 stated that they felt it “worked well”. Testers also highlighted the first interaction, the path following game, as being valuable, with T7 stating they felt it was useful as it was very similar to activities that they already do to improve the fine motor skills and handwriting of children who need support. Similarly T4 and 1 highlighted interaction four, in which participants trace over shapes, as being useful, again stating it reminded them of activities they use with children struggling with fine motor skills. They did both state however that this could be expanded upon to include more complex shapes. Furthermore, T3 highlighted the third interaction as being valuable, as it would improve their “bilateral coordination”, having them use different sides of their body for different actions. They said this could have been used more throughout the game, as here it only appears in one level.

In these interviews, we also explored what may not have worked as well , and what could be improved. These issues were mostly resigned to the user interface (UI) issues which were explored in the observations section, Six of the eight testers did highlight this as an issue they had. T8 said they felt that the buttons could have been made clearer and T5 and 6 felt like the UI could be improved by using a different colour for some of the buttons. Another issue highlighted by testers was the lack of auditory and visual feedback. T2 , 3, and 8 highlighted the lack of audio feedback in the game as an issue, they felt like where it was included it was very useful but could be used in more places such as button presses or when players stray off the path, when using the first interaction. Furthermore T1 and 7 also stated that while they enjoyed the inclusion of medals when successfully completing the level, more could be made of this such as celebratory sound, in order to give the player a stronger sense of accomplishment.

6.3 Conclusions

The playtesting sessions were on the whole positive and led to a number of key findings which could inform further iterations of the game. Firstly based on the System Usability Scale (SUS) the game received a positive score, suggesting that it is a usbable game, however the subsequent feedback suggested there a number of ways the usability could be improved and built on. Based on the feedback, it is clear that UI elements like buttons could be made more obvious, by using more distinct colours in order to make the user experience more seamless and easy to use. Similarly, participants highlighted a lack of auditory and visual feedback in both the game and the user interfaces, something that again could be worked on to make the user experience easier. It can be stated that therefore while the game is certainly usable there are a number ways its usability could be improved.

In regards to the actual game, once again feedback was largely positive, however there were a number of ways the game could be strengthened. Firstly it seemed like some of the elements were underdeveloped and could be expanded, specifically the shape tracing game and the bilateral integration game; participants suggested that both these elements of the game are underused and could be expanded in future versions. Similarly the play testing suggested that the rewards system could be improved allowing players to be better rewarded for their achievements, create a better sense of achievement and hopefully in turn increase engagement.

Chapter 7- Reflection

In the introductory chapter of this thesis, I stated that the goal of this design project was to design an interactive media narrative game which can be used as means of support for children with DCD by working with both experts in the field of DCD and children with DCD as co-designers. This chapter will reflect on the design process and look at why and how it was able to achieve its goal. Additionally this chapter will reflect on difficulties that were faced and how they impacted the project's success. Finally this chapter will explore the possible future work that could be explored.

7.1 Goals

The co-design process sought to combine the work of two distincts groups of participants (experts in DCD and children with DCD), both serving as co-designers with different roles in developing and designing a game for children with DCD. By working with experts in both the initial and follow up interviews I was able to draw on their expertise and develop a game for an area in which I am not an expert. The process supported the notion that games address fine motor skills, and gave ideas for how to do this, such as typing activities, using early writing practice and bilateral integration activities. Overall this process was a success and this is reflected in the playtesting, in which the testers, who were also experts, highlighted the various interactions of the games as being valuable in supporting children with DCD and stated they often reminded them of techniques they had used.

On top of fine motor skills, one of the most significant difficulties that appeared in both the literature review and in the initial interviews was DCD's impact on the social emotional wellbeing of children with it. Due to the limited scope and timeframe of the project, and due to further ethics approval required for work with children which there was not time for I was unable to run testing sessions with children and opted instead to work with experts. And while this came with a number of advantages I was unable to run a testing program in which the game's effectiveness of improving social and emotional wellbeing was tested. It is impossible to say whether the game is effective in improving social and emotional well being. However, since the expert participants, specifically the occupational therapist, stated that children's social and emotional difficulties come from low self esteem because of poor performance and literature suggested that children can often be aware of their failures leading to low self esteem (Mandich et al, 2003), it could be argued therefore by trying to improve fine motor skills, the self esteem and confidence of children with DCD could be improved.

The second group of participants I worked with were children with DCD, and their primary role as co-designers was to ensure the game developed in this process was fun and something that children with DCD would want to use. As stated in the literature review and design workshop sections, many educational games for children were "not as fun as children

expect" (Padilla-Zea et al. 2014) and this was something that I wanted to make sure was avoided. In this process, co-designers were given the responsibility to design the characters, the story and the user interfaces of the game. By allowing children with DCD to adopt these key roles and recognising this by providing them with a bespoke Design Kit sent to them in the post, I felt once again I could draw on their expertise of what they enjoy in video games, producing something which is not only helpful but enjoyable. I feel this process was a success and the work produced can serve its dual role of an enjoyable, yet valuable game, thanks to the ideas and work produced by the co-designers. Although ideally the game would have been tested with children, as well as adult experts, to explore whether this process had been a success, the design process meant I was able to achieve regular feedback on how much the co-designers liked the game throughout. While participants designed these key elements, I developed them into a working game in-between workshops and was able to share the game in various states and ensure it still represented their ideas and designs.

Another success of the process was the enjoyment and engagement of co-designers in the design process. On the whole the co-designers seemed to enjoy the project, growing more confident in talking to me and remaining engaged throughout. All participants except P5 were present at all the design sessions, with P5 only missing one due to a scheduling conflict. Given the difficult circumstances of online co-design and a relatively extended period of engagement in the co-design process, being able to design and run a series of workshops which engage participants throughout was certainly a success.

Overall I feel the co-design process allowed this project to achieve its goal of developing an interactive media video game, which could be used as a means of support for children with DCD and is fun and engaging to use. Furthermore I feel this project suggests that using a co-design process which makes use of expert interviews and co-design techniques with children is an effective way to design and develop such a tool, allowing the perspectives of those with current, first-hand experience to be the driving creative force behind the project. I believe the approach used here led to higher quality output than other similar methods such as a more traditional user centred design method would, as it was the most direct way in which the end users and experts could influence the design. Additionally, I felt that by allowing users to design key elements as opposed to taking part in a user centred design process, created a strong sense of ownership of the project and therefore encouraged sustained engagement as participants wanted to see the project to completion. The 5 co-designers were present for all the sessions, except one participant who missed one session. This sustained engagement helped the project produce high quality output as I was able to use participants first hand experience to design all elements of the game.

7.2 Findings

As well as achieving its goals, this project also led to a number of findings and insights. The main finding of the project came from play testing with teachers which suggested that a touch screen based fine motor skills game could be an effective means to

support children with DCD and this could be expanded to address many of the other impacts of DCD. Beyond this main finding, there were a number of sub-findings which came from different stages of the process. In the initial expert interviews, we discovered the most significant impacts of DCD, with participants highlighting poor fine and gross motor skills and more specific difficulties such as poor handwriting and difficulty with activities such as riding a bike. Similarly participants highlighted the impact of DCD on social and emotional wellbeing, stating that children with DCD can feel left out and can have poor self esteem. These opening sessions also led to insights about how DCD is supported, with the key points being using play and fun activities as a means of support, such as dot to dot puzzles and typing games as well as repeating activities as much as possible. Furthermore these workshops highlighted the ways in which means of supporting children with DCD are lacking, highlighting the lack of availability of support, and access to occupational therapists. The findings in the design sessions were mostly focussed around what could be included in the game, but these sessions served to prove how working with children with DCD to design a game for support can be an effective method. By taking existing therapeutic activities and translating them into a tablet based video game, I believe I have created a tool which could be used by children with DCD to supplement occupational therapy and SENCO support while at home and where this support is not available. These therapeutic activities are combined with video game elements such as narratives and characters to make the game fun and engaging. And while in order to fully implement many of these elements would need to be expanded, early results from testing show the game to be an effective proof of concept for this idea to be explored and developed further.

7.3 Limitations of Work

As stated above, while I feel the project and its process was successful, it was not without its limitations. Although the online workshops were designed to allow participants to be as actively involved as possible, I was not able to have participants interact directly with the development of the final product, whether that is participants playing early prototypes or evening using a simpler system such as Scratch and allowing the participants to code themselves. The rationale behind using a co-design process was to give participants as much control as possible over design and development of the game, to allow the participants' personal experience and expertise to drive the design process. By being unable to participants direct interaction with the product and instead relying on their feedback and my interpretation of the feedback, may have limited how much these designs reflect participants' ideas. In the introductory workshops, I did have to manage the expectations of some of the participants, who expected to be building the game themselves. After their role had been clarified they were happy with it, although it could be argued that the work could be improved by allowing them to be more actively involved.

There were also limitations around the diversity of the participants. All the children with DCD who I worked with were white, assumed male and from the UK. This meant that while the game produced may represent the likes, dislikes and contain ideas of these participants, it may not be representative of a wider, more diverse population. By using a

more diverse group of participants, the design process would stand a better chance of producing a game which is enjoyable for a wide demographic of users. I had hoped to recruit a more diverse group of participants but was unsuccessful, there was simply not enough time to attempt a second round of recruitment.

Another limitation came in the testing phase, although I was able to test the game with experts, I was unable to test the game with children with DCD, i.e. unable to run actual user testing sessions with potential end users. This meant that while the design process suggested that I had made something that children with DCD would enjoy, I was unable to use this phase to test this with children, whether they had DCD or not.

One final limitation of the game and project was the lack of focus on audio. Although, as stated in chapter 5, audio was used in a limited capacity in the game, it was not used as much as it could have and was not discussed at all during the design process with either groups of participants, due to lack of time. Audio can be an extremely valuable tool in creating engaging effective interactive experiences and this could have been used throughout the game. Furthermore it could have been discussed with both the expert participants, to explore how they might use audio to help support children with DCD, and with the children with DCD, to ensure audio is used in a fun and engaging way. The lack of audio was highlighted by participants in the user testing section, further underlining the game's limitations in this area.

7.4 Future Work

Following the completion of this design project there are several ways that the work could be continued and expanded upon. Firstly, while the expert testing at the end of the project did suggest that the game produced could be a useful tool when supporting children with DCD, a rigorous qualitative test in which the effectiveness of the game is tested with children with DCD could be extremely valuable. A longitudinal study and randomised control trial (RCT) with a large sample size could be used to test whether the game produced in this project leads to improved fine motor performance in children with DCD. Additionally a longer study could be used to explore how effective this game is improving the social and emotional wellbeing of children with DCD, as this was also one of the most significant impacts of DCD. This again could be testing with longitudinal study and RCT with a large group of children with DCD.

Another possible future expansion of this study would be to explore how video game tools could be used to improve other difficulties of DCD. While the game in this project attempts to improve fine motor skills as this was one of the main difficulties highlighted by experts in the initial interviews, it was not the only difficulty that experts referenced. Other difficulties, such as poor gross motor skills, were also mentioned by many of the expert participants. A future version of this project could explore how video games could support other issues of DCD.

As stated in 2.2.1, interventions for DCD need to be repetitive and used over a long period of time to be effective, therefore if this game was to be further developed it would need to be designed for repeated use. This could be done in a number of ways, such as adding a minigames section in which players can play the interactions from the stories for a score which they can then try to better. Similarly it could be expanded by creating new story campaigns which can be added to games through downloads, which use the same interactions.

Appendix

Table of Contents

66

8.1 Initial Interviews Information Sheet 69

8.2 Initial Interviews-Consent Form: 73

8.3 Initial Interviews- Tagged Interview Transcript 75

8.4 Initial Interviews- Affinity Map: 76

8.5 Design Workshop- Information Sheet: 77

8.6 Design Workshop- Introductory Document: 81

8.7 Design Workshop- Consent From (Adults): 82

8.8 Design Workshop- Consent Form (Children): 84

8.9 Design Workshop 1- Activity 1 Data: 86

8.10 Design Workshop 1- Activity 2 Data: 88

8.11 Design Workshop 1- Activity 3 Data: 90

8.12 Design Workshop 2- Participant 1 Character Design 91

8.13 Design Workshop 2- Participant 2 Character Design 92

8.14 Design Workshop 2- Participant 3 Character Design 93

8.15 Design Workshop 2- Participant 4 Character Design 94

8.16 Design Workshop 2- Participant 4 Character Design 95

8.17 Design Workshop 2- Participant 1 Character Sheet 96

8.18 Design Workshop 2- Participant 2 Character Sheet 97

8.19 Design Workshop 2- Participant 3 Character Sheet 98

8.20 Design Workshop 2- Participant 4 Character Sheet 99

8.21 Design Workshop 2- Participant 5 Character Sheet 100

8.22 Design Workshop 3- Group 1 Storyboard: 101

8.23 Design Workshop 3- Group 2 Storyboard: 102

8.24 Design Workshop 3- Combined Storyboard: 103

8.25 Design Workshop 4- Participant Menu Wireframes with annotations 104

8.26 Playtesting- Information Sheet: 105

8.27 Design Decision Making Table 109

8.28 Playtesting- Consent Form: 111

8.29 Playtesting-Questionnaire: 113

8.30 Playtesting-Discussion Questions 114

8.31 Playtesting- System Usability Scale results table 115

8.32 Examples of Undergraduate Work 116

8.33 Examples of Undergraduate Work 117

8.1 Initial Interviews Information Sheet

Coordination and Storytelling: Developing Interactive Media Narrative Experiences for Children with Developmental Coordination Disorder (DCD).

UNIVERSITY of York

Department of Theatre, Film, Television and Interactive Media Ethics Committee

Participant Information Sheet –Anonymous Research

Project background

The University of York would like to invite you to take part in the following project: Coordination and Storytelling: Developing Interactive Media Narrative Experiences for Children with Developmental Coordination Disorder (DCD). Before agreeing to take part, please read this information sheet carefully and let us know if anything is unclear or you would like further information.

What is the purpose of the project?

This project is being performed by George Greaves (gg764@york.ac.uk) who is a postgraduate research student on the MSc in Interactive Media by research at the University of York. This project is being supervised by Debbie Maxwell (debbie.maxwell@york.ac.uk).

The work that is being performed for the assessments within the module is being conducted according to restrictions that have been subject to approval by the TFTI Ethics committee. The Chair of the TFTI Ethics committee can be contacted on TFTI-ethics@york.ac.uk.

For this research project, we are interested in the impacts of DCD in both classrooms and at home, the current ways that children with DCD are supported and how these methods could be improved by using interactive media technology and interactive storytelling. Your participation in this project will involve answering questions about DCD, its impacts and its treatments in an interview setting. The interview will take place over Zoom or another video conferencing technology depending on which one works for you, (such as Google Meets).

Please note that to comply with the approved Ethics requirements of this work, we do not intend to discuss sensitive topics with you that could be potentially upsetting or distressing. If you have any concerns about the topics that may be covered in the research study, please raise these concerns with the researcher.

Your participation in this project is voluntary. If you wish, we will provide you with access to the edited film and/or the report that we submit after our marks

have been confirmed. If you would like to receive access to these, you can indicate as such on the consent form.

Interviews will take place over Zoom and will last no longer than 1 hour.

Why have I been invited to take part?

You have been invited to take part because we have highlighted you as someone with relevant expertise in research or working with children and/or DCD. We hope that you would be interested in the project.

Do I have to take part?

No, participation is optional. If you do decide to take part, you will be given a copy of this information sheet for your records and will be asked to complete a participant consent form. If you change your mind at any point during the research activity, you will be able to withdraw your participation without having to provide a reason. To withdraw your participation you need to email George Greaves (gg764@york.ac.uk) and your information will be deleted as soon as possible.

On what basis will you process my data?

Under the General Data Protection Regulation (GDPR), the University has to identify a legal basis for processing personal data and, where appropriate, an additional condition for processing special category data.

For further information and definitions of personal and special category data, please go to:

- https://ico.org.uk/for-organisations/guide-to-the-general-data-protection-regulation-gdpr/key-definitions/
- https://ico.org.uk/for-organisations/guide-to-the-general-data-protection-regulation-gdpr/lawful-basis-for-processing/special-category-data/

Personal data is defined as data from which someone could be identified. For example, in this study we will be collecting your name and email address as this will allow us to send you the final thesis paper should you want access to it.

In line with our charter which states that we advance learning and knowledge by teaching and research, the University processes personal data for research purposes under Article 6 (1) (e) of the GDPR:

- *Processing is necessary for the performance of a task carried out in the public interest*

Special category data is personal data which the GDPR says is more sensitive, and so needs more protection. In this study, we will not be collecting any special category data.

Research activities will only be undertaken where ethical approval has been obtained, where there is a clear public interest and where appropriate safeguards have been put in place to protect data.

In line with ethical expectations and in order to comply with common law duty of confidentiality, we will seek your consent to participate where appropriate. This consent will not, however, be our legal basis for processing your data under the GDPR.

How will you use my data?

Data will be processed for the purposes outlined in this notice.

Will you share my data with 3rd parties?

No. Data will be accessible to the project team and personnel associated with the Department of Theatre, Film and Television at the University of York only.

Anonymised data may be reused by the research team or other third parties for secondary research purposes.

How will you keep my data secure?

The University will put in place appropriate technical and organisational measures to protect your personal data and/or special category data. For the purposes of this project we will store all data using secure University services provided by Google.

Information will be treated confidentiality and shared on a need-to-know basis only. The University is committed to the principle of data protection by design and default and will collect the minimum amount of data necessary for the project.

Will you transfer my data internationally?

Possibly. The University's cloud storage solution is provided by Google which means that data can be located at any of Google's globally spread data centres. The University has data protection complaint arrangements in place with this provider. For further information see, https://www.york.ac.uk/it-services/google/policy/privacy/.

Will I be identified in any outputs?

No. Your participation in this research activity will be treated anonymously and you will not be identified in any outputs.

How long will you keep my data?

Data will be retained in line with legal requirements or where there is a business need. Retention timeframes will be determined in line with the University's Records Retention Schedule.

What rights do I have in relation to my data?

Under the GDPR, you have a general right of access to your data, a right to rectification, erasure, restriction, objection or portability. You also have a right

to withdrawal. Please note, not all rights apply where data is processed purely for research purposes. For further information see, https://www.york.ac.uk/records-management/generaldataprotectionregulation/individualsrights/.

Questions or concerns

If you have any questions about this participant information sheet or concerns about how your data is being processed, please contact the TFTI Ethics Chair (TFTI-ethics@york.ac.uk) in the first instance. If you are still dissatisfied, please contact the University's Acting Data Protection Officer at dataprotection@york.ac.uk.

If you have any questions about the project itself, please contact the producer George Greaves (gg764@york.ac.uk) or project supervisor Debbie Maxwell (debbie.maxwell@york.ac.uk).

Right to complain

If you are unhappy with the way in which the University has handled your personal data, you have a right to complain to the Information Commissioner's Office. For information on reporting a concern to the Information Commissioner's Office, see www.ico.org.uk/concerns.

8.2 Initial Interviews-Consent Form:

Coordination and Storytelling: Developing Interactive Media Narrative Experiences for Children with Developmental Coordination Disorder (DCD).

UNIVERSITY of York

Department of Theatre, Film, Television and Interactive Media
Ethics Committee

Participant Consent Form

Thank you for your interest in this project. This research activity will be used to gather information about DCD and its impacts in classrooms and homes. Furthermore it will be used to gather information about the current treatment methods for children with DCD and how they could be improved. The eventual end goal of this product is to use the information gathered here to develop interactive media narrative experiences to support children with DCD.

Please read the following statements carefully and tick the appropriate box:

	YES	NO
I have read the information sheet about this project.		
I agree to take part in this project.		
I consent to the interviews audio being recorded.		
I consent to the interviews video being recorded.		
I understand my right to withdraw and/or have my data destroyed from this project at any time.		
I understand that my participation in this project will be treated anonymously.		
I am over the age of 18.		

Participant Name:	**Researcher Name:**
_____	_____
Participant Signature:	**Researcher Signature:**
_____	_____
Date:	**Date:**
___/___/_____	___/___/_____

If you wish to be informed about the outcomes from this project, please provide your email address:

_____

8.3 Initial Interviews- Tagged Interview Transcript

In your opinion what is the biggest impact of DCD (on the children)?

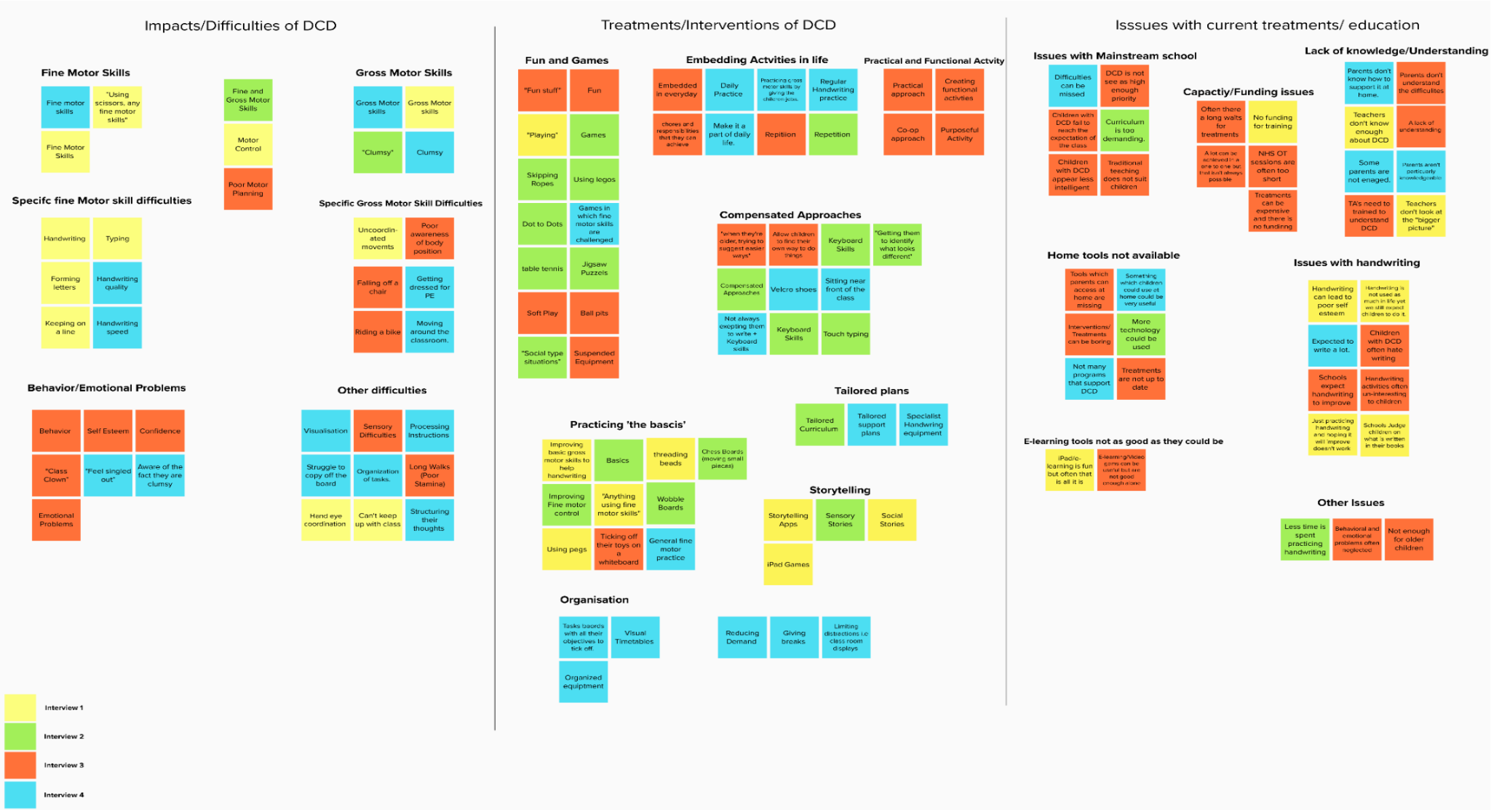
- It's very different for different families, and how families are able to recognize it and deal with it. For me, it's a big thing with confidence, self-esteem, and behaviors. In my longevity of working, I see a lot of children, particularly boys, where there is a higher prevalence, where they have not been able to do things, or it has not been explained to them why, or they have not understood, who have adopted a class clown roll instead, which has exacerbated behavior problems.
There is a lack of understanding, as OT's (occupational therapists) we diagnose DCD in terms of, is it dyspraxia motor planning, is it sensory-based motor disorder, so they have poor awareness of body position, which means movements aren't very coordinated. That one particularly (second) can be very varied, they could be fantastic on a football pitch because they are alert but when it comes to sitting on a chair they are likely to fall off. Then those that have a lot (of problems with) control systems which can impact things like handwriting, which is a massive area for our children with DCD because there is such a big demand in schools and they cant show the level of knowledge and they get frustrated or knocks to self esteem. So to me, it's that and the children have often got amazing siblings, who can do everything, which just isn't fair in life. So to me, it is the behaviors and self-esteem and confidence, whether that is the biggest impact or that it just the things I feel are neglected the most, I don't know.

Question 3

What are the biggest impacts on the people around children with DCD (Teachers, Parents...)?

- I think you often have parents that don't understand the difficulty. Not that children with DCD should not be pushed like anyone else but DCD, if it is a postural one can lead to stamina difficulties, so while all children will winge on a long walk but children with DCD can actually find it hard to do. The bilateral integration of trying to ride a bike can be really difficult for children with DCD and if you are an active family you might just expect your children to learn and you just keep pushing and it can become a bit of a family joke that they are the ones that keep riding into the wall. But then the family can find it quite hard because that is important, with parents who will want to cycle and walk. Which in turn can lead to more avoidant behaviors than you expect to see in children. When you have children you often expect them to fit into your lifestyle and DCD often makes that harder. - DCD doesn't stop them from being an amazingly intelligent person, it is just about getting it out of them. And that's what tends to get a bit missed, 'you can't organize, you can't get your book out of your bags, you can't work from the board' so you can't work the same way. You to establish a new level of what is achievable which isn't necessarily right for that child.

8.4 Initial Interviews- Affinity Map:



8.5 Design Workshop- Information Sheet:

Coordination and Storytelling: Developing Interactive Media Narrative Experiences for Children with Developmental Coordination Disorder (DCD).

UNIVERSITY of York

Department of Theatre, Film, Television and

Interactive Media Ethics Committee

Participant Information Sheet –Anonymous Research

Project background

The University of York would like to invite you to take part in the following project: Coordination and Storytelling: Developing Interactive Media Narrative Experiences for Children with Developmental Coordination Disorder (DCD). Before agreeing to take part, please read this information sheet carefully and let us know if anything is unclear or you would like further information.

What is the purpose of the project?

This project is being performed by George Greaves (gg764@york.ac.uk) who is a postgraduate research student on the MSc in Interactive Media by research at the University of York. This project is being supervised by Debbie Maxwell (debbie.maxwell@york.ac.uk).

The work that is being undertaken for this project is being conducted according to restrictions that have been subject to approval by the TFTI Ethics committee. The Chair of the TFTI Ethics committee can be contacted on TFTI-ethics@york.ac.uk.

For this research project, we are interested in the impacts of DCD in both classrooms and at home, the current ways that children with DCD are supported, and how these methods could be improved by using interactive media technology and interactive storytelling and games. In this project, we worked alongside children who have DCD to design and develop potential methods and tools to help them, with the children acting as co-designers of the game. We are now at the point where the tools have been developed and we are looking to test the usability and enjoyment levels in them.

Your child's participation in this project will involve playing the game produced in the project and answering a series of questions about its usability and their level of enjoyment while playing the game. While they play I will be observing and making notes of any parts they enjoy, don't enjoy, or have difficulty with. These testing sessions will take place in during school (insert here information from the school about the sessions.

Page 1 of 4

Please note that to comply with the approved Ethics requirements of this work, we do not intend to discuss sensitive topics with you that could be potentially upsetting or distressing.

You and your child/children's participation in this project is voluntary. If you wish, we will provide you with access to the report that we submit after our marks have been confirmed. If you would like to receive access to these, you can indicate as such on the consent form.

Why have I been invited to take part?

You have been invited to take part as a parent as a child at Oxton St Saviour's C Of E Aided Primary School, and your child is in the appropriate age group to participate.

Do I have to take part?

No, participation is optional. If you do decide to take part, you will be given a copy of this information sheet for your records and you and your child will be asked to complete a participant consent form. If you change your mind at any point during the research activity, you will be able to withdraw you and your child's participation without having to provide a reason. To withdraw participation you need to email George Greaves (gg764@york.ac.uk) and your information will be deleted as soon as possible.

On what basis will you process my data?

Under the General Data Protection Regulation (GDPR), the University has to identify a legal basis for processing personal data and, where appropriate, an additional condition for processing special category data.

For further information and definitions of personal and special category data, please go to:

- https://ico.org.uk/for-organisations/guide-to-the-general-data-protection-regulation-gdpr/key-definitions/
- https://ico.org.uk/for-organisations/guide-to-the-general-data-protection-regulation-gdpr/lawful-basis-for-processing/special-category-data/

Personal data is defined as data from which someone could be identified. For example, in this study we will be collecting your name and email address as this will allow us to arrange design session times and to send you the final thesis paper should you want access to it. Additionally, if you want to receive a Designer Pack, I will collect your postal address in order to send you one.

In line with our charter which states that we advance learning and knowledge by teaching and research, the University processes personal data for research purposes under Article 6 (1) (e) of the GDPR:

- *Processing is necessary for the performance of a task carried out in the public interest*

Special category data is personal data that the GDPR says is more sensitive, and so needs more protection. In this study, we will not be collecting any special category data.

Research activities will only be undertaken where ethical approval has been obtained, where there is a clear public interest and where appropriate safeguards have been put in place to protect data.

In line with ethical expectations and in order to comply with common law duty of confidentiality, we will seek your consent to participate where appropriate. This consent will not, however, be our legal basis for processing your data under the GDPR.

How will you use my data?

Data will be processed for the purposes outlined in this notice.

Will you share my data with 3rd parties?

No. Data will be accessible to the project team and personnel associated with the Department of Theatre, Film and Television at the University of York only.

Anonymised data may be reused by the research team or other third parties for secondary research purposes.

How will you keep my data secure?

The University will put in place appropriate technical and organisational measures to protect your personal data and/or special category data. For the purposes of this project, we will store all data using secure University services provided by Google.

Information will be treated confidentially and shared on a need-to-know basis only. The University is committed to the principle of data protection by design and default and will collect the minimum amount of data necessary for the project.

Will you transfer my data internationally?

Possibly. The University's cloud storage solution is provided by Google which means that data can be located at any of Google's globally spread data centres. The University has data protection complaint arrangements in place with this provider. For further information see, https://www.york.ac.uk/it-services/google/policy/privacy/.

with this provider. For further information see, https://www.york.ac.uk/it-services/google/policy/privacy/.

Will I be identified in any outputs?

No. Your participation in this research activity will be treated anonymously and you will not be identified in any outputs.

How long will you keep my data?

Data will be retained in line with legal requirements or where there is a business need. Retention timeframes will be determined in line with the University's Records Retention Schedule.

What rights do I have in relation to my data?

Under the GDPR, you have a general right of access to your data, a right to rectification, erasure, restriction, objection or portability. You also have a right to withdraw. Please note, not all rights apply where data is processed purely for research purposes. For further information see, https://www.york.ac.uk/records-management/generaldataprotectionregulation/individualsrights/.

Questions or concerns

If you have any questions about this participant information sheet or concerns about how your data is being processed, please contact the TFTI Ethics Chair (TFTI-ethics@york.ac.uk) in the first instance. If you are still dissatisfied, please contact the University's Acting Data Protection Officer at dataprotection@york.ac.uk.

If you have any questions about the project itself, please contact George Greaves (gg764@york.ac.uk) or Debbie Maxwell (debbie.maxwell@york.ac.uk).

Right to complain

If you are unhappy with the way in which the University has handled your personal data, you have a right to complain to the Information Commissioner's Office. For information on reporting a concern to the Information Commissioner's Office, see www.ico.org.uk/concerns.

8.6 Design Workshop- Introductory Document:

Storytelling and Coordination

Hello!

My name is George Greaves and I am a student at the University of York.

For my research project I am looking to develop an interactive video game, which can be used to help children like you with DCD and I am hoping that you can help me!

What would I be asked to do?

If you decide to take part, you will be invited to become a game designer on the team and to take part in a series of short online interactive design workshops where we will work together to come up with ideas and start to design games. The sessions will take around an hour.
I will need your parent or guardian to be there during the workshops but they will not be asked to take part.

The plan is to have four workshops with you. In the first workshop, I will be asking you some questions about what you would like to see in a game, and we might begin to sketch and draw some ideas.

In the next three workshops, we will continue to come up with ideas and develop the ones we already have. We will also keep drawing and sketching down these ideas. By the end of the last workshop, I hope that we will have some good ideas for games.

These three workshops (if we can arrange it!), will be done in small groups with two other designers like you, and their parents/guardians.

What will I need to take part?

To take part in the session you will need a few things: A computer or tablet (iPad), which is connected to the internet, a quiet space for an hour, a parent/guardian who is able to sit in on the workshops and some pencils, pens and paper.
If you would like we can send you a Designer Pack, which would contain some of the tools to help you come up with ideas and create sketches. This pack will contain pens, pencils and coloured paper.

Looking forward to designing with you!

8.7 Design Workshop- Consent From (Adults):

Coordination and Storytelling: Developing Interactive Media Narrative Experiences for Children with Developmental Coordination Disorder (DCD).

UNIVERSITY of York

Department of Theatre, Film, Television and Interactive Media
Ethics Committee

Thank you for your interest in this project. This research activity will be used to test the usability and enjoyment of games developed over the course of this project.

Please read the following statements carefully and tick the appropriate box:

	YES	NO
I have read the information sheet about this project.		
I agree to take part in this project.		
I agree to allow my child to take part in this project.		
I understand my right to withdraw and/or have my data destroyed from this project at any time.		
I understand that my participation in this project will be treated anonymously.		
I am over the age of 18.		
I consent to my child playing a game designed for children.		
I consent to my child answering a series of short questions about their understanding and enjoyment of a game.		

Participant Name:	**Researcher Name:**
_____	_____
Participant Signature:	**Researcher Signature:**
_____	_____
Date:	**Date:**
___/___/_____	___/___/_____

If you wish to be informed about the outcomes from this project, please provide your email address:

_____

8.8 Design Workshop- Consent Form (Children):

Coordination and Storytelling

UNIVERSITY of York

Department of Theatre, Film, Television and Interactive Media
Ethics Committee

Thank you for your interest in this project!

This research activity will be used to create ideas and designs for games that might help you. You will be asked to write down and draw some of these ideas.

Please read the following statements carefully and tick the right box:

	YES	NO
I have read the information sheet and understand the project.		
I agree to take part in the design sessions.		
I am happy to be audio recorded.		
I am happy to be video recorded.		
I am happy for my writings/drawings to be collected and published in the report.		
I understand that I can stop at any point I want.		
I understand that my name or face will not be shown in any of the project's public information or reports.		

My Name:

_____

Researcher Name:

_____

Researcher Signature:

_____

Date:

___/___/_____

Date:

___/___/_____

8.9 Design Workshop 1- Activity 1 Data:

Participant	Before School	During School	After School	During Weekends and Holidays
1	Play Roblox Watch Youtube. Watch Netflix.	- Running - Playing football - Playing on outside gym equipment - Using the 'Omni Machine' - Lessons: ICT, Food Tech and Design Tech. - Doesn't Enjoy: 'Spelling Shed' and 'Sum Dog'	- Play Xbox: Fortnite, Forza, Fifa and Ark Survival Evolve - Play on iPad - Go to youth club; play football and use computers. - Play online games	- Play Xbox: Minecraft and Roblox Studios. - Play with Animals, dogs and horses. - Meet up with friends
2	Watch Television Not Allowed: Playstation and iPad	- Playing football. - Talking to friends. - Playing with stilts. - Google Classroom - "Learning Websites" - 'Times table Rockstars' - 'Mathletics' - Making websites. - Doesn't Enjoy: 'Spelling Eggs' -	- Play computer games; minecraft and first person shooters - Watch television and films (Pixar)	- Play computer games: Fifa and Star Wars: Battlefront - Walking the dog - Going to the park with friends - Watch educational videos on YouTube about history or geography
3	Watch the news Watch Television (The Flash) Play on playstation (rarely)	- Lessons: Art and Science. - Playing Hide and Seek. - Playing Football. - 'Purple Mash' - 'Mathletics: Multiverse'	- Play football - Play on trampoline - Watch YouTube and television - Play fortnite and minecraft	- Play Fifa - Play rugby - Play football - Ride bikes - Walk the dog - Watch films -

4	Play on a trampet. Play on gym ball Not allowed: on any computers (PC, iPad, Console)	- Recreate Video Games. - Play Tag - Play on monkey bars - 'Nessy' apps - Doesn't Enjoy: Times Table Rockstars.	- Play video games (limited to 30-40 mins) - Writing and reenacting stories. - Talking with family at the dinner table.	- Play video games (more screen time than after school) - Walking - Swimming - Visit friends and family - Read and watch stories
5	Watch television. Watch Netflix Watch YouTube	- Lessons: Design Tech and English. - Playing tag. - Creating their own games. - Doesn't enjoy: Times Table Rockstars.	- Play the '"Lego Video Games" - Play online games - Play with puzzles - Watch YouTube and television - Read up on interests, such as dinosaurs.	- Same activities as after school but for longer.

8.10 Design Workshop 1- Activity 2 Data:

	Participant 1	**Participant 2**	**Participant 3**	**Participant 4**	**Participant 5**	**Average**
Story	**2**	**1**	**1**	**1**	**1.5**	**1.3**
Humour	**1**	**1**	**2**	**2**	**1**	**1.4**
Avatar Creation	**2**	**1**	**1.5**	**1.5**	**1**	**1.4**
Character Customisation	**2**	**1**	**1.5**	**1.5**	**1**	**1.4**
Action	**2**	**2**	**2**	**1**	**2**	**1.8**
Multiplayer	**2**	**2**	**1**	**2**	**2**	**1.8**
Trophies	**3**	**2**	**2**	**1**	**1.5**	**1.8**
Play anywhere	**1**	**2**	**2**	**1.5**	**3**	**1.8**
Easy Difficulty	**2**	**2**	**3**	**1.5**	**2**	**2.1**
Hard Difficulty	**2**	**2**	**2**	**1.5**	**3**	**2.1**
Motion Controls	**1**	**3**	**1.5**	**2**	**3**	**2.1**
Timed Activities	**3**	**2**	**1**	**3**	**2**	**2.2**
Scores	**3**	**3**	**2**	**3**	**1.5**	**2.5**
Share your score with others.	**3**	**3**	**2**	**3**	**1.5**	**2.5**

Realism	**3**	**3**	**2**	**1.5**	**3**	**2.5**

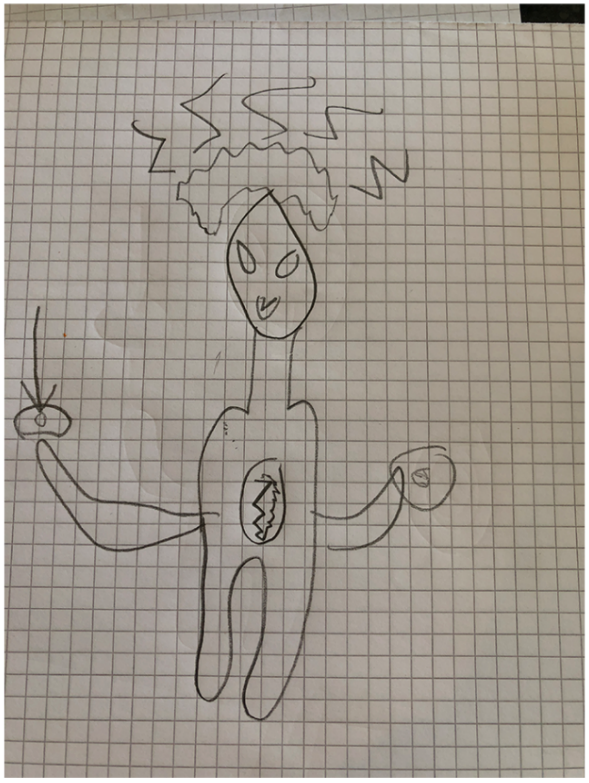
1 = Inner Circle (Most Important) **2 = Middle Circle** **3 = Outer Circle (Least Important**

8.11 Design Workshop 1- Activity 3 Data:

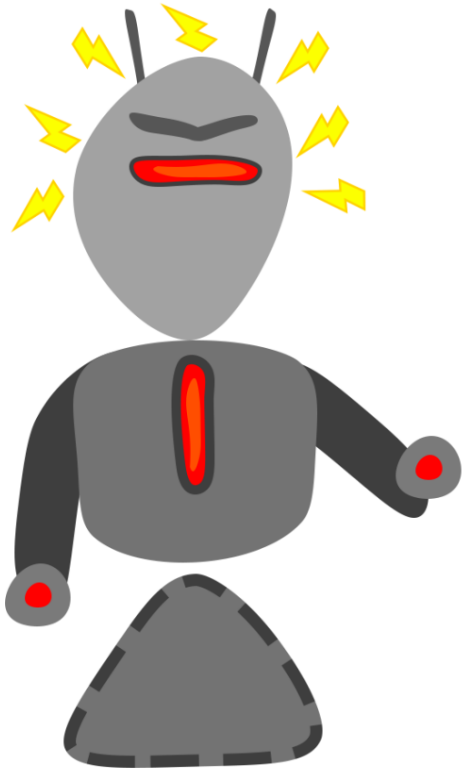
Participant	How is it played?	What type of game is it?	What is the tone of the game?	How does it look?
1	Computer Phone Tablet	Multiplayer Action Story	Funny Dramatic Hard Easy	Colourful Realistic 'Cartoony'
2	PC Tablet Phone Console	Multiplayer Story	Funny	Bright Realistic
3	Phone Tablet	Multiplayer Action Story	Funny Serious	Realistic Dark Bright
4	PC Tablet Console	Story Multiplayer	Serious Dramatic	Bright Dark
4	Console PC	Action Puzzle	Funny	Fun Colourful

8.12 Design Workshop 2- Participant 1 Character Design

Initial Sketch



Potential Design



8.13 Design Workshop 2- Participant 2 Character Design

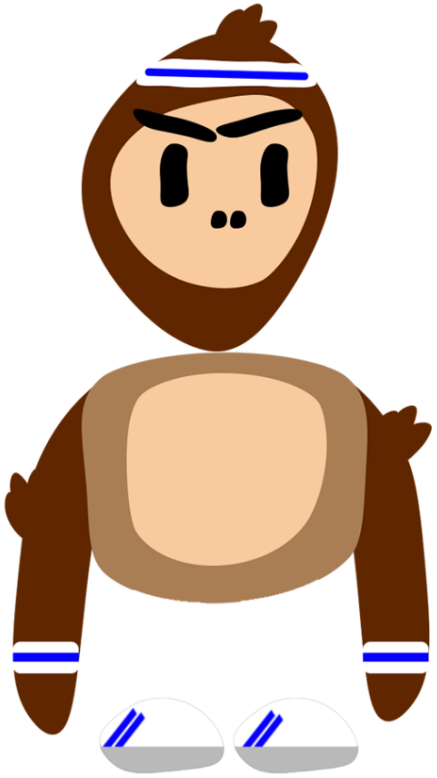
Initial Sketch

Potential Design

8.14 Design Workshop 2- Participant 3 Character Design

Initial Sketch

Potential Design



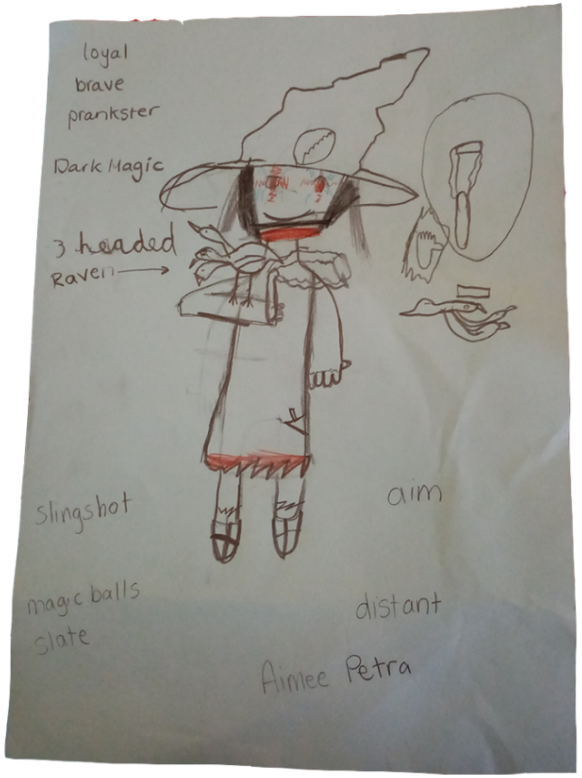
8.15 Design Workshop 2- Participant 4 Character Design

Initial Sketch

Potential Design

8.16 Design Workshop 2- Participant 4 Character Design

Initial Sketch



Potential Design

8.17 Design Workshop 2- Participant 1 Character Sheet

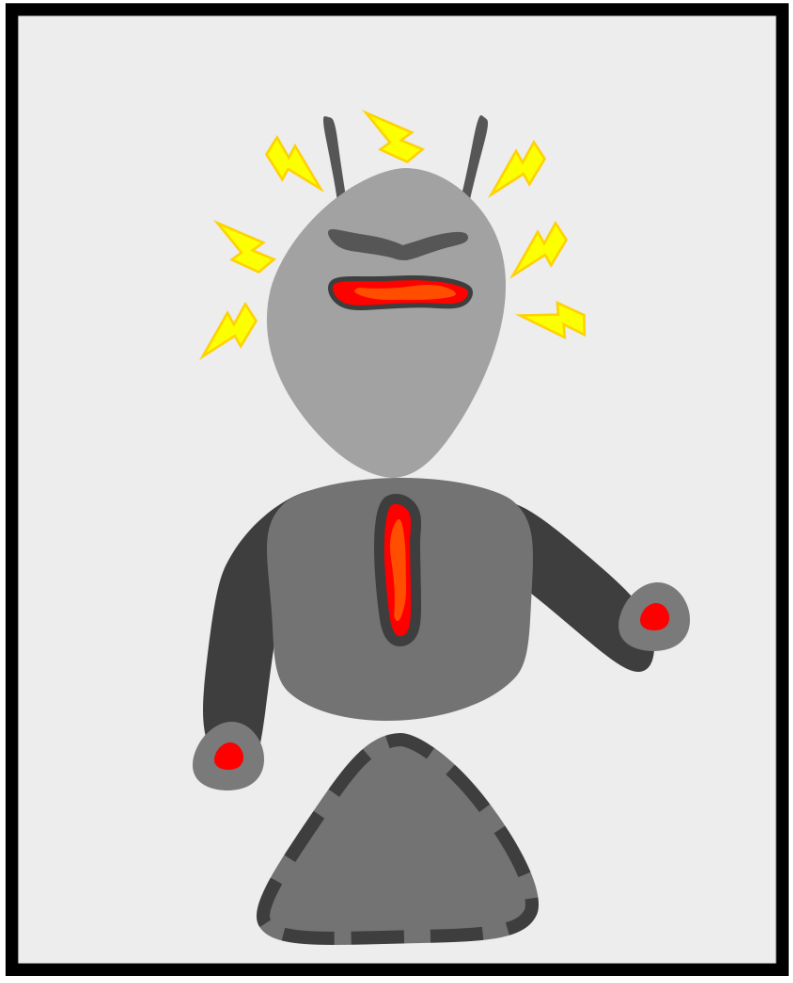
N.U.T.S

(Nonhuman Utlitly Teleportation Super computer)

Personality

- Wild
- Resourceful
- Sneaky

Teleportation



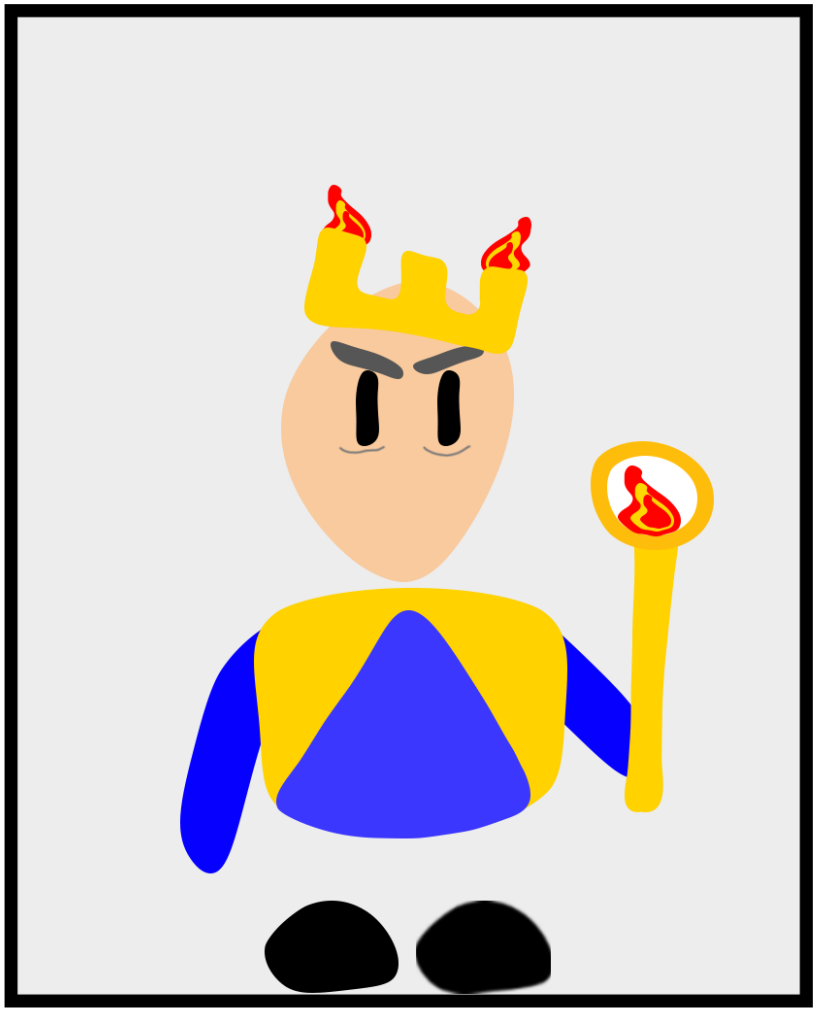
8.18 Design Workshop 2- Participant 2 Character Sheet

King Ember

Personality

- Calm
- Cruel
- Leader

Fire



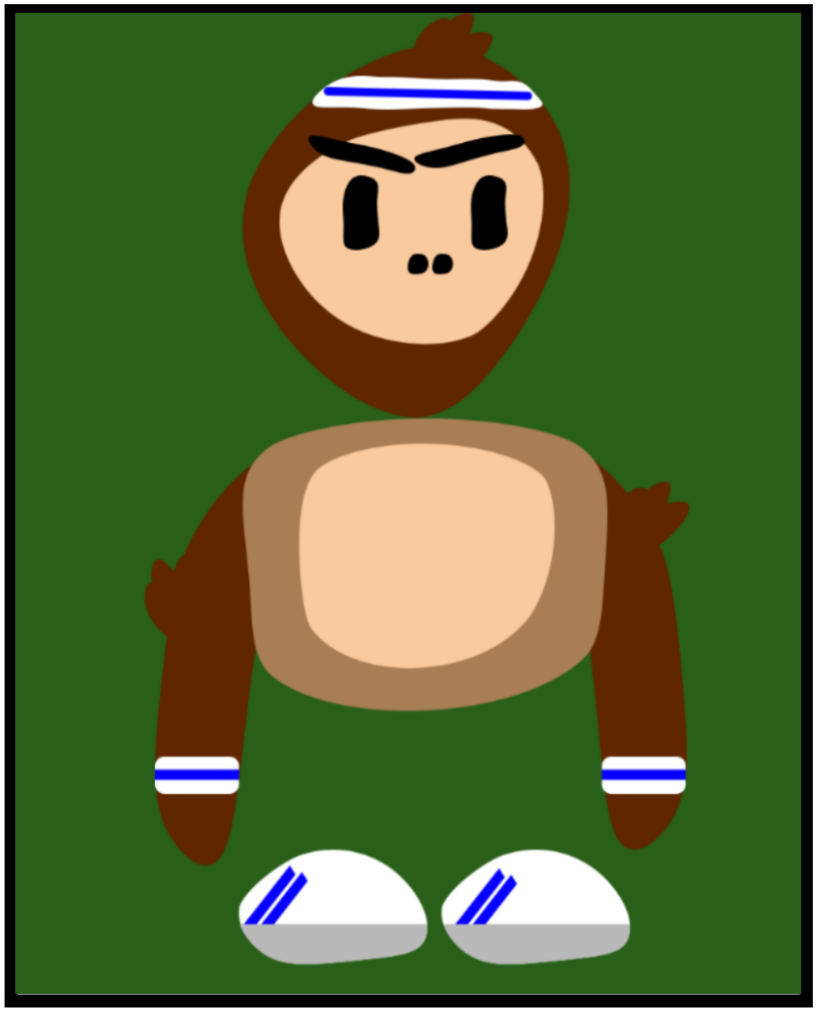
8.19 Design Workshop 2- Participant 3 Character Sheet

Georgey

Personality

- Angry
- Bold
- Cunning

Super speed



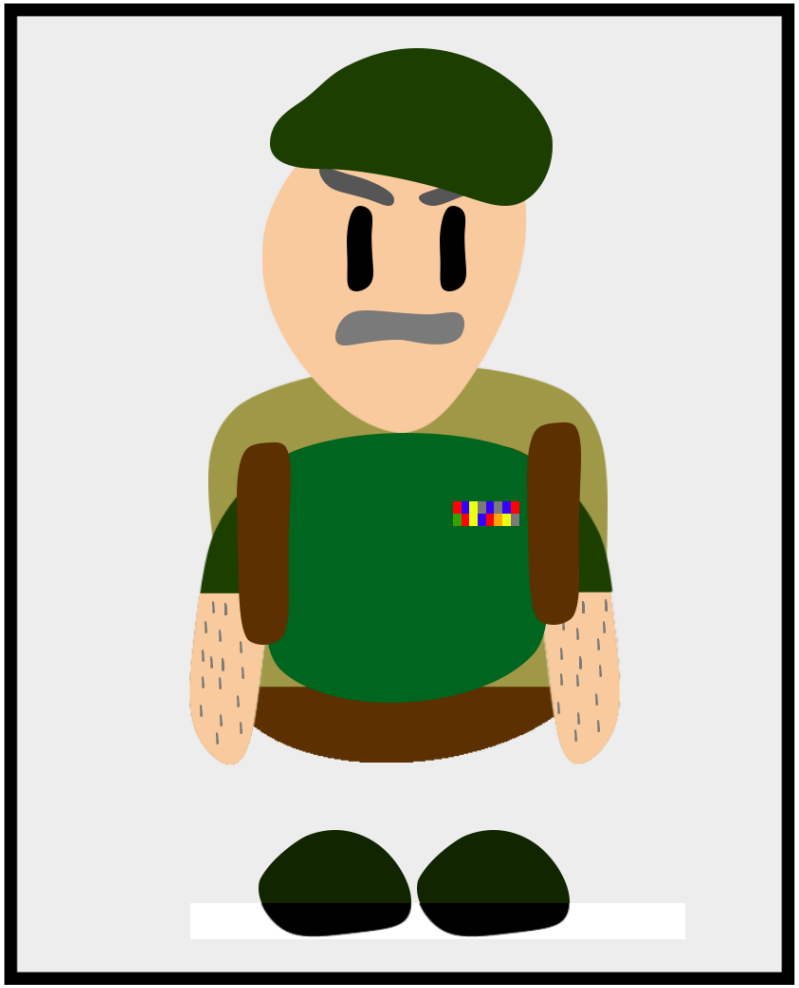
8.20 Design Workshop 2- Participant 4 Character Sheet

Major John Kazowski

Personality

- Loyal
- Brave
- Serious

Equipment



8.21 Design Workshop 2- Participant 5 Character Sheet

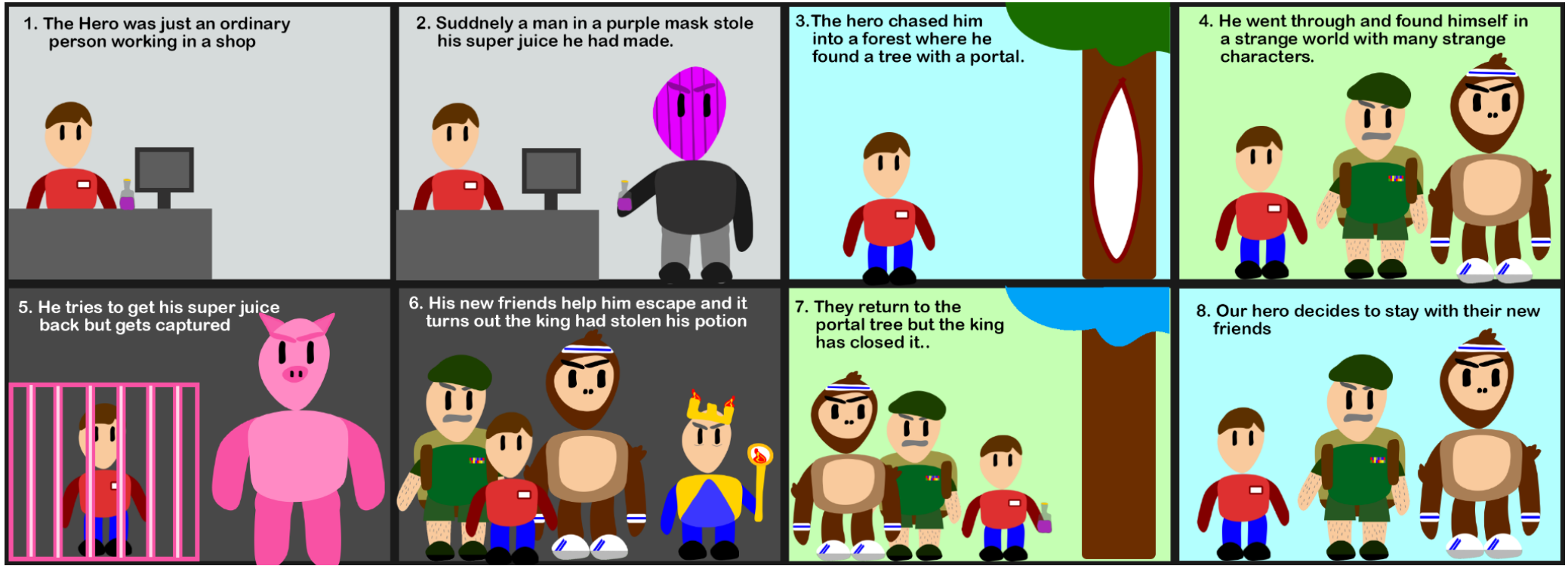
Amy Petra

Personality

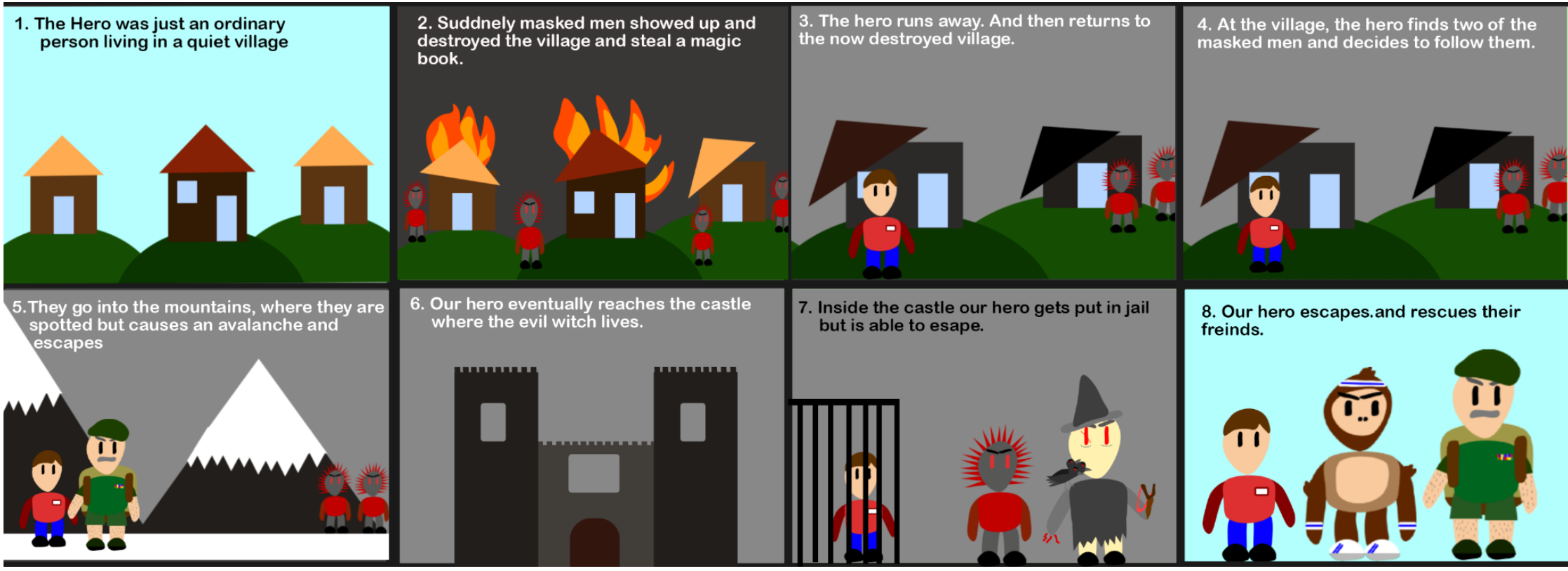
- Loyal
- Brave
- Prankster

Dark Magic

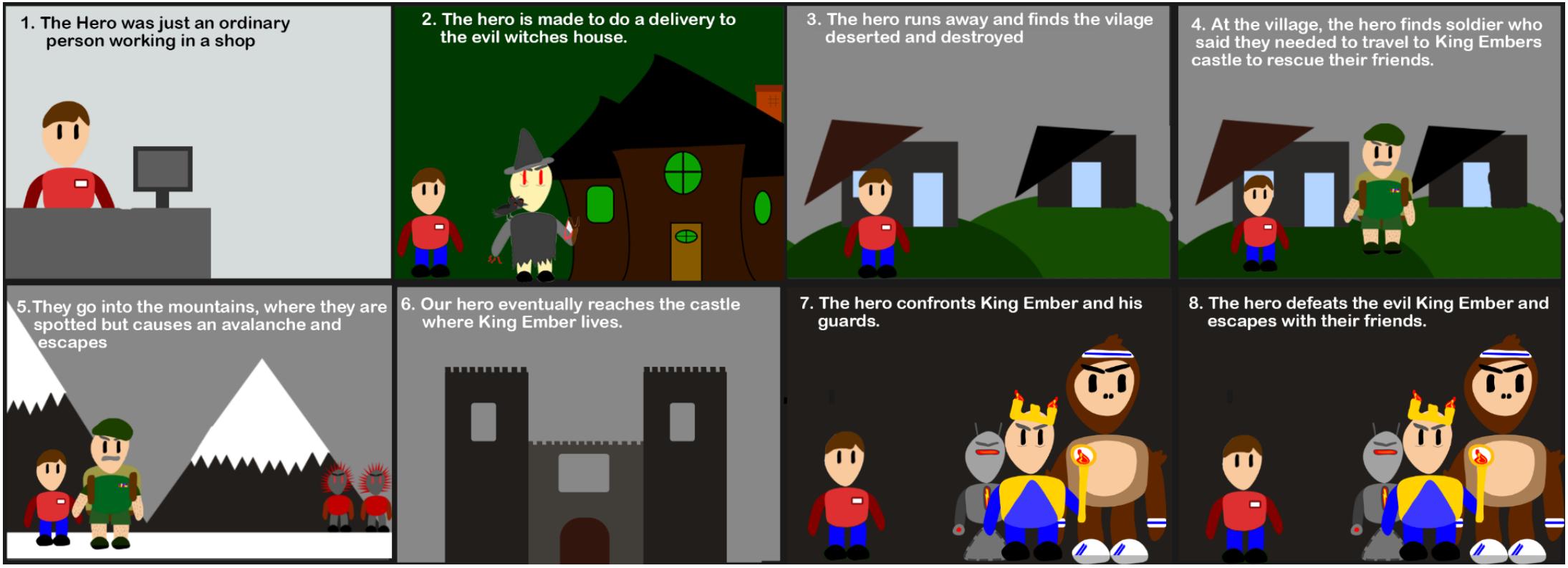
8.22 Design Workshop 3- Group 1 Storyboard:



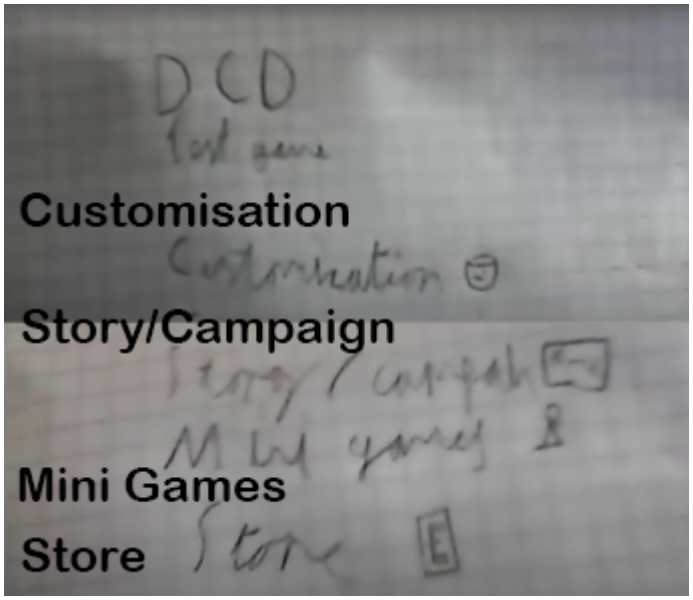
8.23 Design Workshop 3- Group 2 Storyboard:

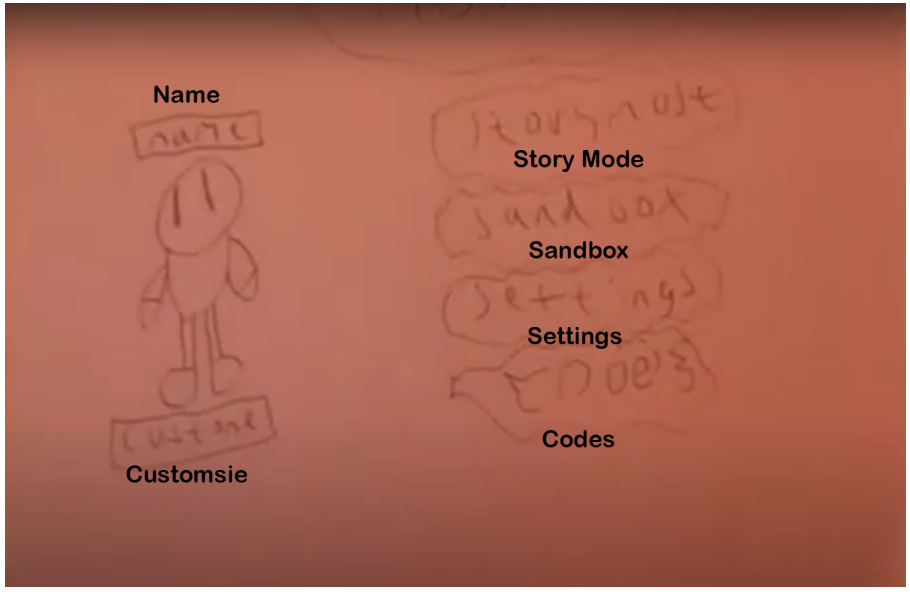


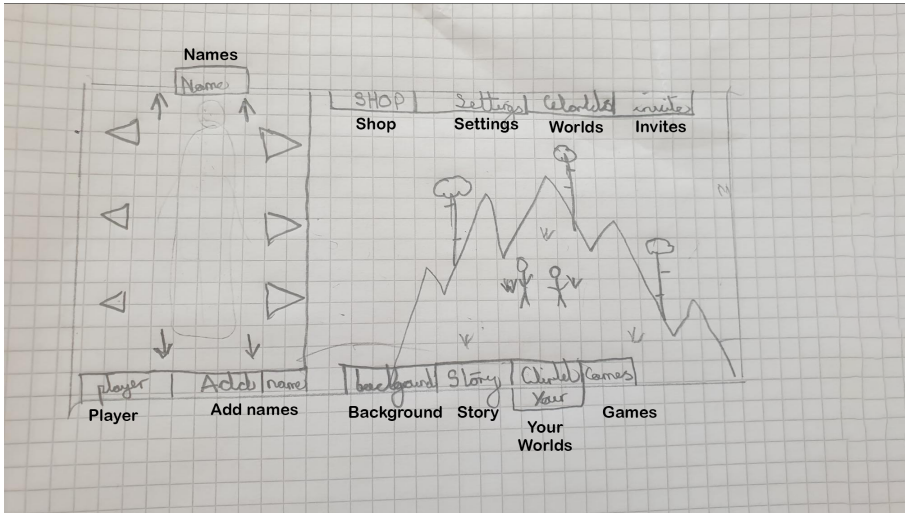
8.24 Design Workshop 3- Combined Storyboard:

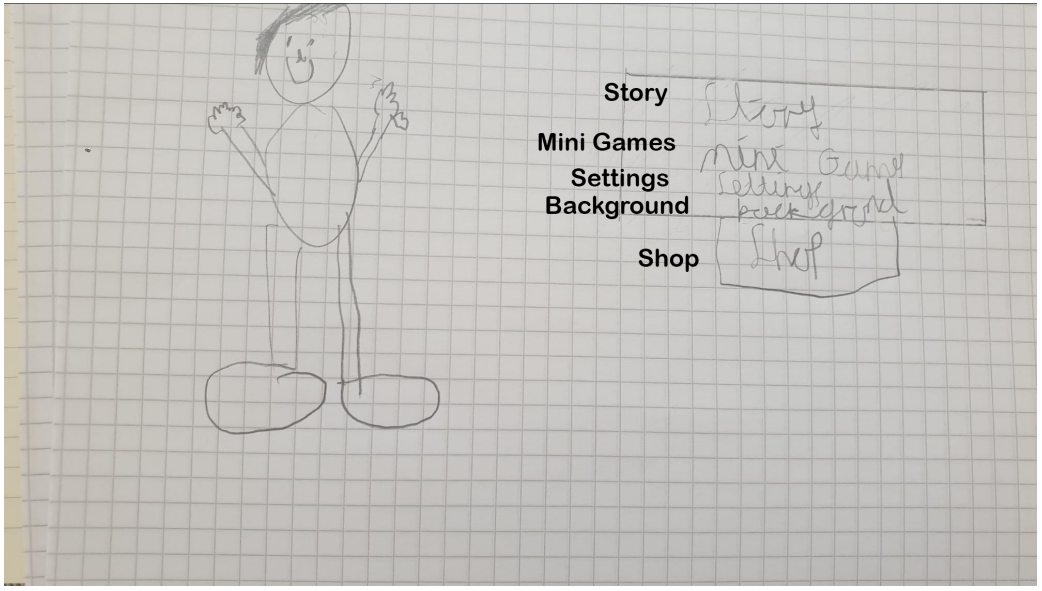


8.25 Design Workshop 4- Participant Menu Wireframes with annotations









8.26 Playtesting- Information Sheet:

Coordination and Storytelling: Developing Interactive Media Narrative Experiences for Children with Developmental Coordination Disorder (DCD).

UNIVERSITY of York

Department of Theatre, Film, Television and

Interactive Media Ethics Committee

Participant Information Sheet –Anonymous Research

Project background

The University of York would like to invite you to take part in the following project: Coordination and Storytelling: Developing Interactive Media Narrative Experiences for Children with Developmental Coordination Disorder (DCD). Before agreeing to take part, please read this information sheet carefully and let us know if anything is unclear or you would like further information.

What is the purpose of the project?

This project is being performed by George Greaves (gg764@york.ac.uk) who is a postgraduate research student on the MSc in Interactive Media by Research at the University of York. This project is being supervised by Debbie Maxwell (debbie.maxwell@york.ac.uk).

The work that is being performed for this project is being conducted according to restrictions that have been subject to approval by the TFTI Ethics committee. The Chair of the TFTI Ethics committee can be contacted on TFTI-ethics@york.ac.uk.

For this research project, we are interested in the impacts of DCD in both classrooms and at home, the current ways that children with DCD are supported, and how these methods could be improved by using interactive media technology and interactive storytelling. Your participation in this project will involve playing the game produced as part of the project and filling in a short questionnaire about its usability and their level of enjoyment while playing the game. You will also be asked a few short questions about your experience playing the game, these will be answered verbally. While you play the game, the researcher will be observing and making written notes to help identify any problems or confusing parts of the game or any parts you enjoy, don't enjoy, or have difficulty with.

Please note that to comply with the approved Ethics requirements of this work, we do not intend to discuss sensitive topics with you that could be potentially upsetting or distressing. If you have any concerns about the topics

that may be covered in the research study, please raise these concerns with the researcher.

Your participation in this project is voluntary. If you wish, wish to receive a copy of the report it can be provided upon request.

The testing session will take no more than 40 mins.

Why have I been invited to take part?

You have been invited to take part because we have highlighted you as someone with a relevant interest in educational technology.

Do I have to take part?

No, participation is optional. If you do decide to take part, you will be given a copy of this information sheet for your records and will be asked to complete a participant consent form. If you change your mind at any point during the research activity, you will be able to withdraw your participation without having to provide a reason. To withdraw your participation you need to email George Greaves (gg764@york.ac.uk) and your information will be deleted as soon as possible.

On what basis will you process my data?

Under the General Data Protection Regulation (GDPR), the University has to identify a legal basis for processing personal data and, where appropriate, an additional condition for processing special category data.

For further information and definitions of personal and special category data, please go to:

- https://ico.org.uk/for-organisations/guide-to-the-general-data-protection-regulation-gdpr/key-definitions/
- https://ico.org.uk/for-organisations/guide-to-the-general-data-protection-regulation-gdpr/lawful-basis-for-processing/special-category-data/

Personal data is defined as data from which someone could be identified. For example, in this study, we will be collecting your name and email address as this will allow us to send you the final thesis paper should you want access to it.

In line with our charter which states that we advance learning and knowledge by teaching and research, the University processes personal data for research purposes under Article 6 (1) (e) of the GDPR:

- *Processing is necessary for the performance of a task carried out in the public interest*

Special category data is personal data which the GDPR says is more sensitive, and so needs more protection. In this study, we will not be collecting any special category data.

Research activities will only be undertaken where ethical approval has been obtained, where there is a clear public interest and where appropriate safeguards have been put in place to protect data.

In line with ethical expectations and in order to comply with common law duty of confidentiality, we will seek your consent to participate where appropriate. This consent will not, however, be our legal basis for processing your data under the GDPR.

How will you use my data?

Data will be processed for the purposes outlined in this notice.

Will you share my data with 3rd parties?

No. Data will be accessible to the project team and personnel associated with the Department of Theatre, Film, and Television at the University of York only.

Anonymised data may be reused by the research team or other third parties for secondary research purposes.

How will you keep my data secure?

The University will put in place appropriate technical and organizational measures to protect your personal data and/or special category data. For the purposes of this project, we will store all data using secure University services provided by Google.

Information will be treated confidentially and shared on a need-to-know basis only. The University is committed to the principle of data protection by design and default and will collect the minimum amount of data necessary for the project.

Will you transfer my data internationally?

Possibly. The University's cloud storage solution is provided by Google which means that data can be located at any of Google's globally spread data centres. The University has data protection complaint arrangements in place with this provider. For further information see, https://www.york.ac.uk/it-services/google/policy/privacy/.

Will I be identified in any outputs?

No. Your participation in this research activity will be treated anonymously and you will not be identified in any outputs.

How long will you keep my data?

Data will be retained in line with legal requirements or where there is a business need. Retention timeframes will be determined in line with the University's Records Retention Schedule.

What rights do I have in relation to my data?

Under the GDPR, you have a general right of access to your data, a right to rectification, erasure, restriction, objection or portability. You also have a right to withdrawal. Please note, not all rights apply where data is processed purely for research purposes. For further information see, https://www.york.ac.uk/records-management/generaldataprotectionregulation/individualsrights/.

Questions or concerns

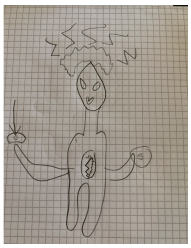
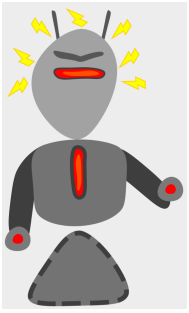
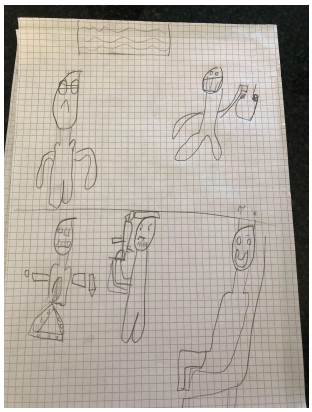
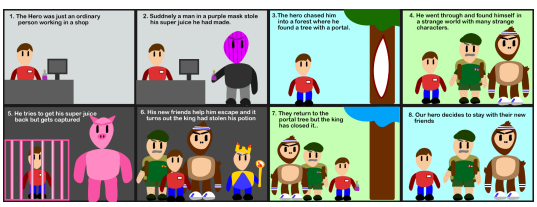
If you have any questions about this participant information sheet or concerns about how your data is being processed, please contact the TFTI Ethics Chair (TFTI-ethics@york.ac.uk) in the first instance. If you are still dissatisfied, please contact the University's Acting Data Protection Officer at dataprotection@york.ac.uk.

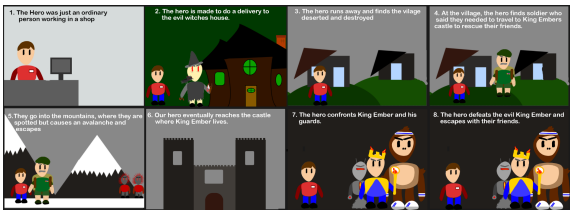
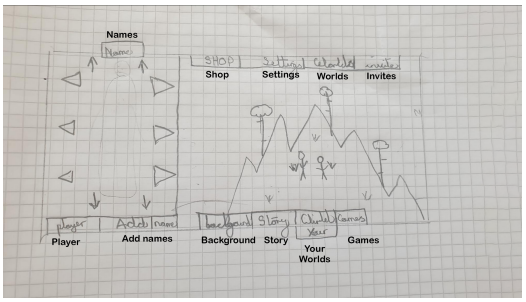
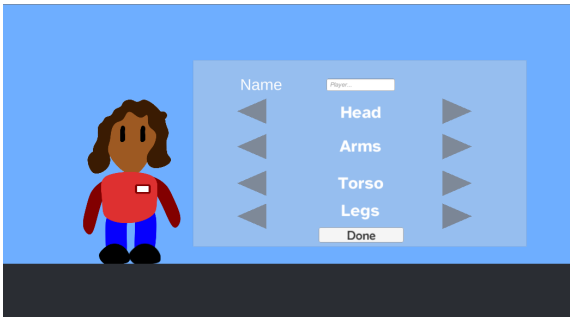
If you have any questions about the project itself, please contact the producer George Greaves (gg764@york.ac.uk) or project supervisor Debbie Maxwell (debbie.maxwell@york.ac.uk).

Right to complain

If you are unhappy with the way in which the University has handled your personal data, you have a right to complain to the Information Commissioner's Office. For information on reporting a concern to the Information Commissioner's Office, see www.ico.org.uk/concerns.

8.27 Design Decision Making Table

Design Element	Designer/Decision Maker
Original Character Designs  	Co-designers*
Redesigned character designs  	Author**
Original storyboards 	Co-designers
Redesigned storyboard 	Author

Combined storyboard  	Author
Main menu wireframe  	Co-designers
 Final Game	Author

*Co-designers refers to the children with DCD who acted as co-designers in the design workshops

**Author refers to

8.28 Playtesting- Consent Form:

Coordination and Storytelling: Developing Interactive Media Narrative Experiences for Children with Developmental Coordination Disorder (DCD).

UNIVERSITY of York

Department of Theatre, Film, Television and Interactive Media
Ethics Committee

Participant Consent Form

Thank you for your interest in this project. This research activity will be used to gather information about the usability and enjoyment of levels of a game developed earlier in this project.

Please read the following statements carefully and tick the appropriate box:

	YES	NO
I have read the information sheet about this project.		
I agree to take part in this project.		
I consent to play a game designed for children.		
I consent to filling in a short questionnaire about the game experience.		
I consent to verbally answering some question about my experience playing the game.		
I understand my right to withdraw and/or have my data destroyed from this project at any time.		
I understand that my participation in this project will be treated anonymously.		
I am over the age of 18.		

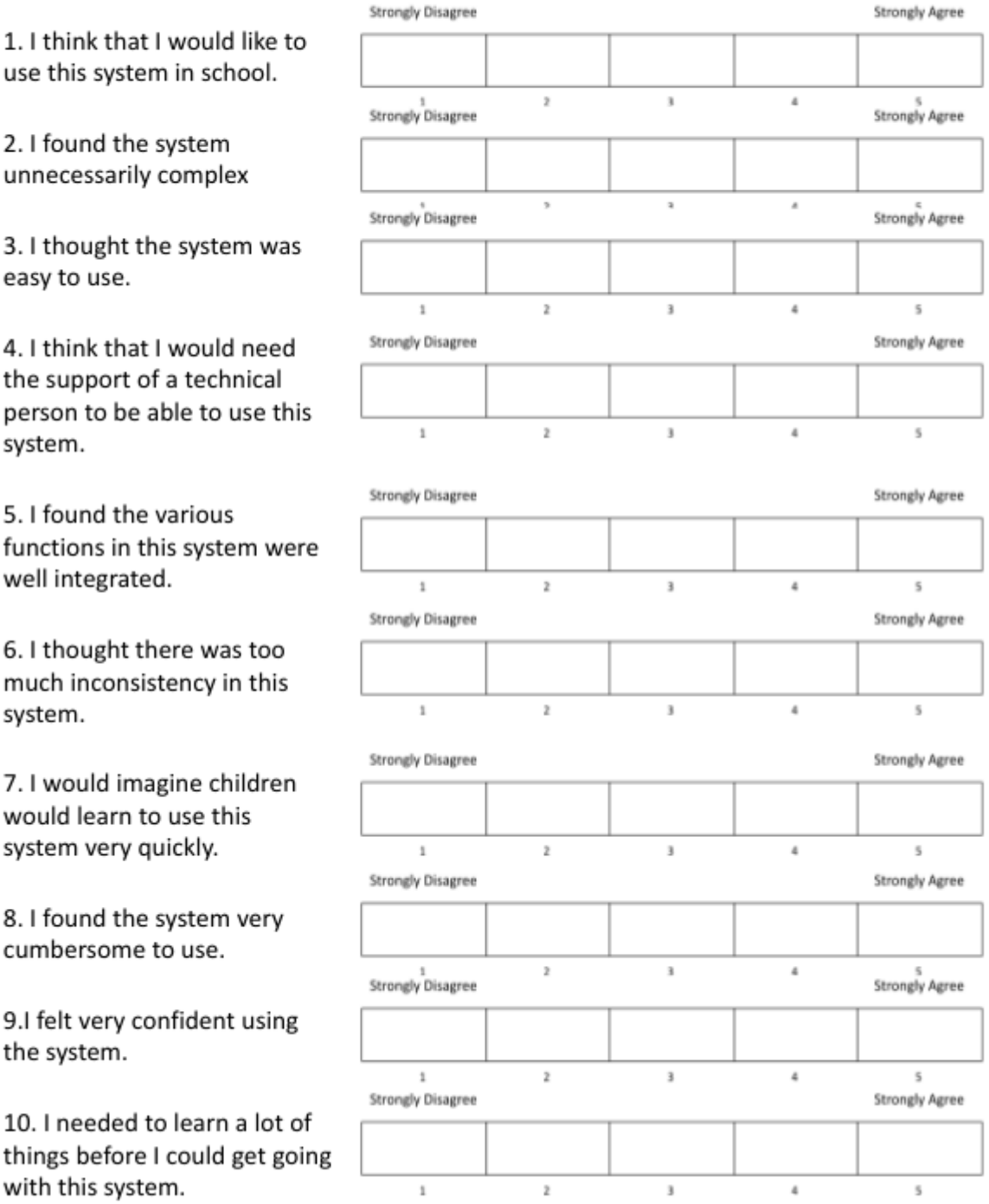
Participant Name:	**Researcher Name:**
_____	_____
Participant Signature:	**Researcher Signature:**
_____	_____
Date:	**Date:**
___/___/_____	___/___/_____

If you wish to be informed about the outcomes from this project, please provide your email address:

_____

8.29 Playtesting-Questionnaire:

Computer and Coordination: Usability Questionnaire



8.30 Playtesting-Discussion Questions

1. **What was your favourite thing(s) about the game? And why**

2. **What was your least favourite thing(s) about the games? And why?**

3. **Was there anything that confused you about the game?**

4. **What would you change or improve about the game?**

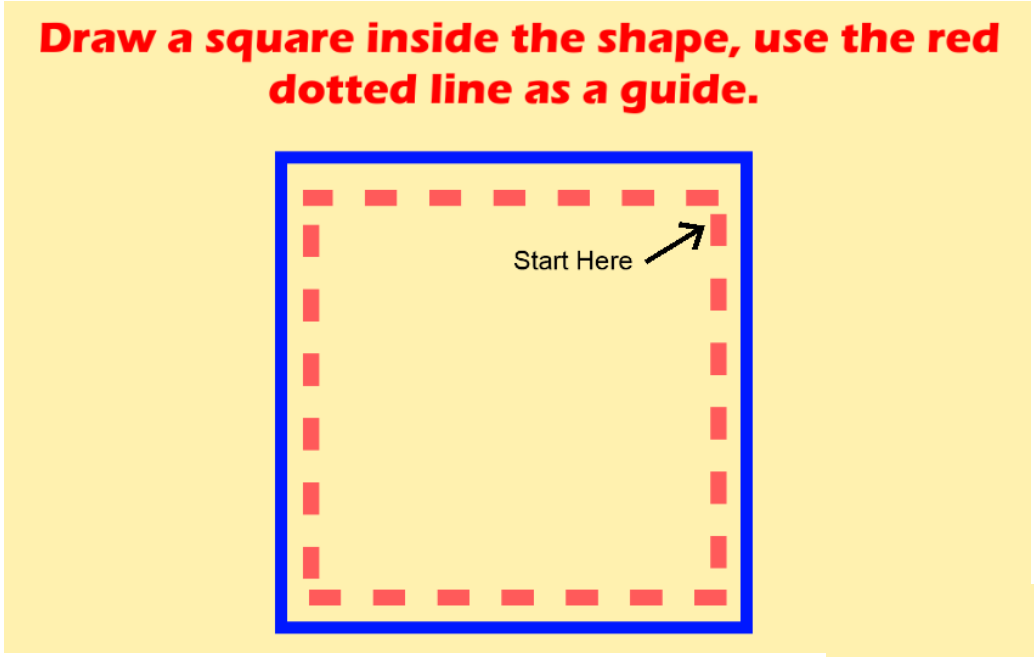
5. **If the game was longer, what would you want more of?**

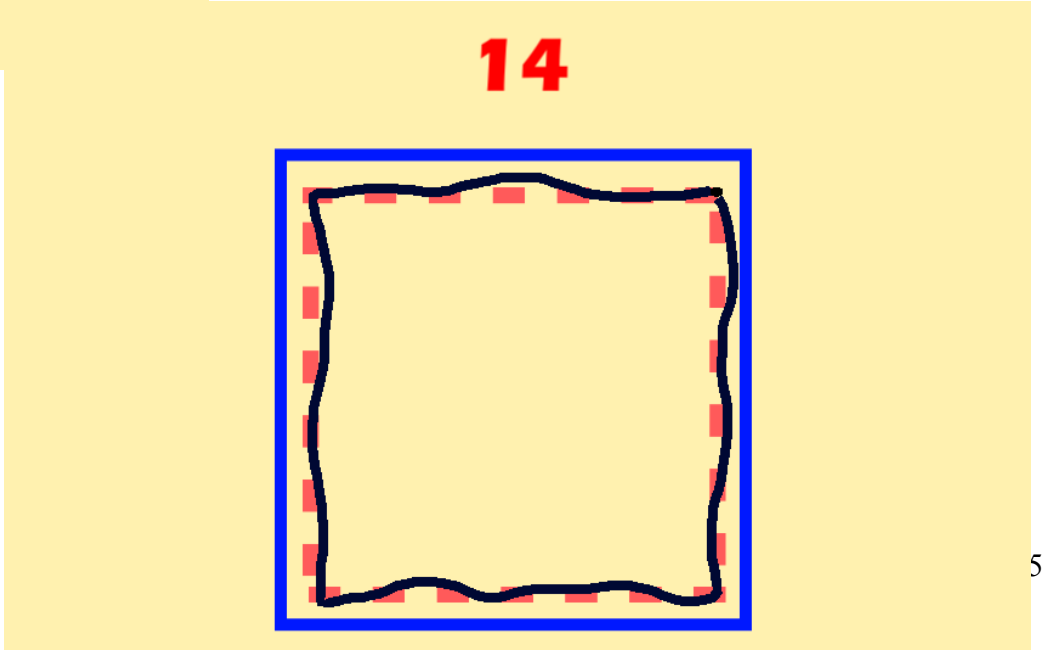
8.31 Playtesting- System Usability Scale results table

SUS Questions	P1	P2	P3	P4	P5	P6	P7	P8
1	5	5	5	5	5	5	5	4
2	1	1	1	1	1	1	4	2
3	5	5	4	4	5	5	5	5
4	2	1	2	1	3	2	2	2
5	5	5	5	5	3	5	4	5
6	1	1	1	1	1	4	2	1
7	5	5	5	5	5	3	4	4
8	1	1	1	1	1	1	1	1
9	5	5	4	5	5	2	4	4
10	1	2	1	1	1	2	1	2
Score	97.5	97.5	92.5	97.5	90	75	80	85

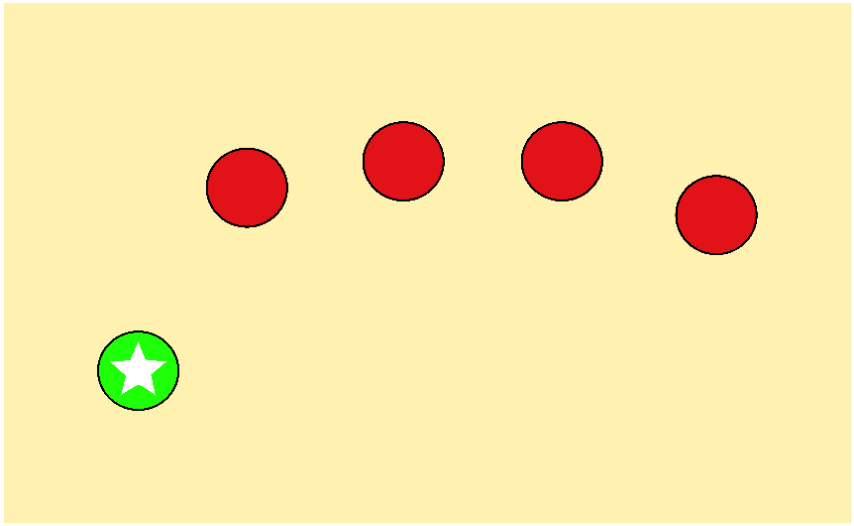
Average SUS Score	89.375

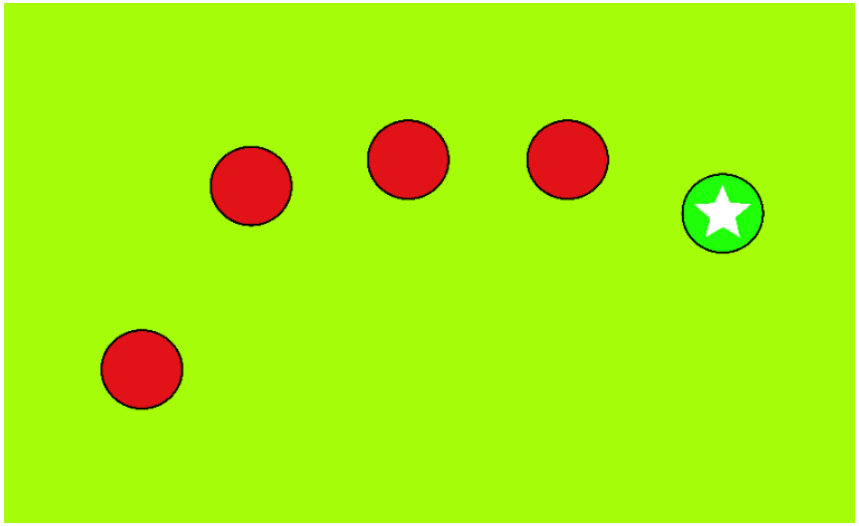
8.32 Examples of Undergraduate Work

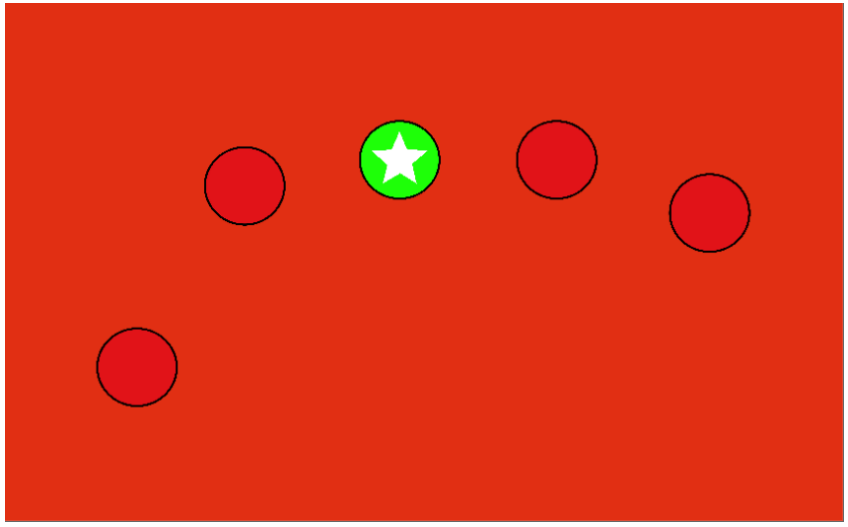


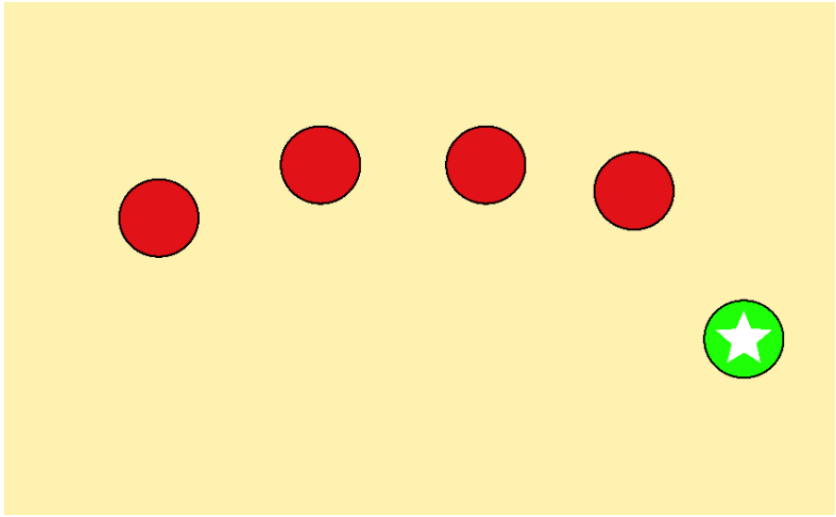


8.33 Examples of Undergraduate Work









References

Alsop, T. (2020). *Tablet computer penetration in the United Kingdom (UK) 2011-2020*. [Online]. Available at: https://www.statista.com/statistics/899103/tablet-penetration-in-the-united-kingdom-uk/ [Accessed 12 October 2021].

Archibald, L. M. D. and Alloway, T. P. (2008). Comparing language profiles: children with specific language impairment and developmental coordination disorder. *International journal of language & communication disorders / Royal College of Speech & Language Therapists*, 43 (2), pp.165–180.

BBC. (2019). Dance Mat Typing. [Online]. 28 November. Available at: https://www.bbc.co.uk/bitesize/topics/zf2f9j6/articles/z3c6tfr [Accessed 24 November 2021].

BBC. (2021). Creating characters. [Online]. 25 March. Available at: https://www.bbc.co.uk/bitesize/articles/zb3cvwx [Accessed 24 November 2021].

Bengtsson, M. (2016). How to plan and perform a qualitative study using content analysis. *NursingPlus Open*, 2, pp.8–14.

Biotteau, M. et al. (2019). Developmental coordination disorder and dysgraphia: signs and symptoms, diagnosis, and rehabilitation. *Neuropsychiatric disease and treatment*, 15, pp.1873–1885.

Bonney, E. et al. (2018). 'Not just another Wii training': a graded Wii protocol to increase physical fitness in adolescent girls with probable developmental coordination disorder-a pilot study. *BMC pediatrics*, 18. [Online]. Available at: https://go.gale.com/ps/i.do?id=GALE%7CA528602427&sid=googleScholar&v=2.1&it=r&linkaccess=abs&issn=14712431&p=AONE&sw=w.

Botturi, L. Bramani, C. and Corbino, S. (2014). Digital storytelling for social and international development: From special education to vulnerable children. *International Journal of Arts and Technology*, 7 (1). [Online]. Available at: doi:10.1504/IJART.2014.058945.

Bratitsis, T. and Ziannas, P. (2015). *From Early Childhood to Special Education: Interactive Digital Storytelling as a Coaching Approach for Fostering Social Empathy*.

Brooke, J. (2013). SUS: a retrospective. *Journal of usability studies*, 8 (2), pp.29–40.

Brooke, J. and Others. (1996). SUS-A quick and dirty usability scale. *Usability evaluation in industry*, 189 (194), pp.4–7.

Brookes, G. (2007). *Dyspraxia [electronic resource]*, SEN series. 2nd ed. London ; New York: Continuum.

Bruner, J. (2010). Narrative, culture, and mind. *Telling stories: Language, narrative, and social life*, pp.45–49.

Byrne, C. A. Rebola, C. B. and Zeagler, C. (2013). Design research methods to understand user needs for an etextile knee sleeve. In: *Proceedings of the 31st ACM international conference on Design of communication - SIGDOC '13*. 2013. New York, New York, USA: ACM Press. [Online]. Available at: doi:10.1145/2507065.2507085.

Caçola, P. and Lage, G. (2019). Developmental coordination disorder (DCD): An overview of the condition and research evidence. *Motriz. Revista de Educacao Fisica*, 25 (2). [Online]. Available at: doi:10.1590/s1980-6574201900020001.

Cairney, J. and Veldhuizen, S. (2013). Is developmental coordination disorder a fundamental cause of inactivity and poor health-related fitness in children? *Developmental Medicine & Child Neurology*, 55 (s4), pp.55–58.

Campbell, J. (2003). *The Hero's Journey: Joseph Campbell on His Life and Work*. New World Library.

Cleaton, M. A. M. Lorgelly, P. K. and Kirby, A. (2020). Developmental coordination disorder in UK children aged 6–18 years: Estimating the cost. *The British journal of occupational therapy*, 83 (1), pp.29–40.

Clement, J. (2021). *Most important video game features in the U.S. 2021*. [Online]. Available at: https://www.statista.com/statistics/697706/most-important-game-features-usa/ [Accessed 24 November 2021].

Crook, L. (2020). *Atkinson Hyperlegible typeface is designed for visually impaired readers*. [Online]. Available at: https://www.dezeen.com/2020/09/11/atkinson-hyperlegible-typeface-applied-design-works/ [Accessed 18 November 2021].

Department For Education. (2021). *Education_Technology__EdTech__Survey_2020-21__1_.pdf*. [Online]. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/996470/Education_Technology__EdTech__Survey_2020-21__1_.pdf.

Diah, N. M. et al. (2010). Usability testing for educational computer game using observation method. In: *2010 International Conference on Information Retrieval Knowledge Management (CAMP)*. March 2010. ieeexplore.ieee.org. pp.157–161.

Duncan, M. Cunningham, A. and Eyre, E. (2019). A combined movement and story-telling intervention enhances motor competence and language ability in pre-schoolers to a greater extent than movement or story-telling alone. *European Physical Education Review*, 25 (1), pp.221–235.

Ebrahimi Sani, S. et al. (2020). Effects of virtual reality training intervention on predictive motor control of children with DCD - A randomized controlled trial. *Research in developmental disabilities*, 107, p.103768.

Elmqaddem, N. (2019). Augmented Reality and Virtual Reality in Education. Myth or Reality? *International Journal of Emerging Technologies in Learning (iJET)*, 14 (03), pp.234–242. [Accessed 10 March 2021].

Elsayed-Ali, S. et al. (2020). Designing for children's values: conceptualizing value-sensitive technologies with children. In: *Proceedings of the 2020 ACM Interaction Design and Children Conference: Extended Abstracts*. IDC '20. 21 June 2020. New York, NY, USA: Association for Computing Machinery. pp.296–301. [Accessed 12 November 2021].

Eyre, E. L. J. et al. (2020). The effects of combined movement and storytelling intervention on motor skills in south asian and white children aged 5–6 years living in the United Kingdom. *International journal of environmental research and public health*, 17 (10). [Online]. Available at: doi:10.3390/ijerph17103391.

Faught, B. E. et al. (2005). Increased risk for coronary vascular disease in children with developmental coordination disorder. *Journal of adolescent health care: official publication of the Society for Adolescent Medicine*, 37 (5), pp.376–380.

Fauville, G. et al. (2021). Zoom Exhaustion & Fatigue Scale. *Computers in Human Behavior Reports*, 4, p.100119.

Ferguson, G. D. et al. (2013). The efficacy of two task-orientated interventions for children with Developmental Coordination Disorder: Neuromotor Task Training and Nintendo Wii Fit Training. *Research in developmental disabilities*, 34 (9), pp.2449–2461.

Field, M. J. Behrman, R. E. and Institute of Medicine (US) Committee on Clinical Research Involving Children. (2004). *Understanding and Agreeing to Children's Participation in Clinical Research*. National Academies Press (US). [Accessed 3 September 2021].

Frauenberger, C. et al. (2015). In pursuit of rigour and accountability in participatory design. *International journal of human-computer studies*, 74, pp.93–106.

Galea, M. P. (2020). Is task-oriented training effective for children with developmental coordination disorder? A Cochrane Review summary with commentary. *Developmental medicine and child neurology*, 62 (2), Wiley Online Library. pp.160–162.

Garzotto, F. and Gonella, R. (2011). Children's co-design and inclusive education. In: *Proceedings of the 10th International Conference on Interaction Design and Children*. IDC '11. 20 June 2011. New York, NY, USA: Association for Computing Machinery. pp.260–263. [Accessed 1 June 2021].

Gibbs, J. Appleton, J. and Appleton, R. (2007). Dyspraxia or developmental coordination disorder? Unravelling the enigma. *Archives of Disease in Childhood*, 92 (6). [Online]. Available at: doi:10.1136/adc.2005.088054.

Gray, D. (2011). *Customer, Employee, Shareholder*. [Online]. Available at: https://gamestorming.com/customer-employee-shareholder/ [Accessed 13 October 2021].

Guha, M. L. Druin, A. and Fails, J. A. (2013). Cooperative Inquiry revisited: Reflections of the past and guidelines for the future of intergenerational co-design. *International Journal of Child-Computer Interaction*, 1 (1), pp.14–23.

Hannibal, G. (2021). Focusing on the Vulnerabilities of Robots through Expert Interviews for Trust in Human-Robot Interaction. In: *Companion of the 2021 ACM/IEEE International Conference on Human-Robot Interaction*. HRI '21 Companion. 8 March 2021. New York,

NY, USA: Association for Computing Machinery. pp.288–293. [Accessed 11 November 2021].

Hibbin, R. (2016). The psychosocial benefits of oral storytelling in school: developing identity and empathy through narrative. *Pastoral Care in Education*, 34 (4), pp.218–231.

Hickman, R. et al. (2017). Use of active video gaming in children with neuromotor dysfunction: a systematic review. *Developmental medicine and child neurology*, 59 (9), pp.903–911.

Jaziar Radianti, Tim A. Majchrzak, Jennifer Fromm b, Isabell Wohlgenannt c. (2020). A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Computers & education*, 147, p.103778. [Accessed 29 November 2021].

Karras, H. C. et al. (2019). Health-related quality of life of children with Developmental Coordination Disorder. *Research in developmental disabilities*, 84, pp.85–95.

Keinan, A. Bar-Shalita, T. and Portnoy, S. (2020). An Instrumented Assessment of a Rhythmic Finger Task among Children with Motor Coordination Difficulties. *Sensors* , 20 (16). [Online]. Available at: doi:10.3390/s20164554.

Kennedy, A. et al. (2021). Translating Co-Design from Face-to-Face to Online: An Australian Primary Producer Project Conducted during COVID-19. *International journal of environmental research and public health*, 18 (8). [Online]. Available at: doi:10.3390/ijerph18084147.

Knexus. (2017). *Top 5 Benefits of Customer Journey Mapping (2020)*. [Online]. Available at: https://www.knexus.co/show/blog/top-5-benefits-customer-journey-mapping/ [Accessed 23 November 2021].

Kramarzewski, A. and De Nucci, E. *Practical Game Design*. Packt Publishing. [Accessed 24 November 2021].

Kraversky, D. G. (2020). *Cognitive Orientation to Daily Occupational Performance (CO–OP) Approach: Evidence-Based, Occupation-Centered Intervention for Children*. [Online]. Available at: https://www.aota.org/~/media/Corporate/Files/Publications/CE-Articles/CEA_July_2020.pdf.

Lingam, R. et al. (2010). The association between developmental coordination disorder and other developmental traits. *Pediatrics*, 126 (5), pp.e1109–e1118.

Lucero, A. (2015). Using Affinity Diagrams to Evaluate Interactive Prototypes. In: *Human-Computer Interaction – INTERACT 2015*. 2015. Springer International Publishing. pp.231–248.

Mandich, A. D. Polatajko, H. J. and Rodger, S. (2003). Rites of passage: Understanding participation of children with developmental coordination disorder. *Human movement science*, 22 (4), pp.583–595.

McGlashan, H. L. et al. (2017). Improvement in children's fine motor skills following a

computerized typing intervention. *Human movement science*, 56 (Pt B), pp.29–36.

McNaney, R. et al. (2013). Designing for and with children with special needs in multiple settings. In: *Proceedings of the 12th International Conference on Interaction Design and Children*. IDC '13. 24 June 2013. New York, NY, USA: Association for Computing Machinery. pp.603–605. [Accessed 12 November 2021].

Melcer, E. and Isbister, K. (2017). Toward understanding disciplinary divides within games research. In: *Proceedings of the 12th International Conference on the Foundations of Digital Games*. FDG '17 48. 14 August 2017. New York, NY, USA: Association for Computing Machinery. pp.1–4. [Accessed 3 September 2021].

Mentiplay, B. F. et al. (2019). Do video game interventions improve motor outcomes in children with developmental coordination disorder? A systematic review using the ICF framework. *BMC pediatrics*, 19 (1), p.22.

Miyahara, M. et al. (2017). Task-oriented interventions for children with developmental coordination disorder. *Cochrane database of systematic reviews* , 7, p.CD010914.

Mojang. (2021). *Minecraft*. [Online]. Available at: https://www.minecraft.net/en-us/login [Accessed 24 November 2021].

Mokhtar, N. H. Halim, M. F. A. and Kamarulzaman, S. Z. S. (2011). The effectiveness of storytelling in enhancing communicative skills. *Procedia-Social and Behavioral Sciences*, 18, pp.163–169.

Mombarg, R. Jelsma, D. and Hartman, E. (2013). Effect of Wii-intervention on balance of children with poor motor performance. *Research in developmental disabilities*, 34 (9), pp.2996–3003.

Morin, A. (2019). *Sensory Integration Therapy: What You Need to Know*. [Online]. Available at: https://www.understood.org/en/learning-thinking-differences/treatments-approaches/therapies/sensory-integration-therapy-what-you-need-to-know [Accessed 19 November 2020].

Nath. (2017). *Tall Tales*. [Online]. Available at: https://dynamicplay.co.uk/tall-tales/ [Accessed 13 October 2021].

Neuromotor Task Training. (2018). *Introduction to Neuromotor Task Training*. [Online]. Available at: http://neuromotortasktraining.org/node/35 [Accessed 20 October 2020].

NHS. (2021). *Finger isolation and finger games*. [Online]. Available at: https://www.buckshealthcare.nhs.uk/cyp/pifs/finger-isolation-and-finger-games/ [Accessed 24 November 2021].

Northumbria Healthcare NHS. (2018). *Occupational Therapy Advice for Children Fine Motor Skills Handwriting Daily Living Skills*. [Online]. Available at: http://northumberlandeducation.co.uk/wp-content/uploads/2018/06/DCD-OT-Activity-Advice-Pack-Final-4.pdf.

Offor, N. Williamson, P. O. and Caçola, P. (2016). Effectiveness of Interventions for Children

With Developmental Coordination Disorder in Physical Therapy Contexts: A Systematic Literature Review and Meta-Analysis. *Journal of Motor Learning and Development*, 4 (2), pp.169–196. [Accessed 22 November 2020].

Orvokki Nygren, M. et al. (2021). Developing Ideas and Methods for Supporting Whole Body Interaction in Remote Co-Design with Children. In: *Interaction Design and Children*. IDC '21. 24 June 2021. New York, NY, USA: Association for Computing Machinery. pp.675–678. [Accessed 19 October 2021].

Padilla-Zea, N. et al. (2014). Modeling storytelling to be used in educational video games. *Computers in human behavior*, 31 (1). [Online]. Available at: doi:10.1016/j.chb.2013.04.020.

Papadimitriou, C. H. (2003). MythematiCS: in praise of storytelling in the teaching of computer science and math. *SIGCSE Bull.* 35 (4), pp.7–9.

Prpa, M. et al. (2020). Articulating experience. In: *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. 21 April 2020. New York, NY, USA: ACM. [Online]. Available at: doi:10.1145/3313831.3376664.

Rampin, R. and Rampin, V. *Taguette*. [Online]. Available at: https://www.taguette.org/ [Accessed 8 December 2021].

Read, J. and Gilutz, S. (2021). Working with Children in HCI: Research, Design and Evaluation. In: *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems*. 144. New York, NY, USA: Association for Computing Machinery. pp.1–3. [Accessed 12 November 2021].

Robin, B. R. (2016). The power of digital storytelling to support teaching and learning. *Digital Education Review*, (30). [Online]. Available at: doi:10.1344/der.2016.30.17-29.

Roblox Corporation. (2021). *Roblox*. [Online]. Available at: https://www.roblox.com/ [Accessed 24 November 2021].

Rosenbaum, S. (1989). Usability evaluations versus usability testing: when and why? *IEEE Transactions on Professional Communication*, 32 (4), pp.210–216.

Sanders, E. B. N. (2002). From user-centered to participatory design approaches. *Design and the social sciences*. [Online]. Available at: https://www.taylorfrancis.com/chapters/edit/10.1201/9780203301302-8/user-centered-participatory-design-approaches-elizabeth-sanders.

Sanders, E. B.-N. and Stappers, P. J. (2014). Probes, toolkits and prototypes: three approaches to making in codesigning. *CoDesign*, 10 (1), pp.5–14.

Schoemaker, M. M. et al. (2003). Effectiveness of neuromotor task training for children with developmental coordination disorder: a pilot study. *Neural plasticity*, 10 (1-2), pp.155–163.

Schoemaker, M. M. and Smits-Engelsman, B. C. M. (2015). Is Treating Motor Problems in DCD Just a Matter of Practice and More Practice? *Current developmental disorders reports*, 2 (2), pp.150–156.

Scratch. *Scratch - Imagine, Program, Share*. [Online]. Available at: https://scratch.mit.edu/ [Accessed 18 November 2021].

Sharda, N. (2007). Applying movement oriented design to create educational stories. *International Journal of Learning*. [Online]. Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.94.196&rep=rep1&type=pdf.

Smeda, N. Dakich, E. and Sharda, N. (2014). The effectiveness of digital storytelling in the classrooms: a comprehensive study. *Smart Learning Environments*, 1 (1). [Online]. Available at: doi:10.1186/s40561-014-0006-3.

Smits-Engelsman, B. et al. (2018). Evaluating the evidence for motor-based interventions in developmental coordination disorder: A systematic review and meta-analysis. *Research in Developmental Disabilities*, 74, Elsevier Inc. pp.72–102. [Online]. Available at: doi:10.1016/j.ridd.2018.01.002.

Smits-Engelsman, B. C. M. et al. (2013). Efficacy of interventions to improve motor performance in children with developmental coordination disorder: a combined systematic review and meta-analysis. *Developmental Medicine & Child Neurology*, 55 (3), pp.229–237.

Speicher, M. Hall, B. D. and Nebeling, M. (2019). What is Mixed Reality? In: *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. New York, NY, USA: Association for Computing Machinery. pp.1–15. [Accessed 3 September 2021].

Stafford, I. (2000). Children With Movement Difficulties: Primary Education and the Development of Performance Indicators. *British Journal of Special Education*, 27 (2), pp.81–86.

Stuart, K. (2015). How do I start playing video games? A beginner's guide. *The Guardian*. [Online]. 18 February. Available at: http://www.theguardian.com/technology/2015/feb/18/how-do-i-start-playing-video-games-a-beginners-guide [Accessed 24 November 2021].

Sugden, D. (2007). Current approaches to intervention in children with developmental coordination disorder. *Developmental medicine and child neurology*, 49 (6), pp.467–471.

Szebeko, D. and Tan, L. (2010). Co-designing for Society. *The Australasian medical journal*, 3 (9). [Online]. Available at: https://www.academia.edu/download/1763194/CodesigningForSociety_SzebekoTan_2010.pdf.

Tal Saban, M. and Kirby, A. (2019). Empathy, social relationship and co-occurrence in young adults with DCD. *Human movement science*, 63, pp.62–72.

Teodorescu et al. (1996). *Handwriting booklet 1 : the Teodorescu perceptuo-motor programme*. [Place of publication not identified.

The Linking Network. (2017). *Identity Circles*. [Online]. Available at: https://thelinkingnetwork.org.uk/resource/identity-circles/ [Accessed 14 November 2021].

Trischler, J. et al. (2018). The Value of Codesign: The Effect of Customer Involvement in

Service Design Teams. *Journal of Service Research*, 21 (1), pp.75–100.

Unity Technologies. (2021). *Unity*. [Online]. Available at: https://unity.com/ [Accessed 18 November 2021].

U.S. National Library of Medicine. (2021a). *Fine motor control*. [Online]. Available at: https://medlineplus.gov/ency/article/002364.htm [Accessed 7 April 2021].

U.S. National Library of Medicine. (2021b). *Gross motor control*. [Online]. Available at: https://medlineplus.gov/ency/article/002368.htm [Accessed 7 April 2021].

Vaajakallio, K. Lee, J.-J. and Mattelmäki, T. (2009). 'It has to be a group work!': co-design with children. In: *Proceedings of the 8th International Conference on Interaction Design and Children*. IDC '09. 3 June 2009. New York, NY, USA: Association for Computing Machinery. pp.246–249. [Accessed 1 June 2021].

Van Gils, F. (2005). Potential applications of digital storytelling in education. In: *3rd twente student conference on IT*. 7. 2005. University of Twente, Faculty of Electrical Engineering, Mathematics and …. [Online]. Available at: https://wwwhome.ewi.utwente.nl/~theune/VS/Frank_van_Gils.pdf.

Van Mechelen, M. et al. (2018). Developing children's empathy in co-design activities: a pilot case study. In: *Proceedings of the 17th ACM Conference on Interaction Design and Children*. IDC '18. 19 June 2018. New York, NY, USA: Association for Computing Machinery. pp.669–674. [Accessed 1 June 2021].

Van Mechelen, M. et al. (2019). Children's Assessment of Co-design Skills: Creativity, Empathy and Collaboration. In: *the Interaction Design and Children*. 12 June 2019. unknown. pp.520–526. [Accessed 12 October 2021].

Van Mechelen, M. et al. (2021). A Systematic Review of Empowerment in Child-Computer Interaction Research. In: *Interaction Design and Children*. New York, NY, USA: Association for Computing Machinery. pp.119–130. [Accessed 3 September 2021].

Vince, B. et al. (2018). *Ultimate List of Different Types of Video Games*. [Online]. Available at: https://www.idtech.com/blog/different-types-of-video-game-genres [Accessed 24 November 2021].

Walker, S. et al. (2018). *Dyspraxia in clinical education: a review*. [Online]. Available at: http://sro.sussex.ac.uk.

Wallace, J. et al. (2013). Making design probes work. In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. CHI '13. 27 April 2013. New York, NY, USA: Association for Computing Machinery. pp.3441–3450. [Accessed 13 October 2021].

Williams, W. M. and Ayres, C. G. (2020). Can Active Video Games Improve Physical Activity in Adolescents? A Review of RCT. International journal of environmental research and public health, 17 (2). [Online]. Available at: doi:10.3390/ijerph17020669.

Yuksel, P. Robin, B. and McNeil, S. (2011). Educational uses of digital storytelling all around

the world. *Technology & Teacher Education …*. [Online]. Available at: https://www.learntechlib.org/P/36461/.

Zwicker, J. G. et al. (2012). Developmental coordination disorder: A review and update. *European journal of paediatric neurology: EJPN: official journal of the European Paediatric Neurology Society*, 16 (6), pp.573–581.

(2015). *Storytelling in Teaching and Learning*. [Online]. Available at: https://www.nyu.edu/faculty/teaching-and-learning-resources/strategies-for-teaching-with-tech/storytelling-teching-and-learning.html [Accessed 20 November 2030].

(2017). *Measuring and Interpreting System Usability Scale (SUS)*. [Online]. Available at: https://uiuxtrend.com/measuring-system-usability-scale-sus/ [Accessed 18 November 2021].

(2021). *MURAL*. [Online]. Available at: https://www.mural.co/ [Accessed 12 November 2021].

Blandford, A., Furniss, D. and Makri, S., 2016. *Qualitative HCI research: Going behind the scenes. Synthesis lectures on human-centered informatics*, 9(1), pp.1-115.