On Accessible Visual Programming Tools for Children with Autism Spectrum Condition and Additional Learning Disabilities

Misbahu Sharfuddeen Zubair

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Copyright Statement

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Abstract

Visual Programming Tools (VPTs) provide a visual programming and execution environment, in addition to other visual resources and tools appropriate for creating visual programs for a particular domain. Several VPTs have been created for teaching children to program at an early age. Research on the use of these tools to teach programming, academic and non-academic skills has reported positive results. However, children with learning disabilities including those also diagnosed with Autism Spectrum Condition (ASC) are left out of research in this area. Therefore, this research aims to contribute to existing knowledge in this area by exploring the accessibility of existing VPTs for this group of users and creating design tools and recommendations for the design of accessible VPTs for this target group.

This research began with the evaluation of the accessibility of the most popular VPT, Scratch. A user evaluation was conducted with seven children with learning disabilities, five of them were also diagnosed with ASC; three special education needs teachers were also interviewed as part of the evaluation. Analysis of the findings from this evaluation showed that the children faced several difficulties while using Scratch to create stories; and also identified the causes of the difficulties. Accessibility heuristics were derived from the identified 'causes of difficulties' and were used to evaluate the accessibility of three additional VPTs. The findings of this second evaluation showed that the assessed VPTs have features similar to those of Scratch that caused accessibility difficulties to the target group.

In creating tools and recommendations for designing accessible VPTs, the research focused on children with ASC (with learning disabilities) due to the match between their reported preferences and the features of VPTs. A method of creating personae to represent their requirements and goals was created and used to create three data-grounded personae. Experts were then interviewed to propose a set of recommendations for designing accessible VPTs for the target group.

Therefore, this research contributed methods for conducting accessibility evaluation of VPTs for children with learning disabilities and for creating personae for children with ASC; a theoretical model for the use of VPTs by children with learning disabilities in a class setting to achieve a learning goal; findings on the accessibility of existing VPTs for children with learning disabilities; and recommendations for designing accessible VPTs for children with ASC.

List of Publications

Zubair, M.S., Brown, D., Hughes-Roberts, T. and Bates, M. (2018), “Evaluating the Accessibility of Scratch for Children with Cognitive Impairments”, *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, Vol. 10907 LNCS, pp. 660–676.

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Chapter 1: Introduction

Visual Programming (VP) allows programmers to "specify a program in a two or more dimensional fashion" (Myers, 1990). VP allows programmers to work at a higher level of abstraction, support rapid prototyping and improve program readability (Jamal and Wenzel, 2002). The collection of icons or visual symbols used in VP to define programs is called a Visual Programming Language (VPL) (Zhang, 2010). VPLs allow users to visually define and manipulate programming constructs such as variables, conditional statements, loops, data structures etc. (Mota-Macias et al., 2019). Shu (1999) describes VPLs as programming languages that provide programmers with 'visual representations' for achieving tasks that are usually achieved using traditional textual 'one-dimensional' programming languages.

Compared to the textual nature of traditional programming languages, VP offers imagery and visualisation. Myers (1990) believes that this is a huge source of appeal for several reasons. Firstly, it presents programs in a format similar to that in which information is stored in the brain, and allows the processing of data in a way similar to that in which data is manipulated in real life. Secondly, it provides a higher level of abstraction by representing information as concrete visual objects that can be interacted with. This is especially useful when dealing with complex programs or when novice programmers are trying to grasp programming concepts. Lastly, it gives the programmer an impression of explicitly defining a program by letting them interact directly with representations of program code.

Although the use of VPLs greatly reduces the amount of textual code required to create programs, this is not the primary objective of VP. The most common objectives driving research in the field of VP are to make programming more accessible to groups that struggle with conventional programming approaches and to increase the correctness and the speed of performing programming tasks (Burnett, 1999; Shu, 1999). It is not surprising then that since the early years of VP, there have been attempts at creating Visual Programming Tools (VPTs) specifically for children to learn to program. VPTs provide a VPL, a visual execution environment and other required resources and tools for program creation based on the domain of application.

A review of the recent literature shows the existence of several VPTs for children such as Scratch (Maloney et al., 2010), Pocket Code (Slany, 2014), Kodu (MacLaurin, 2011) and Scratch Jr (Flannery et al., 2013). These VPTs have been reported to be effective in aiding children's learning of programming (Maloney et al., 2008; Werner et al., 2012). They are also increasingly being used in contexts other than learning computational concepts. For example, research has shown that VPTs are effective platforms for aiding children's learning of curriculum subjects such as mathematics (Calao et al., 2015) and English (Burke and Kafai, 2010) whilst stimulating interest, fun, and enthusiasm (Sáez-López et al., 2016).

Although the available literature praises the use of VPTs and reports the benefits they have for children, not all groups of children are represented in the research on the use and benefits of VPTs. One of the groups left out of this research is the group of children with learning disabilities (also known as intellectual disabilities). The latest Diagnostic and Statistical Manual of Mental Disorders (DSM-5) (APA, 2013) describes learning disability as a disorder that leads to deficits in an individual's general mental capabilities such as "reasoning, problem-solving, planning, abstract thinking, judgement, academic learning, and learning from experience". This disorder is very common amongst individuals with Autism Spectrum Conditions (ASC) (O'Brien and Pearson, 2004). ASC is diagnosed "by the presence of social and communication difficulties, alongside unusually strong, narrow interests and/or repetitive and stereotyped behaviour" (Baron-Cohen et al., 2009). Therefore, in this thesis, any reference to children with learning disabilities includes those with ASC that also have a learning disability.

Technological interventions for various purposes including academic and non-academic have been reported to be successful as well as popular for children with learning disabilities (Alper and Raharinirina, 2006; Kagohara et al., 2013; Maor et al., 2011). This is especially true for those with ASC (Goldsmith and LeBlanc, 2004; Grynszpan et al., 2014) due to their reported interests in the use of technology (Hardy et al., 2002). It should be noted though, that Grynszpan et al. (2014) reported the lack of sufficient representation of children with ASC that have a learning disability in research on technological interventions and the over-representation of children with ASC that do not have a learning disability.

Even with the success of existing technological interventions to this group of users and the increasing popularity of VPTs as learning tools, at the time of writing, few research studies exist in the literature on the use and benefits of VPTs by children with learning disabilities. Few have been identified involving children with ASC, but they do not involve those that also have a learning disability. This observation is surprising since the features of VPTs meet the needs and preferences associated with children with ASC. Children with ASC are fascinated by structured, rule-based, and consistent environments and interactions; children with ASC also have a preference for the visual presentation of information. VPTs provide a rule-based visual language in the form of VPLs for visually defining behaviour to visual objects which then creates a program that is visually executed. Additionally, communicative and social interaction difficulties faced by children with ASC and difficulties in learning academic and independent living skills faced by all children with learning disabilities can be potentially improved through the use of VPTs by these children to create appropriate content. Therefore, this research aims to contribute to existing knowledge in this area by exploring the accessibility of existing VPTs for children with learning disabilities, and by creating design tools and recommendations for designing accessible VPTs for children with ASC.

1.1. Research Questions and Objectives

The main question addressed by the research presented as part of this thesis is: "How can a VPT be designed to meet the accessibility needs of Children with ASC, specifically, those that also have a learning disability?". Therefore, throughout the remainder of this thesis, any reference to children with ASC refers to those that also have a learning disability, unless specified otherwise e.g. when the term 'high-functioning ASC' is used.

This question is answered in two main phases. The first phase is aimed at exploring the accessibility of existing VPTs for all children with learning disabilities, and the second phase, which focuses on children with ASC, is aimed at contributing design tools and recommendations for designing accessible VPTs for the target group. More specifically, the main question the research aims to answer in the first phase is:

- How accessible are existing VPTs for children with learning disabilities?

This phase of the research has the following objectives:

- To design a method for evaluating the accessibility of VPTs for children with learning disabilities.
- To evaluate the accessibility of existing VPTs for children with learning disabilities.

Findings from this phase of the research showed that existing VPTs are not accessible for children with learning disabilities. Therefore, the second phase of this research asks the following two questions while focussing specifically on children with ASC:

- How can the requirements and goals of children with ASC associated with the use of VPTs be gathered and represented using personae?
- What design recommendations should be followed in designing a VPT that meets the requirements of children with ASC?

This phase of the research has the following objectives:

- To propose a method for creating personae for children with ASC.
- To propose a set of recommendations for designing accessible VPTs for children with ASC.

1.2. Research Contributions

The contributions made by this research to the body of knowledge in this area include:

- a grounded theory based method for evaluating the accessibility of VPTs for children with learning disabilities.
- a set of heuristics for performing accessibility evaluations of VPTs for children with learning disabilities.
- a theoretical model that provides insights on the use of a VPT by children with learning disabilities.
- a set of empirical findings that demonstrate that existing VPTs are not accessible for children with learning disabilities.
- a novel method for the creation of data-grounded personae for children with ASC.
- a set of personae describing children with ASC with varying levels of severity that can be used to inform the design of VPTs and other interactive applications.
- a set of recommendations for designing accessible VPTs for children with ASC.

1.3. Overview of Thesis

This thesis is comprised of eight chapters, including this introductory chapter. Chapter two presents a review of the literature that starts with an overview of learning disabilities and ASC. The chapter then presents a discussion on the use and benefits of technology for children with learning disabilities and those with ASC. It then introduces VPTs, discusses the benefits of their use being reported in the literature, and highlights that children with learning disabilities are left out of this research. Finally, the chapter discusses design approaches, tools and evaluation techniques that can be used for designing accessible technologies for use by children with learning disabilities and ASC.

Chapter three presents a formative evaluation of the accessibility of Scratch with seven children with learning disabilities (including five with ASC) and three special needs teachers as participants. The chapter first provides a detailed overview of Scratch, then the methodology used to conduct the evaluation and the findings are presented.

Chapter four builds on the previous chapter by presenting a heuristic accessibility evaluation of additional VPTs. It begins with the presentation of the heuristics and the justification for choosing the evaluated VPTs. Then each selected VPT is introduced and evaluated. The summary of the findings is then discussed.

Chapter five presents a novel methodology for the creation of personae for children with ASC. This is then followed by the application of the method to create a set of three personae for children with ASC for the design of accessible VPTs. Finally, the chapter presents an updated method for the creation of personae for children with ASC.

Chapter six presents a set of recommendations for the design of accessible VPTs for children with ASC. The chapter first presents the method used to collect and analyse data that led to the proposal of the recommendations and their validation. This is then followed by a discussion of the initial and validated recommendations.

Chapter seven extends the final recommendations proposed in the previous chapter by comparing them with existing recommendations for designing a wide range of interactive applications for children with ASC found through a final examination of the literature.

Chapter eight concludes this thesis by summarizing and discussing the findings of this research, the main contributions of this thesis, limitations of the research, and areas of future work.

Chapter 2: Literature Review

2.1. Introduction

This chapter presents a review of relevant literature starting with overviews of learning disabilities and ASC. The chapter then presents a discussion on the use and benefits of innovative technologies for children with learning disabilities and those with ASC. VPTs and the current state of the research on their use and benefits for children are then discussed. Finally, the chapter discusses design approaches, tools and evaluation techniques that can be used for designing accessible technologies for use by children with learning disabilities and ASC.

2.2. Overview of Learning Disabilities

Learning disability is a term usually used in the United Kingdom in place of 'intellectual disability', 'mentally handicapped' or 'mental retardation' (Cluley, 2018). The latest Diagnostic and Statistical Manual of Mental Disorders (DSM-5) (APA, 2013) describes learning disability as a disorder that leads to deficits in an individual's general mental capabilities such as "reasoning, problem-solving, planning, abstract thinking, judgement making, academic learning, and learning from experience". This means individuals with a learning disability have difficulty processing new or complex information and have a diminished ability to cope independently that starts before adulthood and has long-term effects on their development (Cluley, 2018).

According to DSM-5 (APA, 2013), a diagnosis of learning disability requires three criteria to be met: deficit in an individual's intellectual capabilities confirmed by both clinical assessment and standardised intelligence testing e.g. Intelligent Quotient (IQ); a deficit in an individual's adaptive functioning that affects the individual's daily living skills; and the start of the aforementioned challenges during the individual's developmental stage. The disorder can occur in isolation or together with other neurological disorders such as epilepsy, sensory impairments and ASC; and can vary in severity (Vissers et al., 2016). The severity levels are categorised by DSM-5 (APA, 2013) based on an individual's adaptative functioning as Mild Learning Disability (MiLD), Moderate Learning Disability (MLD), Severe Learning Disability (SLD) and Profound Learning Disability (PLD).

Children with MiLD have difficulties in learning academic and non-academic skills, have difficulties with executive functioning, applying academic skills and require support to meet their age-related expectations. They also exhibit immaturity in social interactions compared to their typically developing agemates. They may function at the same level as their typically developing agemates in personal care tasks but will require help in performing complex daily living tasks such as shopping and preparing food.

Children with MLD are significantly behind their peers in their reading, writing and mathematical skills, as well as understanding money and time. Their social skills are affected by challenges in communication, understanding cues, and social judgements. Personal care such as eating, dressing; and recreational activities can be handled by individuals with MLD through extended teaching and training.

Children with SLD require substantial support due to their constrained conceptual skills. They also require support for all their daily living activities. They usually communicate through single words or phrases, although this can be supplemented using augmentative tools.

Lastly, children with PLD have very limited conceptual skills and communication capabilities and are completely dependent on others for all aspects of daily physical care, health and safety.

2.3. Overview of Autism Spectrum Condition

ASC is diagnosed "by the presence of social and communication difficulties, alongside unusually strong, narrow interests and/or repetitive and stereotyped behaviour" (Baron-Cohen et al., 2009). The symptoms associated with ASC "represent a single continuum of mild to severe social communication and restrictive repetitive behaviours or interests" (APA, 2013). The individual conditions that now make up ASC (e.g. autistic disorder, Asperger's disorder, and pervasive developmental disorder) used to be considered as distinct conditions or disorders. However, DSM-5 consolidated them into the spectrum referred to as ASC.

DSM-5 also provides three levels of severity for ASC, they are: Level 1 ("Requiring support"); Level 2 ("Requiring substantial support"); and Level 3 ("Requiring very substantial support"). A severity level is assigned to an individual based on an overall assessment of the needs of the individual. "Requiring very substantial support" implies that in terms of communication, an individual has severe deficits in verbal and nonverbal social communication abilities, which severely limits the individual's ability to interact socially or respond to other's social interactions. In terms of restrictive repetitive behaviours/interests, an individual's inflexibility, restrictive interests and extreme difficulty to cope with changes interfere with the individuals functioning in all aspects. These are characteristics of individuals at the lower end of the ASC spectrum. While "requiring substantial support" implies that in terms of communication, even with supports in place, an individual shows social impairments such as limited social interactions and response to social interactions from others. In terms of restrictive repetitive behaviours/interests, these behaviours appear frequently enough to be noticed by others and affect the individual in several contexts. Finally, "requiring support" implies that in terms of communication, social impairments are noticeable without support, e.g. having difficulty initiating social interactions. In terms of restrictive repetitive behaviours/interests, significant interference is caused by these behaviours to the individuals functioning in one or more contexts.

ASC is very common among individuals with learning disabilities (APA, 2013), so much that there has been a debate on whether the two conditions are distinct (O'Brien and Pearson, 2004). A form of categorising individuals with ASC that differentiates those with ASC only from those with ASC and learning disability uses the terms 'low-functioning' and 'high-functioning' (Szatmari, 2000). Individuals with ASC that have high or superior levels of intelligence are categorised as having high-functioning ASC while those with IQ levels along the lines of those associated with individuals with learning disabilities are categorised as having low-functioning ASC.

Sensory disorders and attention-deficit/hyperactivity disorders are also commonly associated with ASC (APA, 2013). Individuals with ASC can have abnormalities associated with their attention span, either in the form of being overly focused, or being easily distracted. They also often respond to sensory stimuli (e.g. auditory, touch, visual and oral) in unusual ways, and are believed to engage in repetitive behaviours to induce sensory self-stimulation (Liss et al., 2006).

Motor deficits are also associated with ASC diagnosis (APA, 2013). A study on the motor skills of children with ASC indicated the existence of deficits in perception-action coupling, which is crucial for making coherent and controlled movements (Whyatt and Craig, 2012).

2.4. Technology for Children with Learning Disabilities

Due to their characteristics, children with learning disabilities face several difficulties such as learning academic content, performing daily living activities, making decisions, managing time and money etc. Their varying characteristics also make it difficult for them to benefit from traditional teaching and training methods. However, recent innovative technologies have features that make them valuable in this regard as highlighted by Putnam and Chong (2008). Recent innovative technologies can be used to provide a customised learning experience for each child tailored to meet the child's needs, and they can present information through a visual medium. Other features of these technologies that are specifically relevant to children with ASC include the consistency, predictability and the ability to repeat tasks provided by the technologies. These features have made the use of technology for children with learning disabilities widely acceptable and successful in both research and practice.

Another reason for the use and success of technology that is specific to children with ASC is the strong interest they have in the use of technology. Hardy et al. (2002) discuss the positive and enthusiastic responses they received while speaking with parents, carers, support assistants, and teachers of children with ASC when computers are discussed. The most important responses reported that the children like computers, and that they find computers easy to learn and work with. Another popular response according to the authors is the report of the successful use of computers as facilitators of social interactions with children with ASC. Finally, there were also reports of improved confidence and self-esteem of children with ASC resulting from being able to work well with computers to the extent that they help out their classmates in need.

It is therefore not surprising that various technologies such as 'Virtual Reality' (VR) (Standen and Brown, 2006), mobile devices (Kagohara et al., 2013; Kim and Kimm, 2017; Yee, 2012) and robots (Pennisi et al., 2016) are being used to provide interventions, teach and assist children with learning disabilities using games (Tsikinas et al., 2016) and other kinds of interactive applications.

VR environments provide a safe space for children with learning disabilities and ASC to role-play, practise behaviours and repeat learning tasks where appropriate (Parsons and Mitchell, 2002; Standen and Brown, 2005). VR also allow learners with disabilities to learn from their mistakes without having to suffer the real consequences of their errors, hence allowing them to experience real-world experiences without real-world consequences (Standen and Brown, 2006). They can be used to, among other things, promote independent living skills, improve cognitive performance, improve social skills (Standen and Brown, 2005). Although the use and benefits of VR applications are currently being researched for all children with learning disabilities (de Oliveira Malaquias and Malaquias, 2017), research on the use of VR is more common with children with ASC including high functioning ASC. Successful use of VR applications are being reported in teaching them social skills (Alcorn et al., 2011; Didehbani et al., 2016; Ke and Lee, 2016), pretend play (Herrera et al., 2008), collaboration (Parsons, 2015), independent living (Newbutt et al., 2017) and recognising facial emotions (Bekele et al., 2014; Modugumudi et al., 2013).

Recent technological advancements have made mobile devices very common among both typically developing children and children with disabilities. Certain properties of mobile devices such as portability, mobility, affordability, storage and their support for various multimedia formats have made them popular with children with learning disabilities, especially as Augmentative and Alternative Communication (AAC) applications for those with ASC (Lorah et al., 2015; Schlosser and Koul, 2015; Yee, 2012). AAC applications provide a means of communication for children with ASC. Having AAC applications as part of mobile devices instead of as standalone speech generation devices has several advantages including lower cost, adaptability and mobility (Ganz, 2015).

Another group of applications commonly offered to children with learning disabilities on mobile devices is 'serious games', although serious games are also offered using other technologies such as VR (Whyte et al., 2015; Zakari et al., 2014). Serious games are games that have a goal other than to entertain their players (Brown et al., 2010) i.e. a serious goal such as learning to add two numbers. Serious games have been reported to be successful when used by children with learning disabilities and ASC to improve skills such as academic skills (Khowaja and Salim, 2019; Mangowal et al., 2017), improve attention (García-Redondo et al., 2019), and improve daily living skills (Brown et al., 2011; Chang et al., 2016). Specifically for children with ASC, serious games have also been successfully used in improving areas that these children struggle with, such as social and communication skills

(Bernardini et al., 2014), and recognising emotions (Brandão et al., 2015; Fridenson-Hayo et al., 2017) etc.

The use of robots has also been shown to support the learning of children with learning disabilities (including those with severe and profound learning disabilities) (Aslam et al., 2016; Standen et al., 2014). They have also been reported to elicit social behaviours from children with ASC, as reported by Scassellati et al. (2012). The authors provided a number of possible reasons as to why children with ASC are able to interact socially with robots. One reason may be due to the simplified social cues presented by the robots, or it may be because robot responses are exaggerated, or because robot interactions are without the negative associations that some children may have with human interactions. It should be noted that robots are used for other purposes such as for learning skills and for getting feedback (Diehl et al., 2012).

However, it should be noted that some children with learning disabilities are still underrepresented in research on the use and benefits of technology. Children with profound learning disabilities are among those underrepresented in this research (Standen et al., 2014). Another group that is underrepresented in research on the use and benefits of technology is the group of children with ASC and a learning disability, whereas those with high function ASC are overrepresented (Grynszpan et al., 2014). Likely reasons for the underrepresented groups being excluded include the difficulties they face in communicating, performing tasks, following instructions and the difficulty of designing accessible technologies for them.

It can be seen that technology is increasingly becoming part of the lives of children with learning disabilities. Therefore, considerations should be given when designing technology, to the impairments in several cognitive abilities such as language, reasoning, idea creation, memory and visual perception faced by those with learning disabilities, to design with the appropriate 'cognitive accessibility' and ensure access to children with learning disabilities (Wehmeyer et al., 2004).

2.5. Overview of Visual Programming

According to Myers (1990), Visual Programming (VP) "refers to any system that allows the user to specify a program in a two or more dimensional fashion". Declaring programs using a conventional text-based approach is considered one dimensional compared to the VP approach (Zhang, 2010). VP uses collections of icons or visual symbols called Visual Programming Languages (VPLs) to specify programs. VPLs allow users to visually define and manipulate programming constructs such as variables, conditional statements, loops, data structures etc. (Mota-Macias et al., 2019).

Although the use of visual representations greatly reduces the amount of textual code required to create programs, this is not the primary objective of VP. The most common objectives driving research in the field of VP are to make programming more accessible to groups that struggle with conventional programming approaches and to increase the correctness and the speed of performing programming tasks (Burnett, 1999; Shu, 1999). To achieve these objectives Burnett (1999) provides four common strategies that are used in VP: concreteness, directness, explicitness, and immediate visual feedback. Concreteness is used in VP to counter the abstractness of programming. It allows users to express aspects of a program using actual concrete instances or have the system display the effects of parts of a program on an actual instance e.g. an object. Directness minimises the distance between the user and the goal being targeted. VPs practice explicitness by explicitly stating the semantics within a program e.g. by visually depicting dataflow relationships. Lastly, immediate visual feedback is provided by updating the program to display the results of changes made it.

Now, more than three decades since VP's humble beginnings, there has been a massive increase in interest in its applications and potentials. This has led to the development of Visual Programming Tools (VPTs) for several domains. A VPT provides a VPL, a visual execution environment and other required resources and functionalities for creating visual programs within a particular domain.

2.6. Visual Programming Tools as Learning Tools for Children

The earliest VPT created specifically for children found in the literature is the compiled picture language created for Macintosh systems (Choi and Kimura, 1986). Its goal was to support 'keyboard less programming' by using pictures to declare programs, and it was targeted towards school children and novice programmers. Other early VPTs targeted at children include KIDSIM (Smith et al., 1994) and Toontalk (Kahn, 1999).

A review of the recent literature shows newer VPTs for children are now used in research and practice. They include Scratch (Maloney et al., 2010), Pocket Code (Slany, 2014), Kodu (MacLaurin, 2011) and Scratch Jr (Flannery et al., 2013). Scratch is a block-based VPT created at MIT's Media Lab primarily for children aged between 8 and 16 years to learn to program while creating personal projects such as animations or games. ScratchJr redesigned Scratch to meet the developmental and learning needs of children aged between five and seven years. Kodu is a visual programming tool created specifically for young children to learn to program through individual independent exploration and game-making. Finally, Pocket Code is a Scratch inspired mobile VPT targeted at children aged between 13 and 18 years to create animations and programs while learning to program. Other VPTs being used by children according to the literature include Alice (Cooper et al., 2000), Agentsheets (Repenning et al., 2000) and Greenfoot (Kölling, 2010).

The use of these tools as learning aids for children is becoming more and more accepted in today's society. Originally considered extracurricular activities and used as part of after school clubs or for leisure (Maloney et al., 2008), schools are now introducing the use of VPTs to teach programming, computational thinking, curriculum subjects and other skills (Sáez-López et al., 2016; Sengupta et al., 2015). By using VPTs for content creation, children participate in active learning, a teaching approach that centres on the child and the child's creative preferences (Sáez-López et al., 2016). Repenning (2013) also found through his work with Agentsheets since as early as 1991 that the ability to personalise a programming task or project greatly increases the programming motivation of children. And that children are more interested in programming when they are using it as a tool to bring their creations to life in their own world. Therefore, it is not surprising that most studies found in the literature where VPTs are used for learning focus on the creation of fun and engaging content such as games and animations.

Maloney et al. (2008) encouraged the learning of programming without teaching programming, but by letting children use Scratch to create content that interests them such as games and animations. The research involved children aged between 8 - 18 years at a computer clubhouse for 18 months. The authors reported that programming concepts such as loops, conditionals, synchronisation, and user interaction were learnt by the participants. The authors believed that Scratch's simplification of programming mechanics, feedback provision, experimentation support, multimedia support and provision played very important roles in getting the participants interested in programming and making it easy for them to learn.

Using a similar approach, game making using Alice was used in a study by Werner et al. (2012) for teaching children computer science concepts. The study was conducted over two years with a total of 325 middle school participants. The findings of the study were based on the analysis of 231 games created either by individuals or through pair programming. Findings reported that participants showed an understanding of concepts such as abstraction, modelling, event handling and control structures.

Game making was also used by Akcaoglu (2014) in a study on teaching problem-solving skills to children. The study was conducted with 21 middle school participants as part of a summer program for game making using Kodu. Although results did not show significant improvements in the problem-solving skills of participants, they did show improvements in solving system analysis and design, and decision-making problems.

In addition to introducing children to the basics of programming, helping them improve their programming and computational skills and knowledge, the use of VPTs for game making can create interest in programming in children and possibly lead to them further pursuing it (Fowler, 2017; Ouahbi et al., 2015).

The use of VPTs has also been reported to aid in children's learning of specific subject skills. For example, Calao et al. (2015) conducted a study that investigated the effect of using Scratch on the mathematical knowledge of sixth graders. The study was conducted with 42 students divided into two groups (experimental and control) of 24 students each. For three months, the experimental group went through stages of being taught programming concepts and the use of Scratch before finally using their knowledge to create their own content such as games and simulations, while the control group continued their usual classes and activities. Pretests and posttests were conducted to assess the participants' mathematical knowledge across five dimensions (modelling, reasoning, problem-solving, exercising, and average). No significant differences were recorded for the control group. However, the experimental group showed statistically significant improvement across all five dimensions.

Sáez-López et al. (2016) conducted a study over two academic years aimed at assessing the use of a VPT (Scratch) in a classroom with 107 primary school students in five schools. The study analysed outcomes and attitudes of participants as they used Scratch to create arts and social science related content. Findings from the study reported the understanding of concepts within the subjects by the participants.

Burke and Kafai (2010) on the other hand conducted a study that explored the use of a VPT in an English Language classroom. The study involved 10 children aged between 12 and 14 years participating in an elective English language class twice a week for two months to create stories using Scratch. Findings from the study report that all participants learnt the basics of programming through the design, troubleshooting and debugging of their digital story program, and learnt the basics of story writing through drafting, revising and editing their stories. Leon and Robles (2015) also conducted a study with a group of fourth and fifth-grade students (32 as the experimental group, 33 as the control group) using Scratch to measure the impact of programming on the learning outcome of an English class. Findings of the research showed higher improvements in the group that created Scratch projects as part of the English class compared to the group that learnt traditionally.

It should be noted that not all researchers encourage the use of VPTs for learning programming. For example, Lewis (2010) argues that the visual affordances provided by Scratch compared to textual languages prevents its users from focusing on low-level details and understanding how they affect large programs. This study found that those that learn programming using LOGO showed a higher level of confidence in their skill than those that learnt using Scratch. However, the study also reported relative improvement in learning outcomes for those that learnt using Scratch, which supports VPTs advantage as programming learning tools.

Despite the numerous reports and studies in the literature supporting the advantages of using VPTs to teach various skills, at the time of writing, there is very little research done on the use and benefits of VPTs for children with learning disabilities. However, few research reports have been found in the literature on the use and benefits of VPTs for children with high-functioning ASC that show potential benefits for all children with ASC.

Sarachan (2012) proposed a workshop where children with high-functioning ASC can use Scratch or other VPTs to explore their interests in computers and games with the aim of improving their creativity and problem-solving skills. The proposal suggested modelling the workshop after the Computer Clubhouse reported by Maloney et al. (2008).

Results of a pilot study conducted by Munoz et al. (2016) with four teenagers with high functioning ASC showed that they were able to gain intermediate knowledge of computational thinking after participating in a workshop for creating games using Scratch. It should be noted too that participants had no prior programming experience.

The social skills of children with ASC could also be improved with the help of VPTs as reported by (Eiselt and Carter, 2019). The authors conducted an eight-week programming course with eight children with high functioning ASC aged between 9 and 16 years which aimed to teach programming and social skills through game making. By the end of the study, the authors observed improved knowledge in programming and social interactions in participants. Gribble et al. (2017) also reported communication improvements in a single child with ASC that participated in their study of the effect of programming with VPTs on interactions. It is however interesting to note the findings reported by Bossavit and Parsons (2017) from a study with two teenagers with ASC programming a game of their choice using Kodu. The findings report demonstrations of problem-solving and programming skills by the participants, but very little interaction and collaboration between the two participants.

Overall the literature yields only a few studies related to the use of VPTs by children with high-functioning ASC and not children with learning disabilities. This means that children with learning disabilities are left out of this area of research. One reason could be that although existing VPTs are accessible for children with high-functioning ASC, those with learning disabilities find it inaccessible, and hence require an accessible VPT to participate in this research.

2.7. Accessibility Design Approaches

The International Standards Organisation (ISO) (2019) defines accessibility as the *"extent to which products, systems, services, environments and facilities can be used by people from a population with the widest range of user needs, characteristics and capabilities to achieve identified goals in identified contexts of use"*. The phrase "can be used" in this definition is implying "usability", which is defined by ISO as the “extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use”. Therefore, accessibility can be referred to as usability for people with the widest range of needs, characteristics and capabilities including people with disabilities.

Designing accessible technologies for children with disabilities requires understanding the target users, determining the right design approach, designing to meet the target users’ needs and effectively evaluating the accessibility of the technology.

Several approaches for designing accessible technologies have been proposed over the last half-century. One such approach is the “inclusive design” approach, which has the aim of designing to meet the needs of the “widest possible audience, irrespective of age or ability” (John Clarkson and Coleman, 2015). According to Persson et al. (2015), this design approach or very similar versions of it also exist in other cultures and are known by different names e.g. “barrier-free design”, “universal design” and “design for all”. Barrier-free design was started in the 1950s to ensure handicapped war veterans and others with similar conditions have access to buildings. This movement led to the subsequent creation of several household assistive technologies. Universal Design, coined by Ronald L. Mace (Mace, 1988), was inspired by the barrier-free design approach and aims to meet the needs of all individuals irrespective of their ages, ability or status in life without having to perform adaptations or specialised design. Design for all aims to design for the widest range of people in the user base. One common theme across all these approaches is the goal of meeting the needs of everyone including all those with disabilities. However, Petrie and Bevan (2009) argue that this is not possible in practice although it is an “honourable aim”. They warn that these approaches can frighten off designers and developers who may see the impossibility of the task and avoid designing with accessibility in mind altogether.

An approach that tackles the broadness and lack of specificity associated with inclusive design is the User-Centred Design (UCD) approach introduced by Norman (Norman and Draper, 1986). Abras et al. (2004) describe UCD as a spectrum of approaches in which the design is influenced by end-users i.e. end-users influence how a design takes shape. The influence that end-users exact on the design can be at specific times or throughout the process. The contributions they make can range from providing input when consulted to being partners in the process. An example of the UCD approach is the "iterative, user-centred design" approach described by Petrie and Bevan (2009). It involves an iterative process of understanding user requirements which can be done through interviewing users, reviewing guidelines, or conducting ethnographic studies; designing the technology based on the requirements, creating a prototype, and evaluating the prototype with users or experts. This iterative process is continued until an acceptable product is created in terms of meeting user requirements and its accessibility, then it is finally implemented.

Vazquez et al. (2016) employed a UCD approach over three months in designing a tool for encouraging motor movement in children with ASC. During this period, they gathered user requirements by observing target users and interviewed target users and therapists. When designing for children with ASC or other groups of users with communication difficulties, interviewing stakeholders or experts such as teachers, parents or caregivers in place of the target users is common due to the difficulties in communication faced by the target group (Lazar et al, 2017).

An iterative UCD approach was used by de Sá and Carriço (2012) to design fear therapy mobile applications for individuals with ASC. Their approach involved gathering requirements through interviewing and brainstorming with users, parents and therapists, designing and developing porotypes, and evaluating porotypes with users. Another application of UCD was reported by Munoz et al. (2012) to design a tool for supporting the development of empathy in children with ASC. The authors also conducted interviews with users, parents, teachers and therapists; and evaluated prototypes with users in a similar fashion to de Sá and Carriço (2012).

Another approach that has been used for designing accessible technologies is 'participatory design'. Participatory design can be described as the set of approaches in which end-users act as full participants in the complete design process (Muller, 2007). Based on this description, participatory design can be viewed as a type of UCD belonging at the full user involvement end of the UCD spectrum described by Abras et al. (2004).

Benton et al. (2012) reported the successful application of participatory design with children with ASC and describes the positive experiences that the children can gain from participating in the process. Another study by Millen et al.

(2011) reported the use of a participatory design approach with children with ASC to design games for improving social competencies. The study reported that participating children showed engagement by producing valuable ideas and spending time on their design tasks; in the end, they were able to design a game for other children with ASC to use.

Bossavit and Parsons (2017) also reported the use of participatory design to develop an educational gaming app with two teenagers with ASC and a teacher. Their report of this exercise stresses the need for clarifying the roles and contributions of each participant in a participatory design process; having an informal discussion-based approach; being transparent about the acceptance and rejection of ideas. The need for transparency was also stressed by Frauenberger et al. (2017) in their review of their use of participatory design processes with children with ASC. Although Millen et al. (2011b) believe that some participatory design processes have the potential of including children with ASC, they mention that the main challenge of this group of users is their poor imagination skills. Another issue likely to be faced is that of communication difficulties, especially when working with children with ASC and a learning disability, which is why participatory design is more likely to be carried out with children with high functioning ASC (Benton et al., 2012; Frauenberger et al., 2017). Therefore, when designing for children with learning disabilities, employing user-participation in some design activities, as well as requirements gathering from experts, can be a way of finding balance. Caro et al. (2017) reported taking a similar stance when working with children in this group to design an exergame to support children with ASC and motor problems.

2.8. Gathering, Representing and Communicating Accessibility Requirements

An essential part of the UCD approach is understanding the target users, their goals and context of use (Petrie and Bevan, 2009). It is crucial that designers understand and visualise the relevant aspects of the users' relationships with each other, what they want from what is being designed and from their social and physical environments (Cooper et al., 2014). Thus, it is important to answer the question of how best to effectively model or represent gathered user information at design time to aid the decision making of designers and developers. "Personae" are valuable tools used in UCD to represent detailed descriptions of users, their characteristics, and goals (Miaskiewicz and Kozar, 2011).

Cooper (1999) introduced the role of personae in his book “The Inmates are Running the Asylum”. He described personae as simple tools that provide a “precise description of our user and what he wishes to accomplish”. Personae paint a “memorable, engaging and actionable image” of the user being designed for (Adlin and Pruitt, 2010). Each persona describes a hypothetical archetype of real users i.e. it represents a group of users that share similar behaviours towards the use of a product or service (Cooper, 1999; Cooper et al., 2007). Unlike other models of user representation such as profiles which are made up of lists of attributes, a persona narrates a realistic and relatable description of an individual user. It includes a name, a background story, characteristics, needs and goals of the user related to the product or service being designed, and in some cases a photographic image of the user. This personification serves to vividly relay relevant information about the persona as well as a way of drawing empathy, and interest from designers (Adlin and Pruitt, 2010; Cooper et al., 2007).

Personae have numerous application potentials in user-centred design. Personae can be used to explicitly define and set focus on a specific set of users and their goals (Adlin and Pruitt, 2010; Cooper et al., 2007). Without such a clear focus on target users, there is the risk of designing a product for ‘the elastic user’ (Cooper, 1999). The elastic user is an imaginary target user whose needs and capabilities are reimagined at the convenience of the designer. One moment the elastic user is a beginner who requires guiding instructions at every step of the way, at another moment the elastic user becomes an expert able to find his way blindly through the ‘maze’ of a configurations page. Using personae is a valuable way of having designers think about their target users at a personal level. Referring to their personae as individuals, they can make user-centred decisions by asking and answering questions such as “Will Sue use this feature?” or “Is this going to be too complicated for Frank?” (Floyd et al., 2008). Therefore, personae can lead to better design decisions, and help avoid decisions based on assumptions about users (Adlin and Pruitt, 2010). However, personae are not useful to designers alone, they can be used by developers, product managers, executives, and all other stakeholders, especially as tools for communicating about users and for ending feature debates (Cooper, 1999). In addition to their benefits during design and development, personae can also be used during evaluation to ensure the process is user-centred (Friess, 2015)

Even though personae can bridge the gap between the knowledge of designers, developers and stakeholders and the actual needs and requirements of children with ASC, at the time of writing few applications of personae for children with ASC have been found. Leal et al. (2016) reported the creation of a persona describing a 10-year-old with ASC named Nuno. According to the authors, Nuno is the first member of a family of personae for the design of technologies for children with ASC. The characteristics and goals of Nuno were then used to inform the design of a communication application (Vieira et al., 2017).

The Mathisis H2020 project (Brown et al., 2016) also used personae in deriving user requirements. Several personae for children with learning disabilities and ASC with varying severities were delivered as part of the project.

McCrickard et al. (2015) used personae for two children with ASC, six-year-old Greg and seven-year-old Isabelle, to inform the design of applications for anger management for children with ASC. The personae were meant to inform novice designers on the characteristics, needs and goals of their target group.

Two other uses of personae for designing for children with ASC found in the literature are those reported by Al-Wabil et al. (2012) and Prawira et al. (2017). A persona representing preteen children with ASC, and another representing a mother of a child with ASC were used to inform the design of a scheduling application by Prawira et al. (2017). While Al-Wabil et al. (2012) used personae describing children with different conditions including ASC to design, develop and test an Arabic auditory learning system.

Although personae are imaginary representations of users, Cooper (1999) argues that they should be built through a methodical approach of analysing data gathered from real users. However, not all types of personae are built from real user data, and the method used to build personae varies. One major determinant of the data and method used to build a persona is the intended use of the persona (Floyd et al., 2008). For instance, Norman's ad-hoc persona is used to make designer's assumptions and intuitions explicit, aid communication and define possible use cases (Norman, 2006). It is not meant to represent real users and is not used as such. Therefore, it is not built on real user data but rather built using the designer's imagination, intuition, experience and/or stereotypical behaviours of the target user group. The extreme persona by Djajadiningrat et al. (2004) is also not aimed at representing real users, it is used to describe extreme characters and test behavioural boundaries. Hence it is made up of mainly imaginary data.

However, in situations where personae are used as real user representatives for the purposes of identifying user requirements, the personae must be built using real user data. Cooper et al.'s (2007) goal-based persona is meant specifically for this purpose. Therefore, it is built on real user data gathered through ethnographic interviews to ensure that it accurately represents the characteristics and goals of the target users. The gathered data is analysed to identify significant user behaviours and groups of users with similar behaviours. A persona is then created for each group of similar users, i.e. having the main behavioural characteristics, needs and goals common to the group. Fictional personal information and background stories are added to personify each created persona.

The role-based persona by Adlin and Pruitt (2010) also serves as a real user representative. Unlike the goal-based persona (Cooper et al., 2007), the role-based persona uses both qualitative and quantitative sources of user data. Categories and sub-categories of users are created based on similarities of users and their needs extracted from analysing the data. Persona skeletons, which contain brief lists of attributes or assumptions about sets of users within each sub-category are then created, prioritised, and developed into full personae. Lastly, created personae are validated against real user data or by experts on the target users.

Therefore when using personae to represent children with ASC, care must be taken to ensure that they are indeed real data based persona similar to the goal-based persona (Cooper et al., 2007) or the role-based persona (Adlin and Pruitt, 2010). However, not all the personae for children with ASC found in the literature are supported with information about their origin in terms of method of creation and data used. Leal et al. (2016) did not provide a detailed description of the method used in the creation of their persona, but mentioned that it is based on Cooper et al. (2007), and provided a high-level description of how data was collected from the literature and experts.

Prawira et al. (2017) provided even less information about the method used to create their persona but mentioned that data was gathered by interviewing parents and psychologists. Similarly, McCrickard et al. (2015) only mentioned that the personae were created by HCI experts and psychologists familiar with autism.

Al-Wabil et al. (2012) claimed the use of data-driven personae, however, the method for collecting the data was not provided. The authors did, however, provide the set of characteristics that were used to create the persona and claimed that domain experts validated the created personae.

The above observations show that despite the benefits of personae, there is still little information available on the methods used for creating accurate data grounded personae for children with ASC. Therefore, there is a need for the proposal of a method for creating accurate data-grounded personae for children with ASC which takes into account the difficulties, capabilities and needs of this target group in its procedures (e.g. data collection and analysis).

2.9. Accessibility Evaluations

Another invaluable component of the UCD approach is the evaluation of the technology that is being designed. It has been described as the heart of the entire process by Petrie and Bevan (2009). According to Nielsen and Molich (1990), four approaches can be taken to conducting evaluations. The first is by conducting a "formal" evaluation using some form of formal technique. An example of a formal evaluation method is the GOMS method created by Card et al. (1983) for modelling interactions between a user and an interactive system. GOMS has inspired various specialised versions for specific types of analysis including evaluating technologies for individuals with ASC (Quezada et al., 2018). Evaluations using models are very useful in forecasting measures such as time to complete tasks and are usually conducted in situations when user evaluations are not practical or when it is economically advantageous to construct models (Petrie and Bevan, 2009).

Another approach to conducting evaluations is by executing them automatically. In this approach, prototypes and initial final implementations can be automatically tested to ensure that basic accessibility issues are avoided and that they meet relevant accessibility standards and guidelines (Petrie and Bevan, 2009). Examples of tools available for automatic accessibility for the web are provided by the Web Accessibility Initiative (W3C, 2018). Although this method can be fast and efficient, Brajnik (2008) argues that it should not be used alone to evaluate accessibility as it is only as effective as the standards or guidelines it uses. In addition, it should be noted that not all guidelines or standards may be automatically tested (Petrie and Bevan, 2009). An example of the use of automated testing to evaluate the readability of a text simplification output for readers with learning disabilities, including those with ASC is provided by Yaneva et al. (2016).

Evaluations can also be conducted heuristically by having an expert pass judgement on the accessibility of the evaluated technology. This type of evaluation is also known as "expert evaluation" (Petrie and Bevan, 2009) or "conformance reviews" (Brajnik, 2008). It is usually conducted when an initial prototype or prototypes of the technology are available before evaluating with real users, or when it is not possible to perform evaluations with real users (Petrie and Bevan, 2009). Experts are tasked with working through the technology while performing tasks, inspecting features or comparing with guidelines or standards in search of any accessibility issues. A variation of the heuristic approach adds the use of personae in the process to ensure that evaluators are focused on aspects of the system relevant to the user (Friess, 2015). Examples of how the heuristic evaluation technique has been applied in evaluating technologies for individuals with ASC can be found in Isleyen et al.'s (2014) evaluation of a game for teaching facial expressions and Guasch et al.'s (2019) evaluation of an alternative communication tool. However, this method faces a similar limitation to the automatic evaluation method in that it is limited by the guidelines or standards used by the expert, and the expert's experience (Brajnik, 2008).

Finally, evaluations can be conducted empirically through experiments with users. According to Petrie and Bevan (2009), empirical user evaluations should be performed at all stages of development where possible, or at least during the final stage of the development. By performing evaluations with real users, evidence can be gathered on accessibility in real usage contexts. Different approaches to user evaluations can be taken depending on whether formative or summative assessments are intended. Formative user evaluation methods are aimed at understanding the behaviours of users, their intentions and the expectation they have to understand the problems that they encounter while using the technology. Conversely, summative user evaluation methods aim to measure the accessibility of a technology. User evaluation should be conducted iteratively with a small number of participants. However, if only one user evaluation is to be performed, at least eight users should take part in the evaluation. When performing user-based accessibility evaluations, it is very important to take into consideration the special needs of the users participating in the evaluation, such as the need for using assistive technologies to participate in the user-based evaluation; travel considerations to the location of the evaluation; accessibility of the location of the evaluation; provision of explanatory materials consent sheets in the appropriate formats; and finally suitability of the evaluation tasks and the pace in which they are to be performed.

Other types of evaluation methods include evaluating by analysing recorded data from technology use (Petrie and Bevan, 2009) and "pluralistic walkthroughs" (Nielsen, 1994). Evaluation through data analysis is more appropriate in cases where improvements are being planned for existing technology. Analysis of the data collected on the use of the technology can be used to conduct a non-intrusive evaluation. Questionnaires can be used to collect such data from a sample of existing users or data logs can be queried to find measures for error occurrence, feature uses etc. In pluralistic walkthroughs, users and developers evaluate and discuss elements within use scenarios of the technology being evaluated.

2.10. Summary

This chapter discusses learning disabilities and ASC and the difficulties associated with the conditions. This chapter also discusses recent reports from the literature on the use and benefits of various types of technology platforms and approaches for children with learning disabilities in various areas such as social behaviours, collaboration, academic subjects, emotion recognition, independent living etc. VPTs, which also have the potential of being used successfully as technological interventions are discussed. The existence of VPTs created specifically for children, and the success reported in their use for teaching skills across several areas to typically developing children are summarised. The limitation of research in this area with regards to not including children with learning disabilities is highlighted, although few research works conducted with children with high-functioning ASC are found and reported as part of this review. The chapter concludes by discussing approaches, tools, and evaluation techniques that can be used for designing accessible technologies for children with ASC.

Chapter 3: Evaluating the Accessibility of Scratch for Children with Learning Disabilities

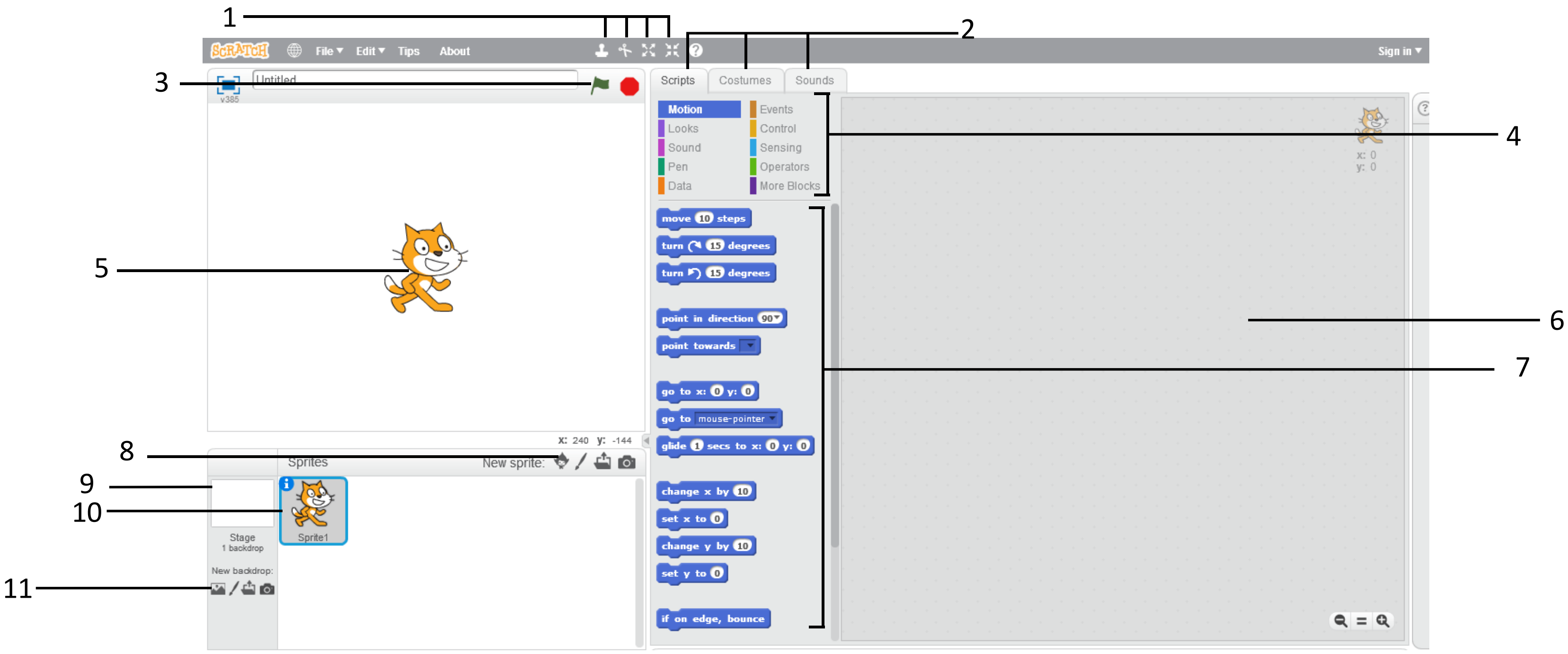
3.1. Introduction

Scratch is currently the most popular VPT for children (Moreno-Leon and Robles, 2016). Research studies have reported benefits of using Scratch such as learning computational thinking skills, problem-solving skills and academic subjects. However, there is currently little research on the use of Scratch by children with learning disabilities. One possible explanation could be that VPTs such as Scratch, although easy to learn and use for children and novice programmers, are not accessible for children with learning disabilities. As part of an initial review of the literature, this research was unable to yield accessibility evaluations of Scratch or any other VPTs for children. Therefore, this chapter presents a formative evaluation of the accessibility of Scratch that includes a user evaluation with children with learning disabilities and interviews with Special Education Needs (SEN) teachers. This chapter first presents an overview of Scratch, followed by the methodology employed for the accessibility evaluation. The findings of the evaluation are then presented and discussed.

3.2. Overview of Scratch

Scratch was developed in MIT's Media Lab primarily for children aged between 8 – 16 years to learn to program while creating personal projects such as animations or games (Maloney et al., 2010). Scratch projects are made up of media and scripts. Scripts are made up of colourful command blocks snapped together to create a more complex command or sets of commands. Media including images and sounds are available in Scratch's inbuilt media libraries. Scratch also allows the importation of existing media files and the creation of new media using inbuilt tools. It also provides an error message free programming environment i.e. there is no wrong way of snapping blocks that fit together, makes data concrete by displaying variables on-screen during execution and visualises execution by highlighting blocks that are executing at runtime. An online community is available for users to share their projects, get feedback and build on other user's projects. Additionally, an online community for Scratch educators exist for sharing resources, stories and building relationships (Brennan, 2009).

Figure 3. 1. A labelled screenshot of Scratch 2.0's interface



Key

1. Tools (duplicate, delete, grow, shrink)
2. Tabs
3. Execute
4. Block categories
5. Sprite
6. Scripting area
7. Blocks (motion category)
8. Add sprite
9. Background
10. Sprite thumbnail
11. Add background

Scratch is designed to “lower the floor” and allow children to get started with programming at an early age, starting from simple programs to sophisticated ones as they progress over time (Utting et al., 2010). A key part of its design is in its encouragement of “self-directed learning” through exploring and collaborating with peers (Maloney et al., 2010). Scratch was publicly launched in 2007, Scratch 2.0 was made publicly available in 2009, and the current version Scratch 3.0 was made publicly available in 2019. It should be noted that this evaluation was conducted using Scratch 2.0 as it was conducted in 2017. A labelled screenshot of Scratch 2.0’s interface is provided in Figure 3.1.

3.3. Grounded Theory Approach to Accessibility Evaluation

The lack of previous research on evaluating the accessibility of VPTs using real users means there are no existing methods available in the literature for performing this evaluation. Although a usability evaluation technique for block-based VPTs using the cognitive dimensions framework was found in the literature (Holwerda and Hermans, 2018), the framework is not meant for evaluating accessibility related to children with learning disabilities. Additionally, due to the nature of children with learning disabilities, the difficulties they face in communication and following instructions, certain evaluation techniques such as user interviews and task-based evaluation were ruled out. To mitigate the limitations of working with the target group, SEN teachers were also included in this evaluation as domain experts (Lazar et al, 2017). The evaluation will then include user evaluations with children with learning disabilities and interviews with SEN teachers. Therefore, a flexible research approach suitable for making novel enquiries, collecting and analysing data of different types from multiple sources was required. Thus grounded theory methodology was chosen as the framework for this evaluation.

Grounded theory is a method of qualitative research that aims to produce new theories that are grounded in the data gathered during the research (Glaser and Strauss, 1967). The method “consists of systematic yet flexible guidelines for collecting and analysing qualitative data to construct a theory from the data themselves” (Charmaz, 2014). A theory is a schema used as an explanation for a phenomenon, based on some observations or experiments (Dix, 2008). Even though grounded theory has its origins in social science research, it is increasingly being used in other research areas including HCI research (Devkar et al., 2015; Muller, 2014). This is due to its applicability in identifying general concepts, developing theoretical explanations based on data, and offering new insights into a phenomenon (Corbin and Strauss, 2015). Grounded theory does not require a prior hypothesis to focus research on, rather the research process formulates a theory built on concepts derived from the data collected (Corbin and Strauss, 2015). As with any grounded theory investigation, this was conducted to understand a phenomenon that has not been researched before. The main objectives of this evaluation are to identify any difficulties faced by children with learning disabilities when using Scratch and the causes of those difficulties.

Although any qualitative or quantitative data types can be used in grounded theory, this evaluation used observations and video screen captures of participating children using Scratch to create content related to their interests. In addition, interviews were conducted with participating teachers to address the gaps in findings from the analysis of data collected from the participating children (Lazar et al, 2017). It should be noted that grounded theory considers the researcher as an 'active participant' in the research being conducted, and so the research questions may change as the researcher acquires information about the phenomenon being observed (Muller, 2014).

The participants, procedure, data collection, analysis, findings and discussion of this evaluation are presented in the following sections.

3.3.1. Participants

The researcher contacted SEN schools in the Nottinghamshire area (where the researcher resides) with information regarding the research and a request for interested participants that have met a provided inclusion criterion (Lazar et al, 2017). Ethical approval for conducting this evaluation was sought and granted by Nottingham Trent University's Ethics Committee before participants were recruited (see Appendix A). Two SEN schools (School A and School B) agreed to participate subject to the agreement of parents of the selected participating children. However, School B dropped out for unspecified reasons before participants were selected. For convenience reasons, School A suggested having an entire class of children participate in the evaluation as opposed to having children from different classes. This was considered beneficial as the children were able to work alongside their regular teacher and teaching assistant as part of the observed activity.

The inclusion criteria provided to the school to guide the selection of participating children stated that a child must be diagnosed with a learning disability, must have experience using a web browser on a computer and must be less than 18 years old to be eligible to participate. Based on these inclusion criteria, a class consisting of eight children, four boys and four girls all aged between thirteen and fourteen years, was identified as the most suitable class to participate in the study. Three teachers in the school, (herein referred to as T1, T2 and T3) were also recruited to participate. For clarity, 'teachers' and 'children/users' will be used to differentiate between the two types of participants throughout the remainder of this chapter. The participating teachers all have several years' experience teaching special needs classes with children with MiLD, MLD, SLD, and ASC. T1 and T2 were the teachers assigned to the class selected for the evaluation. T2 is also the assistant headteacher of the school.

Consent was sought from and granted by the eight children and their parents. Out of the eight children, one (male) could not use a web browser and was disqualified from participating. Therefore, only seven children (three males and four females) herein referred to as C1 - C7 participated. This number is within the acceptable number of participants in HCI research conducted with users with disabilities (Lazar et al, 2017), and in qualitative research (Hayter et al., 2014). A profile for each child stating their diagnosis was then requested from the class teachers. Five of the seven participants were diagnosed with ASC and learning disabilities, while two were diagnosed with only learning disabilities. The teachers were also asked to comment on each child's fine motor skills, reading skills, communication skills, attention, and memory. Table 3.1 shows each child's complete information as provided by the class teachers.

None of the participants (both teachers and children) had any visual or textual programming experience and all were unfamiliar with the Scratch VPT before their involvement in this research.

Table 3.1. Profiles of participating children

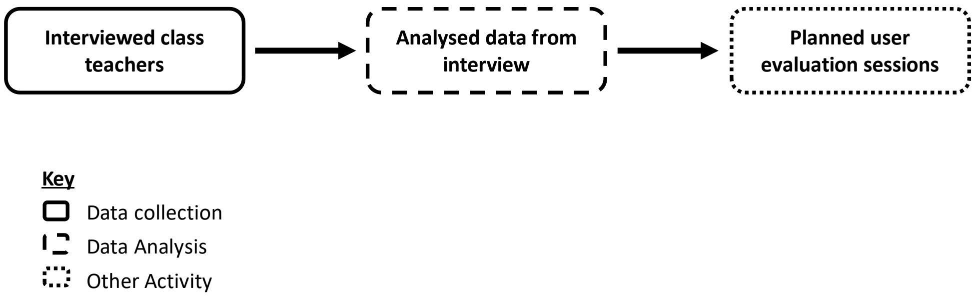
Child	Diagnosis	Fine Motor Skills	Reading Skills	Memory	Communication	Attention
C1	ASC & MLD	Poor	Functional Level	Good	Unwilling to communicate	Poor
C2	ASC & MLD	Good	Functional level	Good	Good, but can be repetitive	Good
C3	ASC & MLD	Good	Functional level	Good	Good	Good
C4	ASC & MLD	Good	Functional level	Good	Good, but can be anxious	Good
C5	ASC & SLD	Good	Poor	Good	Good	Poor
C6	SLD	Good	Poor	Good	Good	Poor
C7	MLD	Poor	Functional level	Good	Unwilling to communicate	Poor

3.3.2. Procedure

This investigation started by gathering data from teachers to inform the design of the user evaluation. This is appropriate as grounded theory supports flexibility in its procedures (Corbin and Strauss, 2015). Semi-structured interviews were used to gather recommendations from T1 and T2 on how best to get the participating children engaged and interested in creating media with Scratch. This data was supplemented by the type of content the children should be asked to create, where to have the observation sessions, and how to collect observational and video data without interfering with the children's activities. The data collected informed the creation of a plan and procedure for the user evaluation.

Due to the regular use of laptops (PCs) by the participating children in their classroom, the teachers recommended using the classroom PCs within the classroom to access Scratch for the evaluation. This meant the user evaluation sessions would feel less 'alien' to the children. The teachers also recommended having the children create animated stories as part of the evaluation, and they argued stories will serve the children better than games as they can help in learning to communicate and share ideas, something most of the children find difficult to do verbally or in written form. Another reason for the teachers' support for creating animated stories is the high level of interest the children had previously shown in a weekly storytelling session using cut out pictures of characters. Finally, an introductory session for using Scratch to create stories was suggested. The steps of the procedure belonging to this stage of the investigation are presented in Figure 3.2.

Figure 3.2. First phase of data collection and analysis (planning phase)



The introduction to Scratch session lasted for an hour and was attended by all the participating class members i.e. children, teachers and Teaching Assistants (TAs) assigned to the class. The researcher demonstrated some of Scratch's features by creating animated stories on topics suggested beforehand by the class teachers. The children were then asked for ideas that were used to create additional short animated stories.

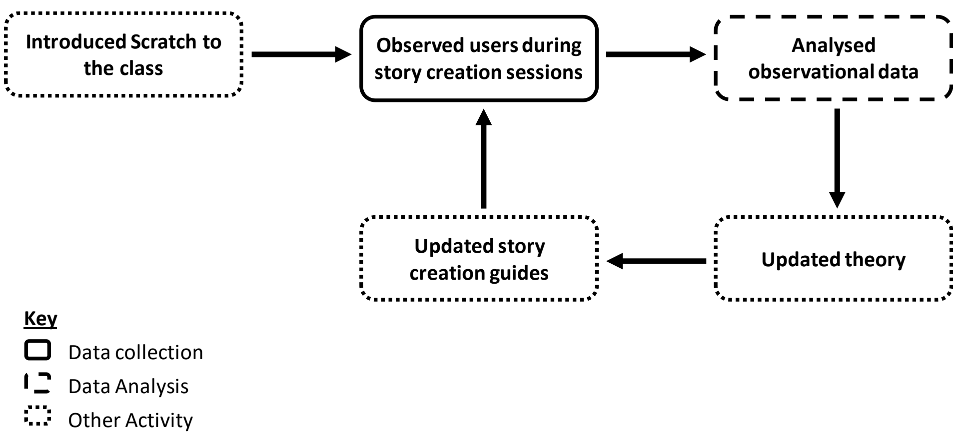
Ten user evaluation sessions were planned for the evaluation, with additional sessions to be scheduled as required. The sessions lasted between 30 to 45 minutes and were conducted weekly in the children's classroom with a subset of the class. The remaining class members simultaneously participated in the class's regular picture cut out storytelling session. This was also recommended by the teachers as a way of reducing disruptions to the children's regular schedule.

At least two children participated in each week's session, and there was always at least one TA present to assist the children participating in a session, and the researcher acting as a participant-observer. Either T1 or T2 determined which children participated in each week's session and which children participated in the paper-based storytelling activity based on the availability of TAs, a child's mood and willingness to participate during that session.

Each child taking part in a user evaluation session was provided with a unique guide to help create the story of their choice (the researcher was informed of each child's story choice by T2 in advance of the session). The interests, cognitive abilities, and communication preferences of the children were all taken into consideration when creating these guides as recommended in previous studies (Jenkin et al., 2015). Widgit (www.widgit.com) visual communication software was suggested by the class teachers and used to create the guides. Each guide took the form of a visual information sheet which provided step-by-step instructions on how to add sprites, backgrounds, and programming blocks to create a personalised animated story. A sample guide can be found in Appendix C. Actions such as resizing sprites, deleting objects and editing objects were taught to the children by the researcher or TA as the children worked on their stories or when they requested it. It should be noted that programming was not taught as part of this research, the children were provided with guidance and assistance on performing basic tasks and were expected to learn more by exploration (Maloney et al., 2008).

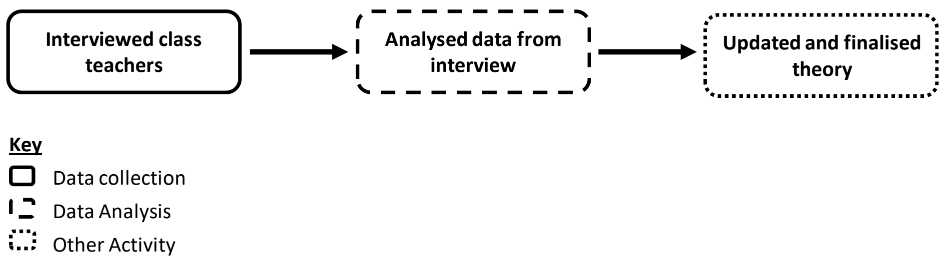
As recommended by grounded theory, data analysis was performed simultaneously with data collection, i.e. each session's data was analysed before the next session. This informed the researcher on actions or occurrences to be vigilant towards during subsequent observation sessions. This analysis also provided information for updating children's guides after each session to add complexity or to simplify the story being created (see Figure 3.3).

Figure 3.3. Second phase of data collection and analysis (user evaluation phase)



No additional sessions were requested after ten weeks of user evaluation sessions as sufficient data was collected. The three class teachers were then interviewed to gather additional information that could not be derived from the analysis of data gathered from observational sessions (see Figure 3.4).

Figure 3.4. Third and final phase of data collection and analysis (interview phase)



The complete grounded theory based method for formative evaluations of the accessibility of VPTs and other interactive applications for children with learning disabilities based on the procedure described above can be found in Appendix D.

3.3.3. Data Collection - Children

Observation was used during this investigation's user evaluation, as is used in most HCI studies to understand the users' interaction with the technology in question and how the technology supports, hinders or shapes their actives (Blandford et al., 2016). During each user evaluation session, the researcher made observational notes of relevant events such as comments, questions, complaints and reactions made by the children related to their use of Scratch. However, due to having to observe multiple users per session, it was unlikely that the researcher would be able to make all relevant observations and take notes in real time. Therefore, video screen capturing was employed to create exact copies of each child's interaction with Scratch for the researcher to analyse at a later time (Goodwin, 2005; Thorsteinsson and Page, 2007). This approach helped the researcher gain a better understanding of events noted down during observations, by viewing video capture of the occurrences before and after the observed events.

Camstudio, a video screen capture software was used to record screen interactions during each session. Camstudio was also configured to record external audio using each laptop's microphone. This meant that each child's on-screen interactions, audible reactions, comments, feedback, emotions and communication with the researcher and TA were recorded. After each session, the recorded data was transferred from the class laptops to the researcher's secure hard drive for analysis.

3.3.4. Data Collection - Teachers

Data collection from participating teachers was performed using interviews. Interviews are typically used to "explore the views, experiences, beliefs and/or motivations of individuals on specific matters" (Gill et al., 2008). According to the authors, interviews can range in structure from completely structured (i.e. asking a predefined list of questions in a fixed order with no room for flexibility), to completely unstructured (i.e. having no guidance, structure or predefined questions). Semi-structured provides a balance and integrates the benefits of both structured and unstructured interviews. The flexibility of this approach implies that the researcher is no longer tied to a predefined list of questions, and can take advantage of any opportunity to gain additional information or insight about a participant's response (Lazar et al, 2017).

Semi-structured interviews were used to collect data from teachers in two phases (see Appendix B). In the first phase, interviews were used by the researcher to understand how best to design the user evaluation sessions to fit the needs of the participating children without disrupting their regular routines. Only T1 and T2 were interviewed during this initial phase.

Interviews were then used after the user evaluation sessions with participating children have concluded. This enabled the researcher to address any questions left unanswered by the findings of analysing observational and video screen capture data. By conducting semi-structured interviews, the researcher was able to control the interview in terms of the concepts that were discussed, without following a predetermined order. Open-ended questions were used to gain in-depth answers which in turn led to in-depth discussions about the aspects that the researcher found interesting. All three teachers participated in this round of interviews. It was made clear to the interviewees that the researcher was looking for information to address limitations in the analysis of data collected from observations and video screen capture. It was also stressed that these findings would be used in understanding the causes of accessibility issues relating to VPTs. The interviews were guided by early questions about each teacher's general opinion on the accessibility of Scratch. Interviews then attempted to clarify causes and reasons for specific observed or recorded behaviours, actions or difficulties.

All interviews were conducted on the participating school's premises at a time convenient for both interviewer and interviewees. Each interview lasted between 30 to 45 minutes, permission to record the interviews was requested from the teachers at the start, and only after it was received was the interview recorded.

3.3.5. Data Analysis

As previously outlined, grounded theory recommends performing data analysis simultaneously with data collection. During each analysis phase of the grounded theory cycle, data must be coded and compared with other data, this is known as "constant comparison" (Muller, 2014). Coding is the process of "categorizing segments of data with a short name that simultaneously summarizes and accounts for each piece of data" (Charmaz, 2014). A theory is then developed based on the data, and then scrutinised with newly gathered and coded data in the following cycle, this process guides the researcher as to what data needs to be collected to scrutinise the theory's weak links (Corbin and Strauss, 2015).

Coding in grounded theory is performed in three stages, open, axial and selective coding (Adams et al., 2008). When conducting open coding, concepts are identified within the data and coded with an open mind with no predetermined codes. Axial coding creates more abstract codes that bring together related open codes to form categories. The final coding phase is selective coding, which involves the unification of all categories around a central category; the central phenomenon of the study.

Corbin and Strauss (2015) also provide a coding tool, 'the paradigm', for making sense of concepts and coding around the main category. This tool has three main features, namely: 'a) conditions', 'b) actions-interactions' and 'c) consequences or outcomes'. Conditions describe the reasons why a phenomenon occurs, actions-interactions describe the responses made on the occurrence of a phenomenon, and consequences are the outcomes of actions-interactions. The paradigm makes it easier for the researcher to explore concepts surrounding the main phenomenon under investigation, and to easily explain findings.

As continuous data collection and constant comparison take place, concepts are created, compared and validated, the existence of relationships between concepts and categories is checked, existing relationships are validated, and categories are defined and refined (Adams et al., 2008). This is continued until saturation is reached, i.e. no new concepts are emerging, and theory has been fully constructed (Corbin and Strauss, 2015). The authors also recommend maintaining a memo as a way of documenting the analysis being performed, the ideas and thoughts being shared, and also as a way of tracking the progression of the theory being constructed.

Following the grounded theory guidelines on analysis, watching and transcribing each week's video screen captures began immediately after conducting the week's user evaluation session. However, due to the high volume of multi-dimensional data present in the videos, only interesting observations were transcribed. Some of these observations may have already been noted by the researcher during the session, so the researcher knew when they would appear on the video. Others were only noticed for the first time during this first pass of data analysis.

After all the videos have been analysed and interesting observations have been transcribed, the researcher then moved on to coding these observations as concepts. During the coding process, each video was re-watched to ensure that no events, actions or behaviours of interest were omitted from the transcripts, and to ensure each observation was understood well enough for it to be coded correctly.

Once all observations had been coded as concepts, concepts were then compared to check the existence of similarities and relationships. Based on the findings, concepts were grouped into categories and subcategories where necessary, and any relationships identified between categories were then documented. All video records were observed for a second time at this stage to verify the similarities and relationships identified. As additional data was collected, new observations and concepts were identified that raised questions concerning some decisions. These included decisions about which concepts to code behaviours as, whether to categorize a concept as part of a particular group, or whether a relationship between categories exists.

Saturation was reached after ten weeks of the above procedure. This meant that collected data was not providing any new information, although there were still aspects of the research question that were unanswered. Four main categories were generated at this point: physical difficulties, logical difficulties, coping strategies, and consequences.

Audio recordings of interviews went through a similar analysis procedure to the video recordings except for a few differences. The researcher first listened to each recorded interview to become familiar with its content. The researcher then listened to each recording for a second time and transcribed it. The transcripts were used to identify and code relevant quotes as concepts. Concepts from this stage of analysis led to the reinforcement of previous categories and relationships, as well as the creation of a new category ('causes of difficulties'). The recorded interviews were listened to for a final time to verify the validity of the concepts in the created category, and their relationships to existing categories and concepts. The addition of this final category completed the theory being developed.

QSR Nvivo 11 (QSR, 2015) was used during analysis to transcribe audio and video data, store observational notes, code data, and create and store memos.

3.4. Findings

Five main categories of findings were identified on the completion of data analysis: difficulties related to physical abilities (referred to as "physical difficulties" from here on), difficulties related to logical abilities (referred to as "logical difficulties" from here on), causes of difficulties, coping strategies, and consequences. Four out of the five categories have sub-categories, which are made up of concepts. 'Coping strategies' is the only category that is made up of only concepts and no subcategories. Each table in Tables 3.2 – 3.6 presents a category, its subcategories (if any) and its concepts.

Further information regarding each category, its subcategories and/or concepts are discussed in Sections 3.4.1 – 3.4.5. Relevant examples from observations and excerpts from interviews are provided where appropriate.

Table 3.2. Physical difficulties

Physical Difficulties	
Sub-Category	**Concept(s)**
Difficulty finding buttons	- Difficulty identifying button - Clicks the wrong button
Difficulty identifying links	- Difficulty finding the right link - Clicks wrong link
Difficulty identifying blocks	- Drags the wrong block - Difficulty finding a block
Difficulty switching area	- Difficulty changing working areas - Difficulty differentiating tabs of working areas - Clicks the wrong tab
Difficulty dragging objects	- Difficulty dragging sprites - Difficulty dragging blocks - Difficulty rearranging blocks in a script
Difficulty selecting objects	- Difficulty selecting a tool - Difficulty switching active sprite - Difficulty switching active costume

Table 3.3. Logical difficulties

Logical Difficulties	
Sub-Category	**Concept(s)**
Difficulty defining instruction	- Project executed without script - Expecting a sprite object to make use of another sprite object's script
Difficulty structuring and sequencing	- Difficulty recreating imaginative events using code - Difficulty sequencing actions and events
Difficulty staying on track	- Abandons initial goal - Repetitive use of a feature

Table 3.4. Causes of difficulties

Causes of Difficulties	
Sub-Category	**Concept(s)**
Text labels	- Difficulty reading textual labels - Difficulty understanding the meaning of textual labels
Similar colours in proximity	- Difficulty processing visual data - Difficulty differentiating similar colours
Lack of templates	- Need for a concrete structure to build on/around - Poorly developed story
Lack of constraints	- Need for focus and clarity - Difficulty controlling repetitive behaviour
Mouse input	- Difficulty interacting with a mouse

Table 3.5. Coping strategies

Coping Strategies
Concept(s)
- Becoming idle - Retrying - Asking for help - Moving to other tasks

Table 3.6. Consequences

Consequences	
Sub-Category	**Concept(s)**
User is kept on track	- User is asked to share plans - Discussing the participant's story
User is guided	- User is shown instructions to follow on the guide - Researcher or Teacher assistant guides user
Task is performed for the user	- Researcher or TA performs the task for the user

3.4.1. Physical Difficulties

Physical difficulties relate to Scratch's user interface design and how it is interacted with. The six subcategories (Table 3.2) that make up this category are discussed below:

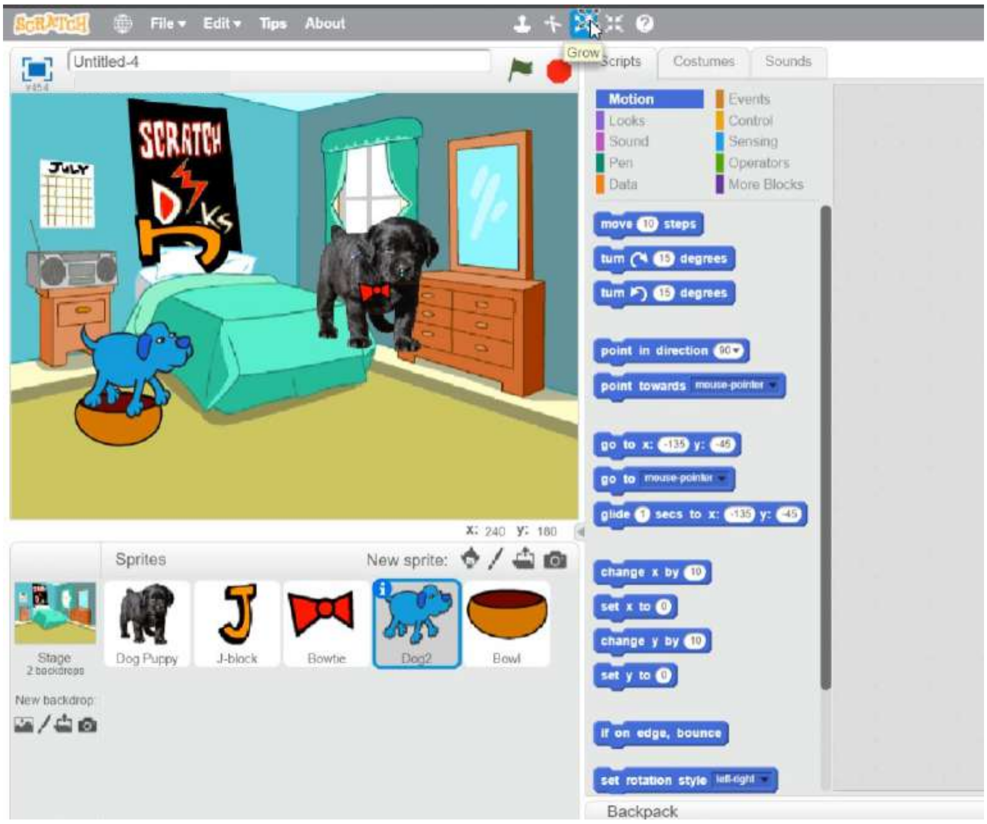
Difficulty finding buttons: At one point or another, all observed users struggled to find the right button for performing an intended task. Regularly used buttons such as the button for importing backdrops and the button for importing sprites caused difficulties at the beginning of sessions but those difficulties became less common as users became familiar with the UI. However, users continuously struggled with differentiating buttons that were used less frequently, such as the respective buttons for activating the shrink, grow and delete tools. An observation to illustrate this point is presented in Table 3.7 and a screenshot is provided in Figure 3.5.

Table 3.7. Example of difficulty finding buttons

Individual	**Dialogue**	**Actions**
C6	How do you make it shrink?	
C6	Oh!	C6 Clicks on the 'Grow' button, and clicks on a dog sprite, causing the sprite to increase in size.

C6	No! I want to make it small.	
TA	You have to go on shrink if you want to make it smaller.	
C6	That one?	C1 hovers the mouse pointer over the 'Grow' button
TA	Next one	
C6	That one?	C1 hovers the mouse pointer over the 'Shrink' button
TA	Yeah	

Figure 3. 5. Screenshot of C6 trying to find the shrink button



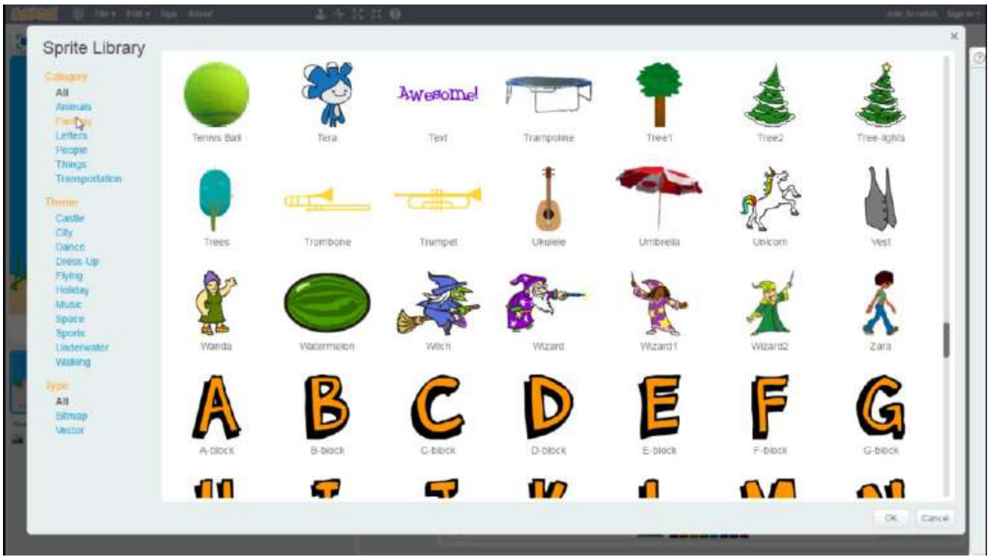
In the observation described and illustrated above, it can be seen that although C6 was able to remember the general area where the button for the 'shrink' tool is located, they could not find the right tool from the set of tools in the area.

Difficulty identifying links: Links within Scratch can be used to access collections of similar items. For example, when importing backdrops or sprites, links can ease the process of locating items by providing access to themes or categories of items. It was observed that users rarely utilised this feature without the help of the researcher or a TA. When working with assistance, users had to be advised to use links, and in most cases, the correct link had to be pointed out. An observation to illustrate this point is presented in Table 3.8 and a screenshot is provided in Figure 3.6.

Table 3.8. Example 1 of difficulty differentiating links

Individual	Dialogue	Actions
C5	I can't find the dragon	Scrolling through the media library
TA	Where is the dragon? It's in 'Fantasy' probably.	
C5		Hovers over 'Animals' link
TA	'Fah'	
C5		Hovers over the 'People' link
TA	'Fah', down	
C5		clicks 'Fantasy' link
TA	Yeah! That's it	

Figure 3. 6. Screenshot of C5 trying to find the 'fantasy' section link



In the observation presented above, C5 received the initiative from the TA to check the 'fantasy' category to find their dragon. However, C5 was not immediately able to recognise which of the available links on the screen referred to the 'fantasy' category.

Another use for links in Scratch is to access block categories. Early in the study, it was observed that users were only able to identify 'block category' when the categories were associated with a colour (block categories are colour coded). Simply using the text associated with the category's link was insufficient to address this issue. However, it was observed that although all categories are coded with unique colours, some of the colours are similar. As a result, some categories were difficult to identify even when associated with colours. An observation to illustrate this point is presented in Table 3.9 and a screenshot is provided in Figure 3.7.

Table 3.9. Example 2 of difficulty differentiating links

Individual	**Dialogue**	**Actions**
C3	How can I make the shark swim?	
Researcher	You want the shark to move?	
C3	Yes	
Researcher	This block is used to make characters move, so add it to the blocks you have	points at 'move _ steps' block on the U3's session guide
C3	This one?	points at 'move _ steps' block on the session guide
Researcher	Yes, what colour is it?	
C3	Blue?	
Researcher	Yes! Now look for that colour here	points at block categories links
C3		clicks on 'Sensing' block category link
Researcher	Not that blue, that's light blue, you are looking for dark blue.	

C3		clicks on 'Motion' block category link.
C3		drags and adds 'move _ steps' block to a script

Figure 3. 7. Screenshot of C3 looking for 'Motion' blocks in the 'Sensing' blocks section

Difficulty identifying blocks: Although the guides provided for sessions included images of the specific blocks that the users needed for specific scripts, the users still encountered difficulty in locating the required block from the identified category. This difficulty was recorded in both cases where users were following a guide, and when users were creating scripts independently. An observation to illustrate this point is presented below:

Table 3.10. Example of difficulty differentiating blocks

Individual	**Dialogue**	**Actions**
C5		Following instructions for creating a script that creates a text dialogue saying 'Hi'
C5		Adds when green flag clicked block

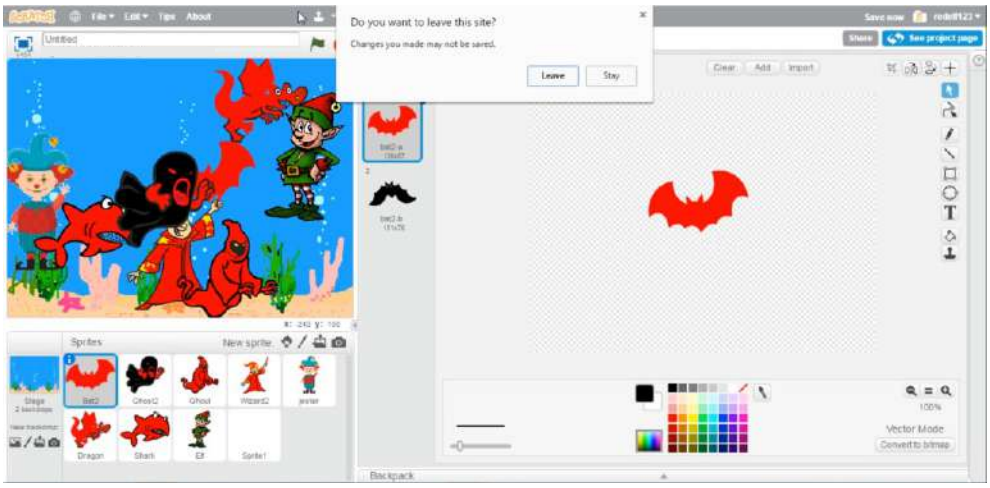
Researcher	Good job, can you add the second block?	Researcher points at 'Say _ for _ secs' block on the sessions guide
C5		Clicks on Looks blocks category
C5		Attempts to add the 'Switch costume' block
Researcher	It's not that one	
C5		Becomes idle
Researcher	It's the one at the top	Points at 'Say _ for _ secs' block on the screen

Difficulty switching area: Most Scratch projects require users to move continuously between the scripts, sounds and costumes areas of the VPT interface by switching between tabs. However, it was observed that users would often find themselves stuck in one area of their projects, unable to switch to other areas. An observation to illustrate this point is presented in Table 3.11 and a screenshot is provided in Figure 3.8.

Table 3.11. Example of difficulty switching area

Individual	Dialogue	Actions
C5		Paints at a sprite in the costumes area
		minimizes the browser, then maximises it
		clicks the browser's back button which produces a pop up with 'stay' and 'leave' options
TA	Do you want to leave or stay and continue?	
C5	Stay	
TA		clicks on stay
C5	How do I get off the painting?	

Figure 3. 8. Screenshot of C5 attempting to leave the costumes painting areas



Observing the above transcript, it can be seen that the user, not understanding the purpose of the tabs, attempted multiple actions (common in operating software to close a page or an application) in an attempt to exit the costumes painting area. Although with time some users came to understand the role of 'tabs' in switching working areas, they were observed to use trial and error to find the correct tab for the working area they were looking for.

Difficulty dragging objects: Users experienced difficulties with dragging objects. For example, when positioning their sprites to set up their stories, and when dragging blocks to create their scripts. Although this difficulty was more frequently faced by those users with fine motor skills, all users had faced this difficulty occasionally, especially when rearranging blocks within a script.

Difficulty selecting objects: To use tools within the VPT environment such as grow, shrink, and delete, together with tools within Scratch's paint editor, one must first click on the required tool to select it. Users with poor fine motor skills were observed to find this task difficult, especially when the tool was found to be small and/or closely positioned to another tool. Another group of items that were difficult to select were sprite thumbnails (used for switching active sprite or for choosing an active sprite to apply a costume). Users were observed to be dragging these thumbnails even though they intended to click, and so multiple attempts were usually required before succeeding in this method of interaction.

3.4.2. Logical Difficulties

Logical difficulties refer to any observed difficulty caused by the level of cognitive abilities required for a user to successfully create a Scratch project. (the collection of assets required to make the application work). These difficulties are discussed below:

Difficulty defining instructions: In Scratch, each component of a project (e.g. a sprite) that has a behaviour (e.g. changing the colour of the sprite) needs to have that behaviour explicitly defined using a script. On various occasions observed, users did not define instructions, or were not able to, and expected their sprites to perform some form of behaviour with no script defined. Users that faced this difficulty were observed to repeatedly execute their projects without adding any script or to expect a script assigned to one sprite to automatically work on another sprite.

Difficulty structuring and sequencing: All users were observed to experience this difficulty. Although most occurrences of this difficulty were observed when users decided to create stories that no guide have been created for. With no guide to follow, users were observed to simply add sprites (relating to characters from their conceptual designs) into a project and struggle with structuring and sequencing events to produce an animated story.

Some users were able to sequence simple animations without the use of guides during the latter sessions of the study. However, these users struggled in particular with managing the duration of animations and synchronising multiple animations.

Difficulty staying on track: It was observed that users easily became distracted from the goal of their session. This was usually due to a discovery within Scratch in the form of a new media object or a previously unseen feature of the tool. These types of discoveries led to losing focus on the overall goal of the session to focus on one aspect of the goal, or in some cases abandoning the goal altogether. For example, Figures 3.9 and 3.10 show screenshots from two separate sessions in which a user became distracted with adding sprites to the project. The depicted example relates to C5 and their session goal to create a story regarding a red elf. On both occasions, after adding the elf sprite, C5 got became interested in adding and customising multiple sprites than the immediate goal of the session.

Figure 3. 9. Example 1 of difficulty staying track (screenshot from C5's sessions)

Figure 3. 10. Example 2 of difficulty staying on track (screenshot from C5's sessions)

3.4.3. Causes of Difficulties

Causes of difficulties refer to the design properties and features of Scratch that led to the existence of the above-discussed difficulties.

Text labels: Throughout this study, users struggled with aspects of Scratch that required proficiency in reading skills; links, blocks and tabs in Scratch are all best identified by reading their text labels, and that proved to be a constant source of struggle for users. T3 has this to say regarding these observed difficulties in using Scratch and how children in other classes would fare using the VPT:

> *Some of the written stuff, I think they will all find that quite difficult. Even though we've got some readers in here, I still think maybe the language and the wording used, they will find it a bit difficult, but I think some of them will eventually get their head around it.* – T3

Therefore, the cause here is not just the use of text, but the complexity of the words used. T3 believes that even those children capable of reading the text may not be able to understand what is meant by the programming terms or what they represent.

Similar colours in proximity: Although using colours helped participants recognise and differentiate objects, using similar colours to differentiate between objects within proximity defeated the purpose. This was mostly observed when participants were trying to locate a block category coded with a colour similar to that of another category. Table 3.9 from the previous section provides an example of this.

Lack of templates: Although Scratch provides a guide for creating example projects, it does not allow users to create a new project from a predefined template. This led to users experiencing difficulty in developing their story ideas or structuring them in the right way:

> *I think having a structure can help them clue in what they're are looking for, and I think they will know exactly what process they are to go through, and*

once they've learnt those processes, they'll be able to add on it and add on it. And the first will become really easy and you'll be able to move them forward, further with it I think - T3

Lack of constraints: One of the most appealing features of Scratch is that it has no restrictions on what users can create. But for the participants in this study, this was considered to be a disadvantage due to the difficulty they exhibited in being creative and staying focused. The excerpt below from an interview with T1 explains why having focus is important, and how it can be implemented in the classroom:

We do that already with our curriculum planning don't we, because if we give ourselves a title that we want, and then that sort of immediately gives you a bit of focus, a bit of clarity… for example, if you are doing a story, and you said 'Right, we are doing something about the sea', then obviously that gets rid of a lot, and that's what you are trying to do. Otherwise, there is far too much choice out there. But in saying that, what we try and do here is get it to be student-led, so what are you interested in, talk to the students about it – T1

Lack of constraints did not only affect users that found it difficult to stay focused on tasks, but also those participants that were repetitive in performing tasks, reusing ideas and using features. T2 discusses how the lack of constraint affected C5 and how restrictions may help, below:

he can't move on, like his favourite colour is red and he has to paint everything red… if he was working with the same 10 sets of characters, what would happen if he uses the program and those 10 characters weren't there, he'd have to use something else. - T2

With Scratch's sandbox nature, users with characteristics similar to the participants of this evaluation are therefore likely to become similarly side-tracked from their original goals.

Mouse input: Users, especially those with poor fine motor skills struggled with mouse operations such as dragging, double-clicking and even single-clicking operations. Clicking was observed to be especially difficult while attempting to select objects with small areas and those that can be clicked as well as dragged. T1 explains why one user struggles with mouse operations in the interview excerpt below:

> *[participating child] would find it extremely difficult just to pick something up off the table because she doesn't have that depth in perception. If you are using a mouse, for it to register your finger, you can't be sort of up and down.*
> - T1

Scratch is a drag and drop environment, and so relies heavily on mouse input. This has been observed to cause several difficulties with this group of users.

3.4.4. Coping Strategies

When faced with difficulties, it was observed that users reacted using one of four coping strategies. These coping strategies are discussed below:

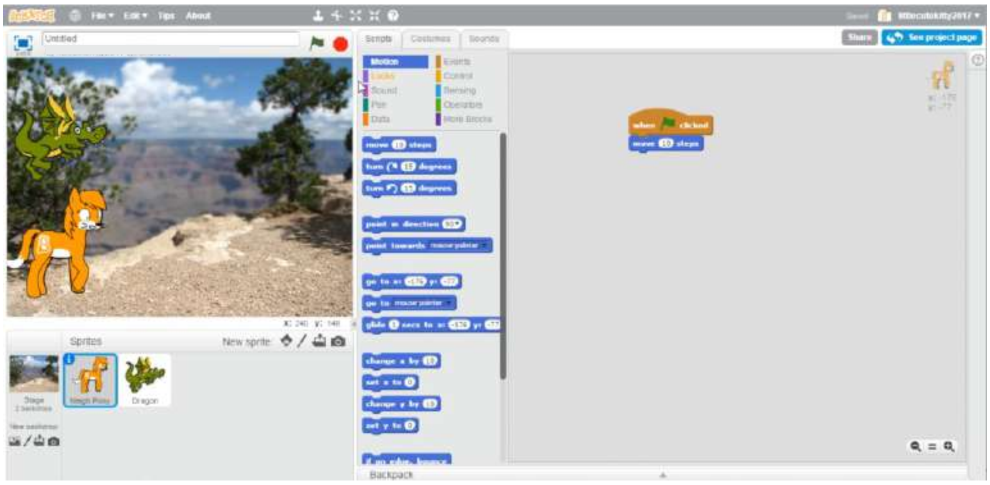
Becoming idle: This strategy was more common among users with communication difficulties. When unsure about the best way to proceed to complete a task, unsure about the next step to take after completing a task, or faced with any other difficulty, these users became idle. An observation to illustrate this point is presented in Table 3.12 and a screenshot is provided in Figure 3.11.

Table 3.12. Example of becoming idle

Individual	**Dialogue**	**Actions**
C1		creates a motion script for "Pony" Sprite
		runs project, "Pony" sprite moves
		runs project, "Pony" sprite moves
		is idle for two minutes

Researcher	How's your story coming along?	
C1		runs project, "Pony" sprite moves
Researcher	Wow! Now let's make the dragon move too.	

Figure 3. 11. Screenshot of C1 being idle after running project



Asking for help: Other users reacted to difficulties by asking for help from either the TA or the researcher. Users asked for help in performing tasks ranging from navigating the user interface to creating scripts for animation. The example outlined below describes how C2 asked the researcher for help to find a sprite needed for their story.

Table 3.13. Example of asking for help

Individual	**Dialogue**	**Actions**
C2		Browses media library for sprites
C2	Researcher, I want to get a diver	
Researcher	Diver? Go on underwater	Points at the "Underwater" category link
C2	Underwater?	Clicks on the "Underwater" category link
Researcher	Yes	

C2	That one!	Browses through and finds a "Diver" sprite

Retrying: Retrying was another strategy used by users to tackle difficulties, mainly physical ones. This was done either by retrying the exact action or series of actions that did not produce the required result or by retrying with changes made to the way an action or a series of actions were performed previously. Observations revealed how participants attempted clicking or dragging objects multiple times until they achieved their objective. Observations also revealed that users would try multiple tools until the right one was chosen, or would observe different links to find the right group of media. However, this approach was not always successful, especially in cases where the same action or actions were repeated.

Moving to other tasks: The last type of strategy that was observed is moving to other tasks. This strategy was mostly employed as a second strategy, after being idle for a while or retrying with no success. Some users then choose to move to a different task that may have been related or unrelated to the goal of that particular session.

3.4.5. Consequences

Consequences refer to the assistive actions taken by the TA or researcher when a user employs a coping strategy. A user employing a coping strategy may be assisted by the researcher or a TA. A user may also be assisted as soon as the researcher or a TA notices a difficulty without the user employing a coping strategy, e.g. when a user is sidetracked. The specific approaches taken by the researcher or TA to provide assistance are discussed below:

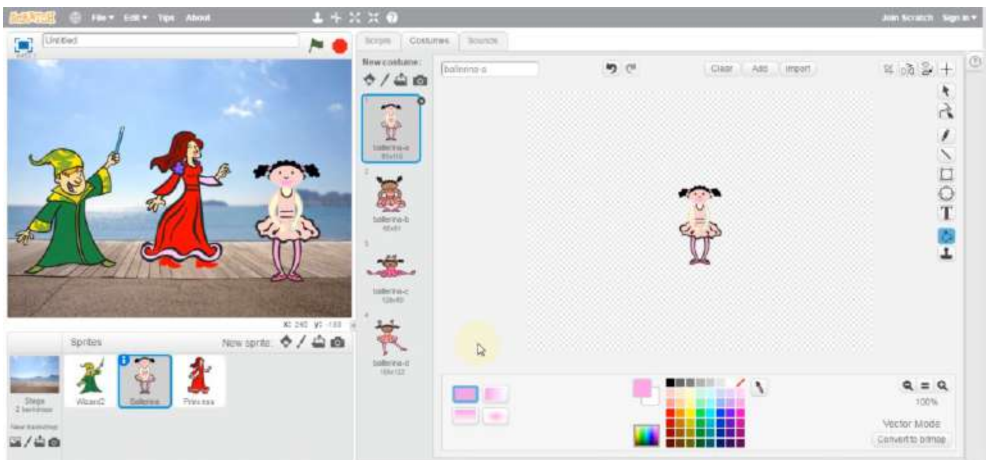
User is kept on track: When the researcher or a TA noticed a user being idle, repeating a single task or performing tasks not related to their original goal, they would try to intervene to help the user achieve the goal of the session. This was usually done by initiating a discussion or asking the user about the progress of their work. An observation to illustrate this point is presented in Table 3.14 and a screenshot is provided in Figure 3.12. This example observation shows how C4 was distracted from the main goal of creating animated stories. A question posed by the

TA was enough to remind C4 about another aspect of the project that the user needed to work on.

Table 3.14. Example of getting the user back on track

Individual	Dialogue	Actions
Researcher	you can also change how they look through costumes	points at the "Costume" tab
C4		switches to the "Costumes" area
Researcher	click on the fill tool, here	
C4		selects the fill tool
Researcher	now choose a colour	
C4		chooses a colour from the colour picker
C4		modifies the "Princess" sprite colour
TA	that's a nice colour	
C4		spends 13 minutes customising sprites
C4	does that look better?	
TA	yeah, are you going to make them do anything?	
C4	of course	switches to Scripts area

Figure 3. 12. Screenshot of C4 customising sprites



User is guided: On other occasions, the researcher or TA guided users that were idle or asked for assistance. The process usually started by the researcher or TA confirming what the user wanted to achieve, and then providing a general explanation on how to achieve that goal. If a general explanation failed to help the user, then step-by-step guidance was provided for the user to follow and achieve the goal. Examples of this type of consequence can be seen in observations illustrated in Table 3.9.

Task is performed for user: In cases where the user tried multiple times independently, or under instruction to complete a task without achieving success, the researcher or TA performed that task for the user. An example is presented below:

Table 3.15. Example of performing the task for the user

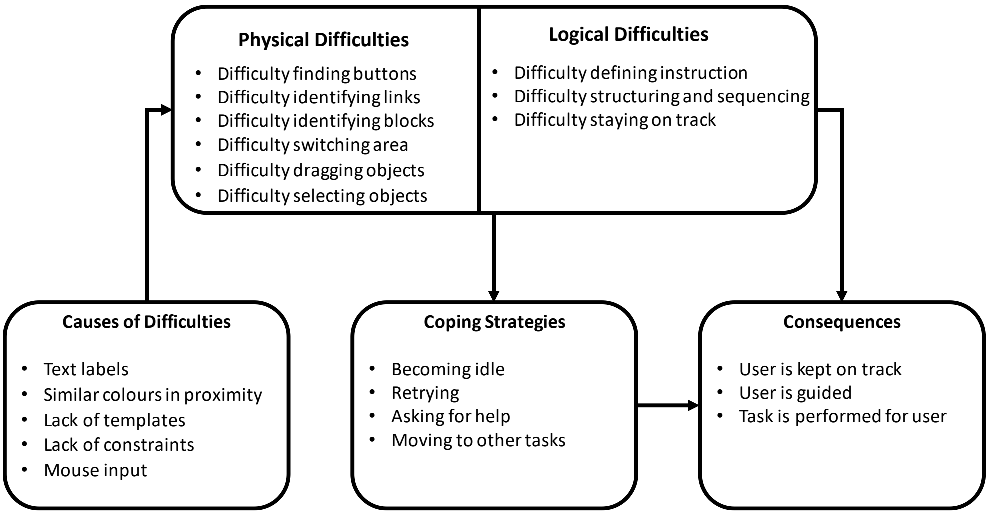
Individual	Dialogue	Actions
C6	I think I want to make it bigger	Selects the 'Shrink' tool
C6		Shrinks the 'Ball' sprite by clicking on it while the 'Shrink ' tool selected
C6		Selects the 'Shrink' Tool
U6		Attempts clicking the 'Ballerina' sprite with the 'Shrink ' tool selected, but instead clicks outside of the sprite
C6	How do you make it bigger?	
Researcher	Use the tool next to that one.	
C6	This one?	Hovers mouse pointer over the 'Grow' tool
Researcher	Yes	
C6		Selects the 'Grow' tool

		Attempts clicking the 'Ballerina' sprite with the 'Grow 'tool selected, but instead clicks outside of the sprite
Researcher	Let me do it for you	Selects the 'Grow' tool
		Grows the 'Ballerina' sprite by clicking on it while the 'Grow ' tool is selected

3.5. Theoretical Model and Discussion

Findings from this study have shown that Scratch is not fully accessible for children with learning disabilities. The study uncovered the difficulties this target group face while using Scratch, the causes of those difficulties, how the children are likely to react when faced with difficulties, and how they can be helped to move past difficulties and achieve their goals. A theoretical model is presented in Figure 3.13 to illustrate these findings.

Figure 3. 13. Theoretical model showing accessibility difficulties faced while using Scratch, their causes, coping strategies employed and consequences



The difficulties discovered are categorised into two areas of difficulty: physical, and logical. Physical difficulties were observed when a user was attempting to perform a task that is achieved by a single UI interaction activity such as a click or a drag. Logical difficulties, on the other hand, are associated with the cognitive skills required to make appropriate decisions/choices that will lead to the completion of the user's goal (for example, being able to stay on track and perform the set activities required to achieve a goal).

The use of text labels and lack of proper visual support to assist users in figuring out or identifying the right UI component to perform a certain task was a major cause of physical difficulties. Individuals with learning difficulties have been reported to have difficulties working with user interfaces or interaction devices due to difficulties with reading (Rocha et al., 2017; Roldán-Álvarez et al., 2016), and children with ASC prefer visual information over text (Putnam and Chong, 2008). Scratch makes use of colours, visual symbols and icons on some of its UI components, however other issues such as having very similar colours within proximity, and similar-looking icons did not adequately support users in taking advantage of the visualisation.

The second major cause of physical difficulties is the use of a mouse input device to perform actions. Even though only two out of the seven participants were officially reported by their teachers to have difficulties with fine motor skills, most of the users repeatedly faced difficulties especially when dragging objects or selecting small objects. However, similar difficulties have been reported in the literature (Harrison et al., 2008; Walsh and Barry, 2008).

The findings also show that Scratch's lack of constraints and templates for projects were major causes of logical difficulties. One of the most attractive aspects of Scratch is its sandbox environment that provides users with an open world and a variety of objects to build a wide range of possible outputs. However, users with ASC, MLD or SLD may struggle with creativity and imagination, and thus find it difficult to build projects without suitable direction or support. For example, even a short story requires a character, setting and plot, which determines the structure and sequence of actions performed by the characters. Even the shortest of animations require an object to animate, and the actions to be performed during the animation. Templates or procedural guides can be used to provide initial ideas, and building blocks for users (Spieler et al., 2017; Wehmeyer et al., 2004). With no template provided by Scratch to create new projects, these tasks were difficult for the users to perform. Even after coming up with the choice of characters, a setting, and an idea for the plot, there is still the complex task of defining each action of each character using a script of instructions, and synchronising actions to follow the sequence of the story or to create the intended animation. While some of the users in this study were able to perform some of these actions independently or with little help, some simply did not have the required cognitive skills for these sorts of tasks.

Finally, due to the lack of constraints in Scratch's sandbox environment, it is very easy for users to get side-tracked from working on achieving their goal. Children with learning disabilities and are known to be easily distracted from activities, easily lose interest or become side-tracked. Therefore guidelines for designing interactive applications for this population propose constraining the user's access to only features or elements that are necessary for goal achievement (Bozgeyikli et al., 2018; Davis et al., 2010). While this may not be necessary when using Scratch for recreational purposes, in this context Scratch was used in a storytelling session where the goal is for users to create stories, and therefore distractions prevented users from being able to achieve these objectives.

Depending on the difficulty faced by users, they either became idle, retried the action that led to the difficulty, tried a different action, moved to perform another task, or asked for assistance. Rocha *et al.* (2016) also reported similar findings while observing individuals with learning disabilities perform tasks on the web.

Assistance was provided to the users depending on the difficulty they were facing. Users were either encouraged to stay on track to achieve their goal for the session, guided to correctly perform an action or resolve a difficulty or received assistance with the task where multiple failed attempts were observed. Similar approaches were also reported by Read et al. (2018) in helping children with learning disabilities. Children were helped to get started, they were guided in case of difficulties, or assisted in performing tasks that are too difficult for them to perform independently.

3.6. Conclusion

This chapter presented a formative evaluation of the accessibility of Scratch for children with learning disabilities using a grounded theory approach. Observations and video screen recordings were used to collect qualitative data from seven children with learning disabilities while they used Scratch to create digital stories over 10 weeks. Following the saturation of data from this source, three SEN teachers were then interviewed to answer questions left unanswered by the initial analysis of data collected from the participating children. Finally, a theory was developed that explained the participating children's use of Scratch.

The findings not only show that children with learning disabilities face accessibility difficulties while using Scratch, but they also show the causes of these difficulties, how to identify them and potential ways of mitigating them within classroom settings. However, more studies need to be conducted on more VPTs with a set of users representing a wider range of the population to validate these findings for all users with learning disabilities.

These accessibility issues could well be one of the factors that lead to children with learning disabilities being left out of research on the use of VPTs such as Scratch. This study has been able to identify certain characteristics present within Scratch that contribute to accessibility difficulties for children with learning disabilities. Therefore, these attributes can be used to derive heuristics for initial evaluations of the accessibility of VPTs for children with learning disabilities moving forward.

However, this study has some limitations that need to be considered. First, programming was not taught to the participating children before or during the study, rather users were guided to create simple programming scripts that they required to create stories of similar complexity to their regular classroom activities. Participating children were expected to learn programming with Scratch through exploration (Maloney et al., 2010, 2008). Therefore, programming difficulties were not considered as part of the analysis of this data. Secondly, even though TAs provided guidance and help to the children during sessions, they were not themselves trained on how to use Scratch, which meant they were also required to experiment with the VPT as part of the sessions. There were few instances where a teaching assistant was unsure of how to guide participants, and in those cases, the researcher was asked for support. Finally, it should be noted that the children in this study represent only a small group of individuals with learning disabilities, which means that these findings may not be applicable for all children with learning disabilities, and may apply more specifically for those that also have ASC.

Chapter 4: Heuristic Accessibility Evaluation of VPTs for Children with Learning Disabilities

4.1. Introduction

The previous chapter presented a formative evaluation of the accessibility of Scratch that included user evaluations conducted with children with learning disabilities, and interviews with SEN teachers. This chapter will present a heuristic evaluation of the accessibility of other VPTs. The set of heuristics used for the evaluation are derived from the findings of Chapter 3. This chapter will first present the heuristics for the evaluation. Then present the motivations for selecting the VPTs to be evaluated. This is then followed by an overview of each VPT and the findings of its evaluation. Finally, the chapter concludes with discussions of findings and conclusions.

4.2. Deriving Heuristics

Heuristic evaluation is conducted by reviewing a technology and providing opinions about the positives and the negatives associated with its design, usually by comparing it to a set of rules or 'heuristics' (Nielsen and Molich, 1990). Heuristics for this accessibility evaluation were derived from the design attributes of Scratch that were identified as the 'causes of difficulties' for children with learning disabilities (see Table 3.4) as part of the outcomes of the evaluation presented in Chapter 3. For each cause of difficulties, a heuristic that provides a way of addressing it was derived. For example, for the identified cause of difficulties named 'text labels', the heuristic 'Visual presentation of information' was derived as a way of avoiding problems caused by using text labels. Therefore, a VPT that satisfies all the derived heuristics avoids the occurrence of the set of difficulties identified in the evaluation presented in Chapter 3. All five derived heuristics, their description and their corresponding cause of difficulties are presented in Table 4.1.

Table 4.1. Heuristics, their descriptions and associated 'causes of difficulties'

Cause of Difficulty	Heuristic	Description
Text labels	Visual presentation of information	Information, especially within the programming environment should be presented visually
Similar colours in proximity	Clear use of colour identification	Where colours are used as means of identification, the use of similar colours should be avoided, or at least should not be used within proximity to each other
Lack of templates	Provision of templates	Provide project templates for users to create projects with
Lack of constraints	Implementing appropriate constraints	Enforce appropriate constraints on users' access to programming elements, media and other features to avoid overwhelming users with lots of choices
Mouse input	Intuitive interaction method	Support the use of intuitive interaction methods. For example, using touch interactions

4.3. Selecting VPTs to Evaluate

The accessibility of the most popular VPT for children, Scratch (Moreno-Leon and Robles, 2016), has already been evaluated by this research. Therefore, three other popular VPTs for children (Scratch Jr, Pocket Code and Kodu) were selected.

Scratch Jr was selected because it was created as a result of redesigning Scratch to meet the needs of children between the age of five and seven years old. To achieve this, changes to its functionality and interface were made to make it more user-friendly, more fun, more enjoyable and to reduce the cognitive load required to create content (Flannery et al., 2013). Therefore, this evaluation will identify if in redesigning Scratch to create ScratchJr, a VPT that is accessible for children with learning disabilities was created.

Pocket Code, which is also block-based similar to Scratch and ScratchJr was chosen because it has features that were designed to support individuals with disabilities. This evaluation will verify whether these features of Pocket Code make it accessible for children with learning disabilities.

Finally, to ensure that not only two-dimensional block-based VPTs are evaluated for accessibility, Kodu was also selected for this evaluation.

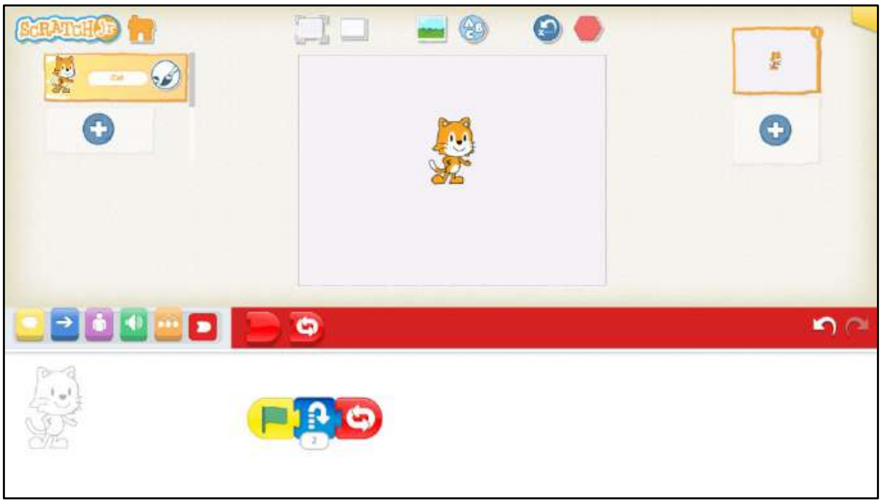
4.4. Heuristic Evaluation of ScratchJr

4.4.1. Overview of ScratchJr

ScratchJr is a product of the redesign of Scratch to meet the developmental and learning needs of children aged between five and seven years. This process of redesign involved testing with children, educators and parents (Strawhacker et al., 2015). The final product is described by Flannery et al. (2013) as a tool for promoting early childhood learning in academic domains e.g. literacy and mathematics; while introducing programming and strengthening problem-solving and foundational cognitive skills. Four main principles guided their design of ScratchJr to ensure its suitability for young children. The first is ensuring that ScratchJr is easy to get started with while providing room to grow, with concepts varying in complexity. The second is allowing children to explore various styles and approaches to creation and learning. The third is encouraging children to incrementally build on knowledge and creations by experimenting with new ideas. And finally ensuring that the interface feels friendly, joyful, inviting and encourages exploration and learning.

ScratchJr is block-based like Scratch, however, the number of blocks and block categories provided by ScratchJr is less than those provided by Scratch. Certain categories and blocks have been eliminated to make it easier to use. Another difference between Scratch and ScratchJr is that the latter is mobile-based while the former is web-based, but can also be accessible as a desktop application. The newly designed mobile interface has a less cluttered and cleaner look compared with Scratch (see Figure 4.1).

Figure 4.1. The ScratchJr programming interface



4.4.2. Evaluating ScratchJr's Visual Presentation of Information

ScratchJr's UI elements are designed to meet the needs of young children. Therefore, the ScratchJr programming interface (see Figure 4.1), has all its information presented visually, including all programming block labels.

Figure 4.2. Block categories in ScratchJr

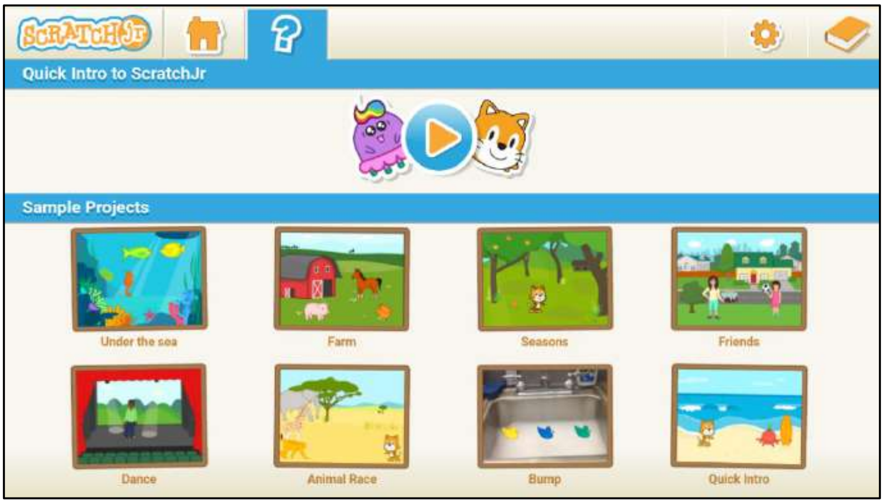
4.4.3. Evaluating ScratchJr's Clear Use of Colour Identification

Although ScratchJr also uses colours to uniquely identify categories of programming blocks, this has been done clearly unlike in Scratch. It can be seen in Figure 4.2 that all block categories have distinctive colours and it is unlikely that one will be mistaken for another.

4.4.4. Evaluating ScratchJr's Provision of Templates

ScratchJr does not allow users to create projects from templates, it only allows empty new projects to be created. However, it allows users to view and edit existing sample projects that are packaged with the VPT. Figure 4.3 shows ScratchJr's sample projects.

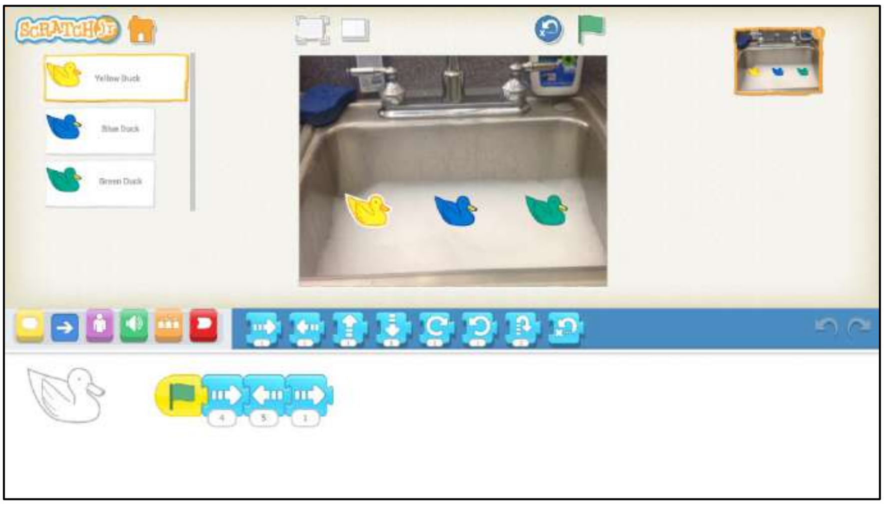
Figure 4.3. ScratchJr's sample projects



4.4.5. Evaluating ScratchJr's Implementation of Appropriate Constraints

ScratchJr imposes no constraints on the use of blocks, scripts, media resources or any other feature when users create their own projects. However, when users view sample projects, they are constrained to working with only the characters, backgrounds, and pages that come with the sample project. Users can only modify the project's scripts. This can be seen in Figure 4.4, which shows the sample project "Bump". The button for adding characters, which is normally placed under the character(s) on the left side of the interface; and the button for adding pages, which is normally placed under the page(s) on the right side of the interface have been hidden (however, these buttons can be seen in Figure 4.1).

Figure 4.4. Editing ScratchJr's 'Bump' sample project



4.4.6. Evaluating ScratchJr's Use of Intuitive Interaction Methods

ScratchJr is mobile-based, thus it supports touch interactions that the target group find intuitive.

4.5. Heuristic Evaluation of Pocket Code

4.5.1. Overview of Pocket Code

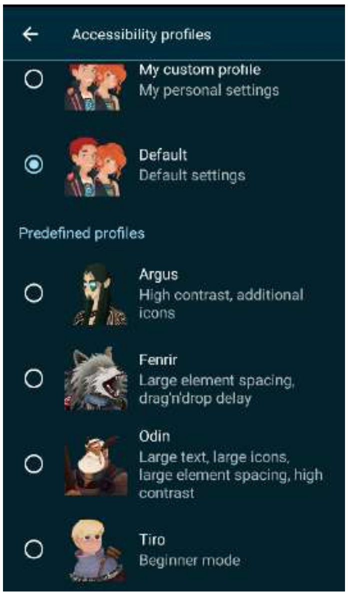
Pocket Code is a Scratch inspired mobile VPT targeted at children for the creation of animations, games and other programs while learning to programme (Slany, 2014). Scratch inspirations such as block representations of programming concepts (see Figure 4.5 – 4.6), an inbuilt media library, the ability to import media, and the provision of an online community can be found in Pocket Code which targets users between 13 and 18 years old. Being mobile-based, Pocket Code programs can also make use of mobile sensors such as the compass accelerator etc. The limitations produced by the size of a mobile screen affect Pocket Code in several ways including support for a high number of nested blocks, therefore pocket code has a formula editor feature that allows users to textually input formulas.

Figure 4.5. Block categories in Pocket Code

Figure 4.6. Scripts assigned to an object in Pocket Code

The latest version of Pocket Code has seen some additions as part of a project that used the Universal Design for Learning approach to teach game-making to children (Spieler et al., 2017). It now provides templates that users can build on, as well as specific user profiles for users with disabilities e.g. those with visual impairments (see Figure 4.7).

Figure 4.7. Pocket Code's accessibility profiles



4.5.2. Evaluating Pocket Code's Visual Presentation of Information

Visual presentation of information in Pocket Code is certainly better compared to Scratch, but not as good as that of ScratchJr based on the heuristic evaluation. Pocket Code usually complements its text with icons that visualise the meaning of information within the user interface. However, when it comes to the visual labelling of programming blocks, Pocket Code can provide icons for block categories (using the 'show icons' feature), but not for individual blocks as provided by ScratchJr. Text labels must be utilised to identify individual programming blocks. Figures 4.8 - 4.9 show what 'block categories' and 'blocks' look like when the 'show icons' option for Pocket Code is selected.

Figure 4.8. Block categories in Pocket Code with the 'show icons' option selected

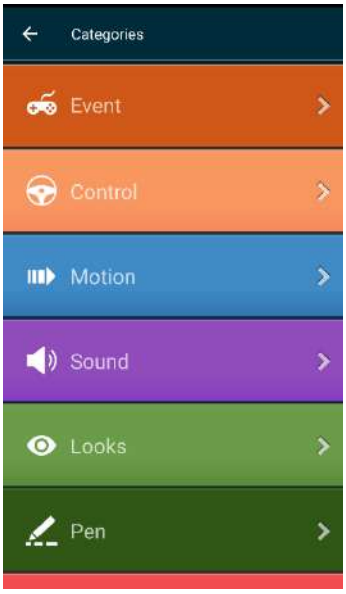


Figure 4.9. Motion blocks in Pocket Code with the 'show icons' option selected

4.5.3. Evaluating Pocket Code's Clear Use of Colour Identification

Clear use of colours as a means of identification in Pocket Code is employed similarly to Scratch and ScratchJr and unfortunately shares the same issues with Scratch's implementation. Figures 4.5 and 4.8 show Pocket Code's block categories without and with icons respectively. From the figures, it can be seen that there are similarities in the colours used to represent 'Events' and 'Control' categories, as well as 'Looks' and 'Pen' categories. Similar to what was observed in their use of Scratch, this is likely to be a cause of difficulty for children with learning disabilities.

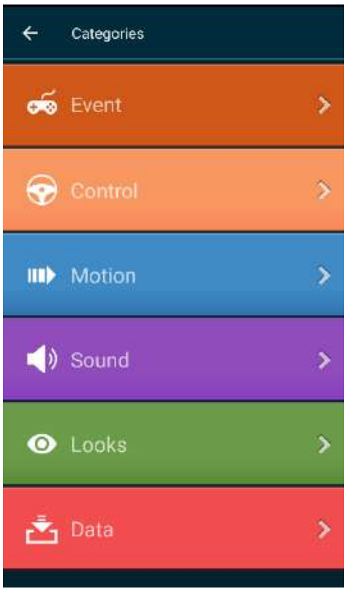
4.5.4. Evaluating Pocket Code's Provision of Templates

When creating new projects, Pocket Code allows users to create either an empty project or a project from an example template. The latter can scaffold the creation of content for children with learning disabilities.

4.5.5. Evaluating Pocket Code's Implementation of Appropriate Constraints

Pocket Code can constrain the number of programming blocks made available to the user if the 'beginner blocks' option is selected. This reduces the number of block categories and the number of blocks to a subset deemed simpler than the complete set. Figure 4.10 shows the block categories that are available when the beginner blocks option is selected. A difference can be seen when compared to the categories in Figure 4.8.

Figure 4.10. Pocket Code's beginner block categories



4.5.6. Evaluating Pocket Code's Use of Intuitive Interaction Methods

Similar to ScratchJr, Pocket Code is also mobile-based, thus it supports touch interactions that the target group find intuitive.

4.6. Heuristic Evaluation of Kodu

Overview of Kodu

Kodu is a VPT created specifically for young children to learn to programme through individual independent exploration and game making (MacLaurin, 2011). It consists of a VPL built within a real-time three-dimensional game and includes features to assist users in creating 'worlds' during game development like a terrain editor, layout tools, character menus and other features for users to create worlds within which their program will operate (see icons at the bottom of Figure 4.11). It takes away some complexity by predefining physics, collision detection and camera control. It also provides templates worlds for users to create projects with, as well as pre-created worlds that users can load, play and edit.

Figure 4.11. The Kodu programming interface

Programming in Kodu is achieved by declaring instructions using a 'when – do' approach. In the 'when' slot, sensors are declared to determine a condition, and in the 'do' slot, the actions that should be performed are listed (see Figure 4.12). Unlike in Scratch, actions provided to users are context-sensitive to avoid syntax errors. In Scratch, syntax errors don't happen because codes that don't belong together won't fit (Maloney et al., 2010). In Kodu, users only get suggestions of possible actions that can be used in their context.

Figure 4.12. Declaring programming instructions in Kodu

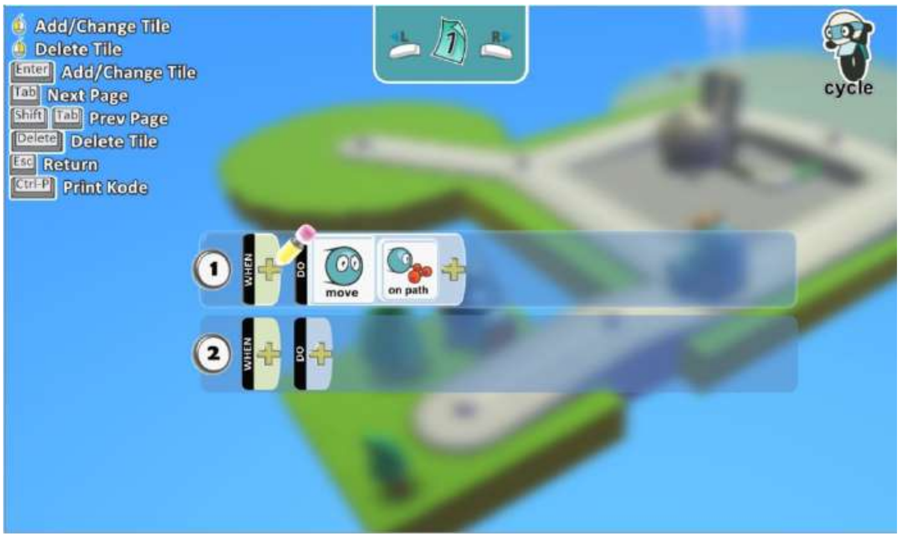


Figure 4.13. Viewing an object's options in Kodu

4.6.1. Evaluating Kodu's Visual Presentation of Information

Kodu's visual presentation of information is similar to that of Scratch. In some areas, it provides visual-only information, in other areas it provides a mixture of textual and visual information, and provides only text information in other areas. This will provide a mixed experience for children with learning disabilities. In Figure 4.13 visual icons can be seen at the bottom of the user interface representing Kodu's tools. At the top left of the user interface, a combination of icons and text is presented showing the actions that can be performed with a selected tool, and to the right of the user interface are the options provided for a selected object, including the option to program, which are completely textual.

4.6.2. Evaluating Kodu's Clear Use of Colour Identification

Since Kodu is not block-based there was no need to check if it had a similar issue of confusing use of colours to represent block categories. However, analysis of the use of colours within other parts of the Kodu interface was conducted and findings show that Kodu does not utilise colours as a means of identification, and thus is not affected by this heuristic.

4.6.3. Evaluating Kodu's Provision of Templates

When creating projects, Kodu provides the option to either create an empty world or to build on world templates. It also allows users to load 'worlds' from a collection of example worlds that come with the VPT. All these can be used by children with learning disabilities as forms of scaffolds.

4.6.4. Evaluating Kodu's Implementation of Appropriate Constraints

Kodu does not constrain the use of any features during programming. Even when working within example worlds or lessons, the user can perform any action on any object with no constraints. As observed during the accessibility evaluation of Scratch, this can be a cause of difficulty for children with learning disabilities.

4.6.5. Evaluating Kodu's Use of Intuitive Interaction Methods

Kodu is available on Microsoft's gaming console, Xbox, as well as on PCs. Therefore, it can be interacted with using a mouse, keyboard and the Xbox control pad. This means it is likely to present children with learning disabilities with the same difficulties they faced using Scratch. Furthermore, when using Kodu on desktop, it provides shortcuts to actions using buttons meant for the Xbox controller, which can cause further confusion to users as these are not the usual shortcuts associated with computers. For example, Figure 4.14 shows Kodu providing options to either change a programming instruction or see possible examples by either pressing A or Y respectively.

Figure 4.14. Shortcuts in Kodu

4.7. Discussion

The findings of the conducted heuristic evaluation have shown that all three VPTs evaluated will cause accessibility difficulties to children with learning disabilities, although these difficulties, and their degree of severity, vary from one VPT to another. A summary of the findings is presented in Table 4.2, with each VPT assigned a rating of either good, average or poor (Fung et al., 2016). A good rating here implies that a VPT has satisfied a heuristic to the extent that its associated difficulties are unlikely to occur. An average rating implies that a VPT has satisfied a heuristic to the extent that its associated difficulties will not occur all the time. Finally, a poor rating implies that VPT has not satisfied a heuristic at all, thus its associated difficulties will always occur. based on its performance per heuristic.

Table 4.2. Summary of the findings of the heuristic evaluation

	VPTs and their ratings		
Heuristics	**ScratchJr**	**Pocket Code**	**Kodu**
Visual Presentation of Information	Good	Average	Average
Clear Use of Colour Identification	Good	Poor	N/A
Provision of Templates	Poor	Average	Average
Implementing Appropriate Constraints	Poor	Average	Poor
Intuitive Interaction Methods	Good	Good	Poor

Findings show that ScratchJr has the best visual presentation of information among all evaluated VPTs, while both Kodu and Pocket Code require improvement. Although both Kodu and Pocket Code use icons, or a combination of icons and text, in most parts of their user interface, this is still not sufficient to support users with learning disabilities in performing the most crucial actions needed to create content without relying on textual information.

ScratchJr resolved the colour identification confusion in its redesign of Scratch, however the influence of Scratch on Pocket Code also affected that aspect of its design, therefore improvement is needed in Pocket Code. Kodu, on the other hand, has no use for colour identification of block categories, and therefore this issue does not apply to it.

In the provision of templates, Pocket Code and Kodu both provide templates that users can build on, however, only a few choices are provided by both. ScratchJr, on the other hand, does not provide the option to build new projects from templates.

Only Pocket Code can implement constraints on the use of its features by users by reducing the number of programming blocks made available to a subset containing 'beginner blocks'. ScratchJr only has constraints within sample projects, and Kodu has not constraints at all.

Finally, both ScratchJr and Pocket Code are mobile-based which means they are interacted with using intuitive touch operations. Kodu, on the other hand, can only be interacted with using the Xbox Controller, mouse or keyboard which are likely to cause difficulties to users with learning disabilities.

4.8. Conclusion

This chapter presented the heuristic accessibility evaluation of popular VPTs (created for children) for children with learning disabilities. The evaluated VPTs are ScratchJr, Pocket Code and Kodu; and they were evaluated using the following five heuristics: visual presentation of information, clear use of colour identification, provision of templates, implementation of appropriate constraints, and intuitive interaction method. Findings show that although these VPTs are more accessible than Scratch in certain aspects, none is completely accessible for children with learning disabilities. Therefore, there is a need for understanding the requirements and goals of children with learning disabilities associated with the use of VPTs, for example using personae; and to propose design recommendations that will lead to the design of accessible VPTs for them.

This study contributes to knowledge by providing an insight into the accessibility of popular VPTs for use by children with learning disabilities, and a set of heuristics for performing accessibility evaluations of VPTs.

However, it should be noted that this study has some limitations. Firstly, only the author conducted the heuristic evaluation, and secondly, the heuristics used have not been validated before use in this study. However, the evaluation aims to identify whether or not existing VPTs are accessible for children with learning disabilities, and not at this stage to identify all accessibility difficulties. Therefore, a single evaluator and the current set of heuristics are sufficient in this case.

Chapter 5: Creating Personae for Children with ASC for the Design of Accessible VPTs

5.1. Introduction

Chapters 3 and 4 presented the accessibility evaluation of VPTs for children with learning disabilities. The remainder of the research presented in this thesis focuses specifically on proposing design tools and recommendations for designing accessible VPTs for children with ASC (that also have a learning disability). This is because VPTs offer features that suit the needs of children with ASC more than the needs of those with learning disabilities without ASC. These features include visual rule-based environments for creating predictable and manageable content. Therefore, by focusing only on children with ASC, this research will be able to propose tools and recommendations that more accurately meet the needs of the target group.

As a first step towards specificity, this chapter presents the proposal of a method for the creation of personae for children with ASC, and the creation of a set of personae for children with ASC. A Persona is a simple tool that provides a "precise description of our user and what he wishes to accomplish" (Cooper, 1999). Unlike other models of user representation such as profiles which are made up of lists of attributes, a persona narrates a realistic and relatable description of an individual user. It includes a name, a background story, characteristics, needs and goals of the user related to the product or service being designed, and in some cases a photographic image of the user. This personification serves as a way to vividly relay relevant information about the persona as well as a way of drawing empathy, and interest from designers (Adlin and Pruitt, 2010; Cooper et al., 2007).

The creation of personae for children with ASC as part of this research is intended to serve two major purposes. First, it is meant to inform designers and developers on the varying characteristics and needs of children with ASC and highlight the fact that personalisation is needed for successfully designing any type of interactive application for this group. Second, it is hoped that by having these descriptions, designers and developers will be able to step into the shoes of children with ASC and understand their accessibility needs when designing and evaluating VPTs.

This chapter is divided into three parts, part 1 presents a novel method of creating personae for children with ASC, part 2 presents the process of applying the method and the resulting set of three personae created, and finally, part 3 presents an analysis of the personae creation method and suggested improvements.

5.2. Part 1: A Method of Creating Personae for Children with ASC

Although personae have been used as real user representatives when designing for children with ASC (Al-Wabil et al., 2012; McCrickard et al., 2015; Vieira et al., 2017), there is still little information in the literature on the methods used for creating accurate data-based personae for this target group. This study addressed that gap by proposing a method for creating accurate data-grounded personae for children with ASC. The proposed method takes into account the difficulties, capabilities and needs of this target group in its procedures (e.g. data collection and analysis).

5.2.1. Proposed Method

The persona creation method proposed here takes and improves from Cooper et al.'s (2007) steps for constructing personae from empirical data, Adlin and Pruitt's (2010) subject matter experts approach to validation and Leal et al.'s (2016) method of expert validation. It emphasizes the use of real target-user data, recommends the involvement of experts in various stages of the creation process in addition to the validation stage, and supports the possibility of reusing existing personae.

Data collected from target users are used as the foundation of the personae created using this method, the users' behaviours, needs and goals are identified through analysing these data. The data should be collected preferably through the observation of target users using the product or a similar product.

Data from experts can play three major roles as follows: add to what is known about the target users; analyse and clarify data collected from the users; validate the accuracy of constructed personae. Interviews or focus groups should be used to collect data from experts aimed at adding knowledge or clarifying user data. While any (or a combination) of interviews, focus groups or questionnaires can be used to collect supplementary data for validating the personae.

Existing personae can be reused or extended in cases where persona(e) similar to the users being described exist. A literature search can be used to find existing personae for children with ASC.

The proposed method is made up of eight sequential tasks, Tasks 1 – 8 (see Figure 5.1), based on the tasks for constructing personae proposed by Cooper et al. (2007). It should be noted that the first task (Task 1) begins after data has been gathered from target users. At least seven of the eight tasks must be performed to construct a persona. Either Task 6 or Task 7 can be bypassed depending on the outcome of Task 5. Each task is described below:

Task 1 - Identify and list significant user behaviours from observational data:

Analyse the gathered user data to identify and list unique significant behaviours exhibited by users. The aim is not to list all behaviours, but only those that are significant to the product or service being designed. The resulting list becomes the list of "behavioural variables" (Cooper et al., 2007) and will be used in some of the subsequent tasks. Cooper et al. (2007) proposed five types of behavioural variables that can be used to distinguish behaviours, they are activities, attitudes, aptitudes, motivations and skill.

For example, consider analysing observational data of users using a task management application. Behaviours that fall under the "Activities" type can be things like creating a task, sharing task details, setting a reminder, checking free time etc. Behaviours that fall under "Motivations" can be things planning the day, tracking school timetable, tracking house chores etc. It should be noted however that these categories may not be perfect for all users, products, or contexts of use. Therefore, behavioural variables types may need to be added or removed accordingly.

Task 2 - Map observed users to the identified behavioural variables:

Show the behaviours exhibited by users by mapping each observed user to the identified behavioural variables in Task 1. Mappings should be informed purely by the data collected on each user. This step aims to show the position of each user on each behaviour in relation to other users. This allows users with similar behaviours to be spotted easily.

For example, in the task management app scenario, you may have the following users: John who uses the app as a school requirement creates tasks related to school activities, and marks them as completed when they are done; Alexa who uses the app to plan her day, create tasks regularly, uses reminders, shares task info with her family and best friend; and another user Jane who receives tasks from her mum, marks them when completed, share task status with her mum, and checks her available free time. This task aims to identify a user's behaviours in relation to other users i.e. whether user A exhibits a behaviour more, less or about the same amount as users B, C, D.

Task 3 - Identify and group users with similar meaningful patterns of behaviour: Using the user to behaviour mappings created in Task 2, identify users with similar meaningful patterns of behaviour. Patterns of behaviour with no reasonable explanation should be avoided. For example, in the task management app scenario, users who create and update their own tasks can be grouped with John and Alexa, while users who receive tasks and send task status updates can be grouped with Jane.

The example above is a straightforward one, however, in some cases differentiating between meaningful and non-meaningful patterns of behaviour when dealing with children with ASC may not be as straightforward. Therefore, this method recommends taking advantage of the experience and background knowledge of experts in identifying meaningful patterns that may not be obvious to others.

Task 4 - List the characteristics and goals of the identified groups to form persona abstracts: For each group of users identified in Task 3, create a persona abstract by listing the characteristics and goals associated with each of the patterns of behaviour associated with the group's users. Characteristics and goals are usually the reasons behind the group's behaviours and can be extracted from the user data. However, since the user data being analysed is likely to be observational data, extracting user characteristics and goals may not be straightforward. As such, the knowledge and experience of experts are needed in this task to analyse the information known about users and inform on the characteristics and goals leading to such behaviour.

Once characteristics and goals have been listed, personify the persona abstracts by providing each with basic personal information (fictional) such as name and age, and some background details.

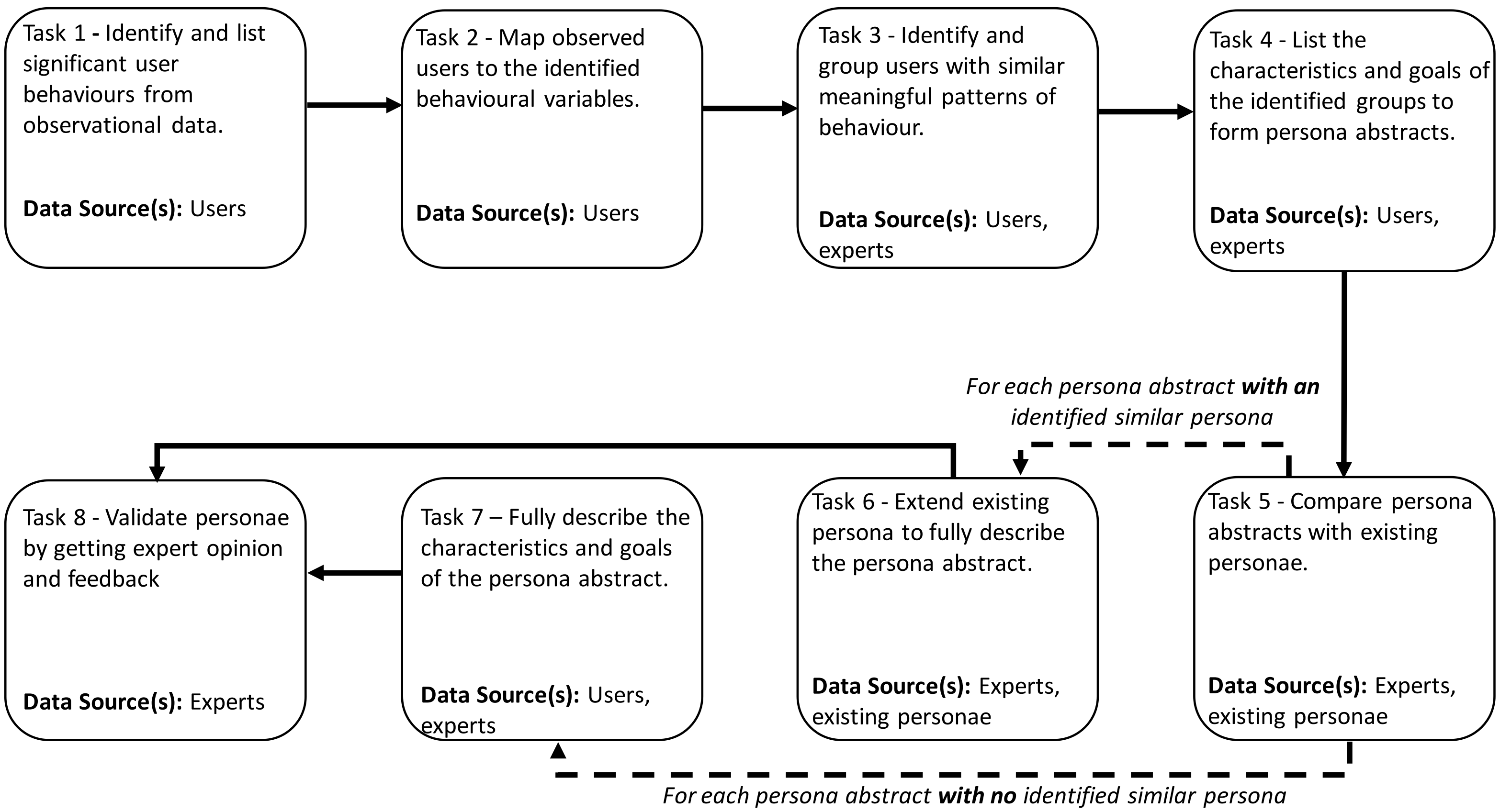
Task 5 - Compare persona abstracts with existing personae: Compare each persona abstract's listed characteristics and goals with those described in the personae from the gathered set of existing personae for children with ASC. Make sure the gathered personae are for the same target users and similar context of use. This task aims to identify personae that closely matches the persona abstracts. Personal information, which is fictional should not be used to determine similarities or lack of. The focus should be strictly on comparing characteristics and goals.

Task 6 - Extend existing persona to fully describe the persona abstracts: If an existing persona is found that is similar to a persona abstract, modify the existing persona's descriptions of characteristics and goals so that it now fully describes the characteristics and goals of the users described by the persona abstract. For an existing persona to be chosen for this task in the first place, it needs to be very similar in characteristics and goals with the persona abstract (see Task 6).

Task 7 - Fully describe the characteristics and goals of persona abstracts: For each persona abstract without a similar counterpart in the gathered set of existing personae, construct rich descriptions for its characteristics and goals to form a full persona. Descriptions should be in the form of a third-person narrative that uses fictional situations in explaining the needs, requirements, and goals of the group of users described.

Task 8 - Validate personae by getting expert opinion and feedback: Finally, validate all constructed personae to ensure that their descriptions accurately describe the intended children with ASC. Validation should be carried out by seeking expert opinion on the correctness of the characteristics and goals described in each persona created, and on recommendations (if any) on how to improve the persona.

Figure 5.1. Proposed method of creating personae for children with ASC, its methods and required data.



5.3. Part 2: Application of the Proposed Method

The application of the proposed method to create a set of personae describing children with ASC for the design of accessible VPTs is presented in this section. The data collection methods, participants, procedure, and results of the persona creation process are discussed below:

5.3.1. Data Collection

Data required for the creation of personae using this method includes observational data from target users, existing personae representing the target users, and data from experts.

Data collected during the user evaluation of Scratch presented in Chapter 3 were used as the source of target-user data. These data included observational and video screen capture data of five children with ASC using Scratch to create stories, which were extracted and utilised in this personae creation process.

A review of the literature was conducted to find existing personae for children with ASC that could be extended to form new personae. Research indexing sites and databases such as Google Scholar, Scopus, IEEE, ACM and Science Direct were all searched using keywords “Autism” “Autistic” “Asperger’s Syndrome” and “Persona” or “User Model”. Although several research publications on the subject were found, very few included an actual persona. On closer inspection, it was realised that some of the personae were fully descriptive, and some did not describe children with ASC but described their caretakers. After eliminating the personae that are not fully descriptive (e.g. McCrickard et al., 2015) or do not describe children with ASC (e.g. Prawira et al., 2017), six personae (Brown et al., 2016; Leal et al., 2016) were chosen to be used for this study (see Appendix F). The set of personae described children aged between 10 to 12 years with ASC.

A semi-structured interview approach was the chosen data collection method for gathering data from experts. The flexibility offered by the method made it easy for the researcher to have a continuously flowing conversation with experts that involved both collecting new data and collecting data to help make meaning out of gathered target user data. Each interview lasted between 30 – 60 minutes depending on several factors such as the availability of the interviewee, and the nature of responses provided by the interviewee.

However, it should be noted that each interview consisted of two parts. The first part dealt with tasks and questions related to the creation of personae for this study by asking experts to group users based on their behaviour, discuss the characteristics and goals associated with each group's behaviours and identify existing personae that are similar to each group. The second part of each interview was used to collect data for gathering accessibility recommendations for VPTs that will be presented in the next chapter (see Appendix G).

In fulfilling the last task of this personae creation process i.e. validating the created personae, questionnaires were used to request feedback from experts that participated in the earlier stages of the process. Questionnaires are data collection tools that consist of "a set well defined and well-written set of questions to which an individual is asked to respond" (Lazar et al., 2017). The validation questionnaire aimed to evaluate the accuracy and consistency of each of the created personae (Leal et al., 2016). Close-ended questions can be used in questionnaires to collect opinions (Lazar et al., 2017), as was required in this situation. Respondents to close-ended questions usually have to provide their opinions by choosing where they fall on a provided rating scale and the most common of these scales is the Likert scale. Examples of Likert scales include a scale of "1, 2, 3, 4, 5", "poor, fair, average, good, excellent" and "agree, neutral, disagree". However, to avoid giving respondents the chance to opt out from making decisions and providing neutral responses on the Likert scale (Adams and Cox, 2008), a four-point Likert scale was used. Experts were asked to rate their agreement with each section of each persona based on its consistency with typical behaviours of children with ASC.

In addition to the closed-ended questions, two open-ended questions were provided at the end of the questionnaire to gather qualitative feedback. One question asked whether experts found any of the personae's sections inconsistent with other sections, and the other asked experts for any recommendations they have for improving the personae. A copy of the questionnaire instrument is provided in Appendix H.

Since the researcher is usually not present when questionnaires are answered, the questionnaire must be easy for the respondent to understand and fill out correctly (Lazar, Feng, Hochheiser, et al., 2017). The questionnaire used in this study was designed following this recommendation to be brief and straightforward and was accompanied by the persona it requested feedback on.

5.3.2. Participants

Two groups of participants are required by this method of personae creation, they are target users (children with ASC) and experts (e.g. SEN teachers and researchers). The details of the five children with ASC whose data is being used in this personae creation process are extracted from Table 3.1 and are presented in Table 5.1.

Table 5.1. Profiles of children with ASC

Child	**Diagnosis**	**Fine Motor Skills**	**Reading Skills**	**Memory**	**Communication**	**Attention**
C1	ASC & MLD	Poor	Functional Level	Good	Unwilling to communicate	Poor
C2	ASC & MLD	Good	Functional level	Good	Good, but can be repetitive	Good
C3	ASC & MLD	Good	Functional level	Good	Good	Good
C4	ASC & MLD	Good	Functional level	Good	Good, but can be anxious	Good
C5	ASC & SLD	Good	Poor	Good	Good	Poor

In recruiting experts, existing links with researchers and SEN schools were used in identifying participants that met the inclusion criteria (either having teaching experience or published research experience with children with ASC). Internet searches were also conducted to find additional researchers and teachers. A total of seven experts (E1 – E7), two SEN teachers and five researchers agreed to participate. Their experiences are described in the table below:

Table 5.2. Profiles of experts

Expert	Profession	Experience
E1	Researcher	Associate professor in education with research interests within the field of special education needs and disabilities including the use of technology to provide personalised learning experiences for those with disabilities. Also provides training to teachers, carers and parents.
E2	Researcher	A senior researcher with more than 10 years of research experience in the area of assistive technologies. Recent research interests include the use of virtual reality for children with ASC.
E3	Teacher	Assistant headteacher at a school for students aged from 3 - 18 years with severe learning difficulties, profound and multiple learning difficulties and ASC. Also has more than 20 years of experience in the SEN field.
E4	Researcher	Professor in the field of learning disabilities with more than 30 years of research experience. Expertise in the design and evaluation of technology for students with a range of cognitive impairments and ASC including virtual environments, serious games and robotics.
E5	Researcher	Associate professor with research interests in the behaviour of individuals with ASC, the use of interactive applications (e.g. video games) as a method of intervention or to understand their behaviours. Has received research funding from several bodies from multiple countries and has collaborations in several countries.
E6	Researcher	Associate professor with research interests in autism in education. Over 20 years of research experience in various university research centres in multiple countries.
E7	Teacher	Classroom teacher with several years of experience at a school for students aged from 3 - 18 years with severe learning difficulties, profound and multiple learning difficulties and ASC.

The variation in the experience and specialisation of the experts produced rich data about understanding children with ASC, their behaviours, characteristics, needs and requirements.

Ethical approval was sought and received from Nottingham Trent University's Ethics Committee before participants were recruited and interviews were conducted (see Appendix E). Steps were also taken to ensure the anonymity and confidentiality of participants.

5.3.3. Procedure and Findings

Task 1 – Identify and list significant user behaviours from observational data: Data gathered from observing five children with ASC use Scratch to create stories and the video screen capture of their interactions with Scratch were analysed to identify "behavioural variables" i.e. significant behaviours. Video screen captures of each user were watched, and the transcripts of the video read, observational notes were also read for each user's sessions to identify interesting and relevant behaviours associated with using Scratch. After listing all the behaviours identified, it was noticed that not all of the behavioural variables fit into Cooper et al.'s (2007) behavioural variable categories (activities, aptitudes, skills, motivations attitudes), therefore new categories had to be introduced (difficulties and problem-solving strategies). Therefore, seven categories were used to group the identified behavioural variables. The complete list of behavioural variables is provided in Table 5.3.

Task 2 - Map observed users to the identified behavioural variables: Data for each user was analysed again, this time paying close attention to occurrences or events related to the identified behavioural variables in Task 1. Video recordings were re-watched, transcripts and observational notes were reread. A five-point Likert scale was then used to indicate the observed regularity with which a user exhibited each behaviour, the points of the scale are "almost always", "often", "sometimes", "seldom" and "never". This was deemed an efficient enough mapping technique since precision is not the key requirement of this process, rather the process aims to show behaviours of each user in relation to other users. Thus, the use of a five-point Likert scale in this case only provides a range of choices that can be effectively used to compare behaviours amongst users and is not affected by the neutral position dilemma.

The complete mapping of the five children with ASC to the identified behavioural variables is shown in Figure 5.2 where colours ranging from white (never) to black (almost always) are used to represent the points of the Likert scale. The use of colour to map children to behaviours created a representation of user behaviours that makes obvious the behavioural similarities and differences between users. For example, it can be vividly seen that two (C3 and C4) out of the five children have significantly fewer difficulties based on the light colours used to show the regularity with which they showed behaviours related to having difficulties.

Table 5.3. Identified behavioural variables

Activities	Motivations
Adding/removing media	Personalising & interacting with media
Repositioning sprites	Animating media
Personalising media	Creating animated stories
Adding/removing scripts	Creating games
Skills	**Difficulties**
Creativity and imagination	Difficulty finding buttons
Operating a computer	Difficulty identifying blocks
Programming skills	Difficulty switching areas
Problem Solving Strategies	Difficulty identifying links
Asking for help	Difficulty performing mouse operations
Becoming idle	Difficulty defining instructions
Moving to other tasks	Difficulty structuring & sequencing
Retrying	Difficulty staying on track
	Being repetitive
Aptitudes	**Attitudes**
Reading and writing	Enjoys interacting with VPT

Figure 5.2. Participating children and their observed activities, skills, difficulties etc.

Behavioural Variables	Participant's Behaviour				
	C1	C2	C3	C4	C5
Activities					
Adding/removing media	Sometimes	Sometimes	Sometimes	Sometimes	Almost always
Repositioning sprites	Sometimes	Sometimes	Almost always	Sometimes	Almost always
Personalising media	Sometimes	Sometimes	Sometimes	Often	Often
Adding/removing scripts	Sometimes	Sometimes	Almost always	Almost always	Seldom
Attitudes					
Enjoying interacting with the software	Often	Almost always	Almost always	Often	Often
Motivations					
Personalising and interacting with sprites	Sometimes	Seldom	Seldom	Seldom	Almost always
Animating media	Seldom	Sometimes	Almost always	Seldom	Sometimes
Creating animated stories	Almost always	Almost always	Sometimes	Almost always	Seldom
Creating games	Never	Never	Sometimes	Never	Never
Skills					
Showing creativity and imagination	Sometimes	Sometimes	Often	Often	Seldom
Comfortably operating a computer	Sometimes	Often	Almost always	Almost always	Often
Showing programming skills	Seldom	Seldom	Often	Sometimes	Seldom
Difficulties					
Difficulty finding buttons	Sometimes	Sometimes	Seldom	Seldom	Sometimes
Difficulty identifying blocks	Almost always	Almost always	Seldom	Seldom	Almost always
Difficulty switching areas	Often	Sometimes	Seldom	Seldom	Often
Difficulty identifying links	Almost always	Almost always	Often	Sometimes	Almost always
Difficulty performing mouse operations	Almost always	Sometimes	Seldom	Seldom	Sometimes
Difficulty defining instructions	Often	Often	Seldom	Seldom	Almost always
Difficulty structuring & sequencing	Almost always	Almost always	Sometimes	Sometimes	Almost always
Difficulty staying on track	Sometimes	Sometimes	Sometimes	Seldom	Often
Being repetitive	Seldom	Sometimes	Sometimes	Sometimes	Almost always
Aptitudes					
Showing good reading and writing skills	Sometimes	Sometimes	Sometimes	Often	Seldom
Problem Solving Strategies					
Asking for help	Seldom	Often	Often	Seldom	Often
Becoming idle	Almost always	Sometimes	Seldom	Seldom	Seldom
Moving to other tasks	Seldom	Seldom	Seldom	Seldom	Often
Retrying	Seldom	Seldom	Almost always	Often	Seldom

Figure 5. 2. Participating children and their observed activities, skills, difficulties etc.

Key	
(black)	Almost always
(dark grey)	Often
(grey)	Sometimes
(light grey)	Seldom
(white)	Never

Task 3 - Identify and group users with similar meaningful patterns of behaviour: During each expert interview, the interviewee was asked to group the five children with ASC based on the similarities they share in their patterns of behaviour (note: one expert believed there was not enough information and did not participate in this task). Although some behavioural patterns are obvious from the created mapping (see Figure 5.2), it was expected that experts have the knowledge and experience to identify similar patterns that are not obvious to non-experts or point out similar patterns that may not be relevant within the context of this research. The groups of users identified by each expert are shown in Table 5.4.

Table 5.4. Experts' groupings of participating children with ASC

Expert	Group 1 User(s)	Group 2 User(s)	Group 3 User(s)
E1	C3 & C4	C1 & C2	C5
E2	C3 & C4	C1, C2, & C5	*NULL*
E3	C3 & C4	C1 & C2	C5
E4	C3 & C4	C1 & C2	C5
E6	C3 & C4	C2	C1 & C5
E7	C3 & C4	C1, C2 & C5	*NULL*

One thing all experts agreed on is that C3 and C4 are the most capable among the children. This is based on the lack of difficulties they faced compared to the other children. Their activities show that they interacted with media as well as used scripts, they showed the most programming skills, and they faced the least difficulties. Therefore, all experts agreed that C3 and C4 should be grouped.

The next group of children that most experts believed to be very similar are C1 and C2. Five out of the six experts believed that their similarities in activities, skills, motivations and difficulties make them suitable candidates for a separate group. However, two of these five experts also believed that C5 should be in the same group due to C5's similarities to C1 and C2 in terms of behaviours associated with facing difficulties.

Four out of the six experts created a third group, and three among them included only C5 in this group due to his unique pattern of behaviour. His behaviour mappings showed lots of difficulties, together with motivations and concentration on activities that may not yield a meaningful output relative to what the sessions are for. One other expert, however, believed that C1 also shared this pattern of behaviour, and therefore should be included in the group.

Although experts unanimously agreed that C3 and C4 should be grouped together, their opinions on grouping C1, C2, and C3 varied. Therefore, further analysis had to be conducted to come up with a final grouping for these children. Since five out of six experts believed that C1 and C2 are similar, it was decided that they should be in the same group. However, there remained the question of whether to include C5 in that group or to create a separate group for C5. Those experts that believed C5 should be in the same group as C1 and C2 believed so because all three users share similar difficulties which show similarities they have in intellectual deficits. Those that believed C5 should be in a different group cited that C5 showed more repetitive behaviour than all the other users, which shows a different level of severity of autism, even though they may share similar intellectual difficulties. Since the personae being created are for those with ASC, this difference in the severity of ASC characteristics between C5 and the other two children was considered justification enough to create a separate group for C5. Therefore, a third and final group containing only C5 was created. Table 5.5 shows the final groupings of the participating children.

Table 5.5. Final grouping of children

Group	Group 1	Group 2	Group 3
Children	C1, C2	C3, C4	C5

Task 4 - List the characteristics and goals of the identified groups to form persona abstracts: For each group of children identified by an expert, the expert was asked about the characteristics and goals of the members of that group. Experts made use of the information provided to them about the children from the previous study, what they know about children with ASC, and from their experiences to describe the characteristics and goals of the children. The collected data was then analysed to find common themes for children in each identified group. Persona abstracts were then created for each group by adding a name, a date of birth and listing the characteristics and goals of the group gathered from experts. Names and dates of births were generated randomly using a constraint that ensures the corresponding age is between 13 to 14 years (to stay within the age ranges of the children whose data was used to build the personae). The created persona abstracts are shown in tables 5.6 - 5.8.

Table 5.6. Group 1 persona abstract

<table>
<tr><th colspan="2">Group 1 Persona Abstract</th></tr>
<tr><td>Name: Ralph</td><td>Date of Birth: 28th November 2005</td></tr>
<tr><td colspan="2">Characteristics:
▪ Moderate learning disability
▪ Poor reading and reading comprehension skills.
▪ Understands visual symbols.
▪ Not very good at communicating needs.
▪ Difficulties with fine motor control.
▪ Prefers touch screen devices due to fine motor control difficulties that affect his use of a mouse.
▪ Requires scaffolding to get started on tasks requiring creativity, structuring, sequencing and abstraction.</td></tr>
<tr><td colspan="2">Goals:
▪ Easily locate, interact with and personalise sprites of favourite objects.
▪ Easily identify programming blocks to create and programming scripts.
▪ Get ideas and scaffolds for creating new and exciting animated stories</td></tr>
</table>

Table 5.7. Group 2 persona abstract

<table>
<tr><th colspan="2">Group 2 Persona Abstract</th></tr>
<tr><td>Name: Lilly</td><td>Date of Birth: 22nd August 2004</td></tr>
<tr><td colspan="2">Characteristics:
▪ Moderate learning disability.
▪ Does not like interacting with others.
▪ Restrictive interests.
▪ Likes working independently.
▪ Can read and write simple sentences.</td></tr>
</table>

▪ Struggles with comprehending complex sentences or words in foreign contexts. ▪ Able to come up with creative and imaginative ideas independently. ▪ Understands basic concepts of programming and sequencing of actions. ▪ Does not like asking for help and gets frustrated or loses interest when faced with too much difficulty.
Goals: ▪ Easily identify programming blocks to create and programming scripts. ▪ Create animated stories independently without requiring help.

Table 5.8. Group 3 persona abstract

Group 3 Persona Abstract	
Name: Oliver	**Date of Birth:** June 15th 2005
Characteristics: ▪ Severe learning disability ▪ Very restrictive interests. ▪ Can be highly repetitive. ▪ Likes to work with no goal or focus. ▪ Gets overwhelmed when faced with a high number of choices. ▪ Very poor reading and reading comprehension skills. ▪ Prefers visual presentation of information. ▪ Has difficulty communicating needs. ▪ Requires constant scaffolding to perform tasks requiring creativity, sequencing, structuring and abstraction. ▪ Interacts well with technology (PCs, mobile and tablet devices), but rarely uses it in a goal-directed manner.	
Goals: ▪ Easily locate, interact with and personalise sprites of favourite objects ▪ Create animations without having to use the confusing programming blocks	

Task 5 - Compare persona abstracts with existing personae: During each interview, each expert was asked to compare the characteristics and goals of the groups they created with the characteristics and goals of the six existing personae for children with ASC identified from the literature. Data from this exercise was used in this stage to identify any existing persona that is similar to any persona abstract. However, it should be noted that at the time of the interviews, persona abstracts have not been created and therefore the groups that each expert compared to the existing personae may or may not differ from the groups that became persona abstracts. Therefore, only data that resulted from an expert comparing groups that became persona abstracts with existing personae were used. In summary, all experts' comparisons of the characteristics and goals of the group containing C3 and C4 with existing personae were analysed. E1, E3 and E4's comparison of the characteristics and goals of the group containing C1 and C2, and the group containing C5, with existing literature was also analysed.

Although experts found similarities, not all found them in the same existing persona(e). In addition, some experts found few characteristics in one existing persona and found other characteristics in one or more other existing personae.

This led to the conclusion no single persona in the set of gathered existing personae is significantly similar in characteristics and goals to any of the persona abstracts. At least not similar enough to justify its extension to fully describe any of the persona abstracts without making major modifications that defeat the purpose of extending an existing persona instead of creating a new one.

Task 6 - Extend existing personae to fully describe the persona abstracts: Since no single existing persona was found to be similar enough to the persona abstracts for an extension to be justified, this step was not necessary.

Task 7 – Fully describe the characteristics and goals of persona abstracts: Each persona's descriptions were presented in three sections named: background, use of VPTs and goals. These sections all provide information that paints a picture of a fictional child with ASC. The background section introduced the child being described by name, provides the child's age, mentions the child's diagnosed condition and some (fictional) personal information e.g. school attended. It then mentions some of the child's characteristics that are important in making sense of the child's use of VPTs e.g. reading and communication skills.

The “use of VPTs” describes what is expected from the child during the typical use of a VPT. It describes typical activities performed by the child, the child’s motivations and the child’s difficulties. Although these personae are meant to represent behaviour and goals for using all kinds of VPTs designed for children, Scratch and its features are used in writing the descriptions in the personae to ensure that all scenarios described are concrete and not ambiguous.

Finally, the “goals” section describes the child’s ultimate goals related to the use of VPTs. This section also describes the child’s accessibility preferences as suggested by experts.

The three personae created at the end of this task are presented in tables 5.9 – 5.11, and Table 5.12 provides a comparison of their key characteristics.

Table 5.9. Persona describing Lilly

Persona Name: Lilly
Background: Lilly is a 14-year-old with Autism Spectrum Condition (ASC) and a moderate learning disability. She is verbal but rarely speaks and avoids social interactions unless it is with people she trusts. If given time to prepare, she sometimes interacts with people that share or are willing to share her interests. Lilly can read and write short simple sentences but struggles with long narratives and words used in a context she is not familiar with. However, she is a fast learner as long as she finds the subject or activity interesting.
Use of VPTs: Lilly enjoys using Scratch at school to create short animated fairy tales. She finds it easy to add images of her favourite fairy tale characters like ‘the princess’ and ‘the witch’ to her projects. Although she understands basic programming concepts such as sequencing and loops, she sometimes struggles with finding programming blocks or creating scripts, but she usually finds a way after a few trials and errors. She rarely asks for help even if she is unable to find a way herself, in those cases she gets frustrated and abandons Scratch.
Goals: Since Lilly does not own a laptop or have a desktop in her room, she wishes she could have a Visual Programming Tool (VPT) like Scratch to work with on her phone when she is not at school. She would also like to get hints, guides or templates to work with to reduce the number of times she is stuck. Her teacher thinks templates will not only help her work on her interests but could also introduce her to new interests.

Table 5.10. Persona describing Ralph

Persona Name: Ralph
Background: Ralph is 13 years old; he has Autism Spectrum Condition (ASC) and a moderate learning disability. He attends a special school for children with ASC a few minutes away from his home. Ralph is verbal but only speaks when he is around his parents, teacher or some classmates. Ralph recognises all the letters of the alphabet and can read words syllabically, but he struggles with reading comprehension. He is, however, able to recognise words and their meanings better when supported with visual symbols.
Use of VPTs: Ralph loves using Visual Programming Tools (VPTs), especially Scratch. He uses Scratch to create short animated stories about Sharks, his favourite sea animals. His favourite animation to make is that of a diver running away from a shark, and he has learnt to create it independently using Scratch. Ralph also likes creating new stories, however, he struggles to do so without his teacher's help in coming up with story plots, structuring and sequencing events. He also struggles to locate images for his new story characters due to the large number of images available to choose from, and he struggles to understand the blocks of instruction he needs to create scripts. Ralph also struggles to perform some mouse operations while using Scratch such as dragging objects or selecting objects.
Goals: Ralph does not mind getting help from his teacher when he is creating new stories, but he will love to independently create new stories and some games about sea creatures if only he could find a VPT with a scaffold similar to the one offered by his teacher. He would love to browse through sprites of sea creatures without scrolling through all the other sprites of things that he is not interested in. It will also be easier for him to find and use blocks if they are labelled using visual symbols he understands. Finally, because of his problems with mouse operations, he will love to have a VPT that he can use on his touch screen phone.

Table 5.11. Persona describing Oliver

Persona Name: Oliver
Background: Oliver is 13 years old and attends a special school for students with autism. He has Autism Spectrum Condition (ASC), severe learning disability and a short attention span. Although he sometimes makes simple requests verbally by uttering words, he usually uses visual communication symbols to communicate.
Use of VPTs: Oliver loves Visual Programming Tools (VPTs) like Scratch and enjoys using them at school in his weekly animated storytelling session. However, when he creates projects, he mostly adds images of his favourite things (jets and spaceships) and colours them blue. He rarely works with other images or adds any programming instructions to create animations, even though his teacher encourages him and shows him how to. When he does attempt to create flying animations for his jets or spaceships, the number of programming blocks available to choose from confuses him. He is also unable to read each block's text label or understand what instruction it represents. Therefore, he usually goes back to adding more images until there is no space for more, and then he creates a new project and repeats the same process.
Goals: Oliver will love to have a VPT with features that let him create animations by just adding images and not having to work with confusing programming blocks. He will also like to work with more visual communication symbols instead of text. His teachers think he will be able to make meaningful projects if he uses a VPT with goal-oriented restrictions and scaffolds.

Task 8 - Validate personae by getting expert opinion and feedback: An online questionnaire was created using Google Forms and used to get expert opinions and feedback on the created personae. For each of the three sections of each persona, the questionnaire used closed-ended questions to ask experts to provide their level of agreement for the descriptions in each section using a four-point Likert scale (1 - strongly disagree to 4 - strongly agree). Two open-ended questions were also included at the end of the questionnaire. The first asked experts to explain any inconsistencies they found between the descriptions of the persona's sections. The second asked the experts to provide any additional recommendations (if any) that they have for improving the quality of the persona.

Links to the questionnaires were sent to all of the seven experts that took part in the persona creation process through email. Each email contained three links to identical questionnaires, and each questionnaire had a unique persona attached. Instructions that asked the respondent to read the attached persona and answer the questions that followed based on their opinions of the persona were provided with each questionnaire. Although the questionnaire links were emailed to all seven experts, only four responded to the questionnaire.

The responses received from all four experts were analysed and discussed within this section, charts showing the quantitative responses received for each persona are shown in Figures 5.3 – 5.5. Responses for Oliver and Ralph showed that all experts strongly agreed with descriptions provided in the "Use of VPTs" section of the personae. Three experts strongly agreed with their "Goals" sections, and two experts strongly agreed with their "Background" section. Only one response was received from the disagreeing part of the scale for both personae, one expert responded with "2" as their opinion on the "Goals" section.

Figure 5.3. Quantitative results for the validation of Ralph

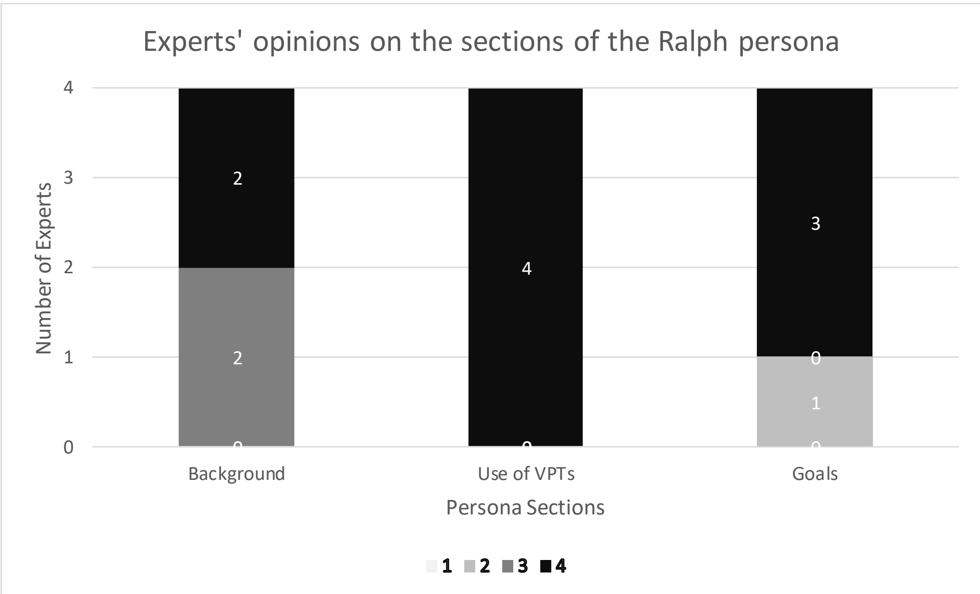
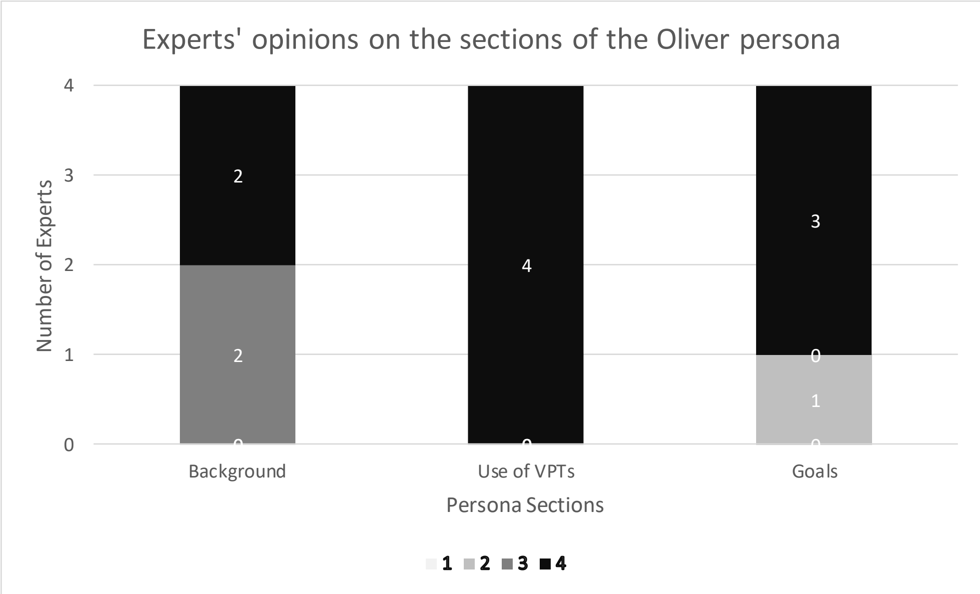
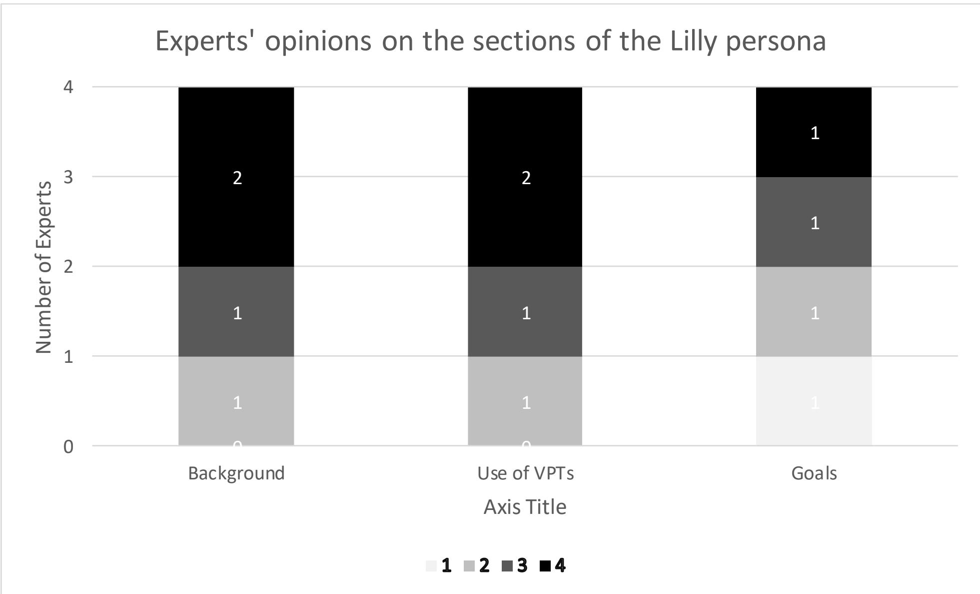


Figure 5.4. Quantitative results for the validation of Oliver



The responses received for Lilly were not as positive as those for Ralph and Oliver, although they were positive overall. Two experts strongly agreed (4) with the descriptions in the "Goals" and "Use of VPTs" sections, and only one expert agreed with the "Goals" section. Four responses were received on the disagreeing part of the scale, one expert strongly disagreed (1) with the descriptions of the "Goals" section, and an expert each responded with 2 for each of the sections of the persona.

Figure 5.5. Quantitative results for the validation of Lilly



The qualitative feedback received from experts was also mostly positive especially for Oliver and Ralph, however, as in the quantitative feedback, Lilly faced criticism especially in the goals section. Fortunately, the feedback also included qualitative feedback (discussed below) on how to make improvements.

E3 commented on an inconsistency in the Oliver persona, he stated that the goals section of the persona gives a much higher understanding than the other areas and suggested a review of the persona's goals. However, no particular aspects of the goals section were highlighted by E3, and all other experts completely agreed with the consistency of the goals, therefore no changes were made to Oliver.

Only E3 noticed an inconsistency and provided improvement feedback for Ralph. He noticed that the use of "plot" as a difficulty in Ralph's use of VPT implies a depth in storytelling that may not be consistent with Ralph's abilities, and suggested using "sequencing of events" instead. This change was implemented by substituting "plot" with "sequencing of events" in the persona.

Finally, independent use of VPTs at home and sharing of interests were pointed out as things that Lilly is unlikely to do by E1 and E3. In addition, E2 pointed out that based on her background, Lilly may not be able to program at the level suggested by the Persona. Changes were made to the persona to reflect this feedback.

The updated versions of the two modified personae are presented in figures tables 5.12 – 5.13 (Note: new descriptions in the personae are shown in bold and highlighted*).* Table 5.14 highlights the key characteristics of all three personae in order to emphasize their similarities and differences.

Table 5.12. Updated persona describing Ralph

Persona Name: Ralph
Background: Ralph is 13 years old; he has Autism Spectrum Condition (ASC) and a moderate learning disability. He attends a special school for children with ASC a few minutes away from his home. Ralph is verbal but only speaks when he is around his parents, teacher or some classmates. Ralph recognises all the letters of the alphabet and can read words syllabically, but he struggles with reading comprehension. He is, however, able to recognise words and their meanings better when supported with visual symbols.

Use of VPTs: Ralph loves using Visual Programming Tools (VPTs), especially Scratch. He uses Scratch to create short animated stories about Sharks, his favourite sea animals. His favourite animation to make is that of a diver running away from a shark, and he has learnt to create it independently using Scratch. Ralph also likes creating new stories; however, **he struggles to do so without his teacher's help in structuring and sequencing events in his stories**. He also struggles to locate images for his new story characters due to the large number of images available to choose from, and he struggles to understand the blocks of instruction he needs to create scripts. Ralph also struggles to perform some mouse operations while using Scratch such as dragging objects or selecting objects.
Goals: Ralph does not mind getting help from his teacher when he is creating new stories, but he will love to independently create new stories and some games about sea creatures if only he could find a VPT with a scaffold similar to the one offered by his teacher. He would love to browse through sprites of sea creatures without scrolling through all the other sprites of things that he is not interested in. It will also be easier for him to find and use blocks if they are labelled using visual symbols he understands. Finally, because of his problems with mouse operations, he will love to have a VPT that he can use on his touch screen phone.

Table 5.13. Updated persona describing Lilly

Persona Name: Lilly
Background: Lilly is a 14-year-old with Autism Spectrum Condition (ASC) and a moderate learning disability. She is verbal but rarely speaks and avoids social interactions unless it is with people she trusts. Lilly can read and write short simple sentences but struggles with long narratives and words used in a context she is not familiar with. However, she is a fast learner as long as she finds the subject or activity interesting.
Use of VPTs: Lilly enjoys using Scratch at school to create short animated fairy tales. She finds it easy to add images of her favourite fairy tale characters like 'the princess' and 'the witch' to her projects. **Lilly understands basic programming concepts such as sequencing and loops and is able to create**

simple scripts. However, she struggles with creating complex scripts and resolves to trial and error when she needs to create one. She rarely asks for help even if she is unable to find a way herself, in those cases she gets frustrated and abandons Scratch.
Goals: **Lilly would love to get hints, guides or templates to work with in order to improve the complexity of projects that she creates and to reduce the number of times she is stuck.** Her teacher thinks templates will not only help her work on her interests but could also introduce her to new interests.

Table 5. 14. Key characteristics of Lilly, Ralph and Oliver

	Lilly	**Ralph**	**Oliver**
Age	14	13	13
Learning Disability	Moderate	Moderate	Severe
Scaffolding Need	Mild	Moderate	Severe
Reading Difficulties	Mild	Moderate	Severe
Repetitive Behaviour	Mild	Mild	Severe
Motor Skill Difficulties	None	Moderate	None
Interests	Fairy tales	Sea creatures	Space travel

5.4. Part 3: Analysis of the Persona Creation Method

Based on the application of the proposed method of creating personae for children with ASC, the results and findings described above; lessons were learnt, and observations and reflections were made that can be used to improve both the method and how it should be applied. These are summarised below:

5.4.1. Required Data, Sources and Collection

The results collected so far have further confirmed the efficiency of data grounded persona creation methods. Upon reflection, it is clear how instrumental experts were in uncovering characteristics, patterns and goals associated with the recorded actions and behaviours of users. Without the help of experts, the same value could not have been extracted from the target user data. However, one modification that could be used in better utilising experts in this process is to have focus groups rather than individual interviews. This could potentially lead to participants reacting to each other's beliefs and opinions and subsequently lead to more interconnected data (Kitzinger, 1994). It was also observed that the data collected and used can be categorised based on its purpose in the persona creation process; this led to the introduction of the terms base data, supplementary data, fictional data and validation data. Base data are the data collected from users to identify behaviours and generate user mappings to behaviours; it provides the basic information that the persona is built from. Supplementary data are data from experts that either adds to base data or clarify and interpret it. Fictional data consist of the imaginary personal details added to a persona to make it seem human and relatable. Finally, validation data are data collected from experts to validate and improve created personae.

5.4.2. Extending Existing Personae

The method proposed in this work encourages the creation of data grounded personae. It recommends the use of observational data gathered from target users and seeking experts to provide additional data and analyse existing data. However, it was observed that the method's inclusion of the extension of existing personae created an unnecessary risk of contaminating the characteristics and goals extracted from real target user data. At the end of Task 4, persona abstracts contained a list of characteristics and goals purely based on target user data and expert knowledge. Extending a similar existing persona in Task 5 to fully describe a persona abstract could produce a final persona with inherited characteristics and goals that may not be true for the children with ASC represented by the persona abstract. Several reasons can cause this such as extending a persona not built on real data or extending a persona that represents a larger group of children with ASC than the persona abstract. It should be noted though that this does not mean existing personae are entirely useless in this creation process. They can be used as foundations to build new personae in situations where enough qualitative data are not available, for example, where sufficient data collection activity is not feasible due to limited time, resources or access to participating children with ASC. They can also be used as verification tools to verify and validate observations made and the results of data analysis. However, care must be taken in choosing the existing personae used for such purposes. They must be based on a sound methodical approach to analysing real target user data. Otherwise, their inclusion could risk the validity of the produced persona(e).

5.4.3. Validation and Feedback

In the final stage of the proposed and applied persona creation method, feedback was sought from experts on the correctness of the descriptions contained in the three personae constructed, and recommendations (if any) for improving them. Although only four out of the seven experts that were contacted responded to the questionnaire, they provided enough quantitative and qualitative data to confirm the correctness of aspects of the personae and recommend improvements to other aspects. Even though in one of the qualitative feedbacks an expert commented on an inconsistency in the goals of one of the personae, but the comment did not specify which aspect of the goal was inconsistent.

Therefore, as a way of improving this method, an additional step specifically for implementing feedback will be useful in stressing the importance of utilising the feedback received from experts in improving created personae. Additionally, experts can be advised to highlight sections of the personae when making comments to ensure all relevant recommendations and corrections can be addressed during the step for implementing feedback.

5.4.4. Revised Method for Creating Personae for Children with ASC

Taking the observations and suggestions presented above into account, a revised version of the persona creation method is proposed. It should be noted that these are major revisions that include the elimination of two tasks and the introduction of a new one. The tasks eliminated are the tasks associated with comparing and extending existing personae (Task 5 and Task 6). The new task introduced is for implementing feedback gathered during the process of validating personae with experts. Further validation can be conducted after implementing the feedback if required. The visual representation of the revised and improved method showing the seven tasks involved, the sequence in which they occur, and the “required data” for each task is illustrated in Figure 5.6. Required data can be one or a combination of the following: base data, supplementary data, fictional data and validation data. These data types and how they can be sourced are briefly discussed below:

- *Base data:* these data are collected before the persona creation process begins. They are collected directly from users, preferably through observations, but can be collected through other qualitative data collection approaches. They form the foundation for all personae to be constructed on.

- *Supplementary data:* these data are collected during the persona creation process. They are collected from experts through discussions on user characteristics, needs and goals. Supplementary data is also gathered by getting experts' opinions on the results of analysing base data. Interviews or focus groups should be used to gather supplementary data.

- *Fictional data:* Although the characteristics and goals of personae are extracted from real target user data, fictional details such as personal information are needed to add life to personae and make them more relatable. Fictional data for building personae can be generated from user generation sites on the internet.

- *Validation data:* validation data are collected by gathering expert opinions on the constructed personae through interviews, focus groups, or surveys. Validation data not only rates the correctness of personae but also provides useful data that can lead to improvements in the quality of personae. This is why it is very useful to collect qualitative feedback as part of validation data.

5.5. Conclusion

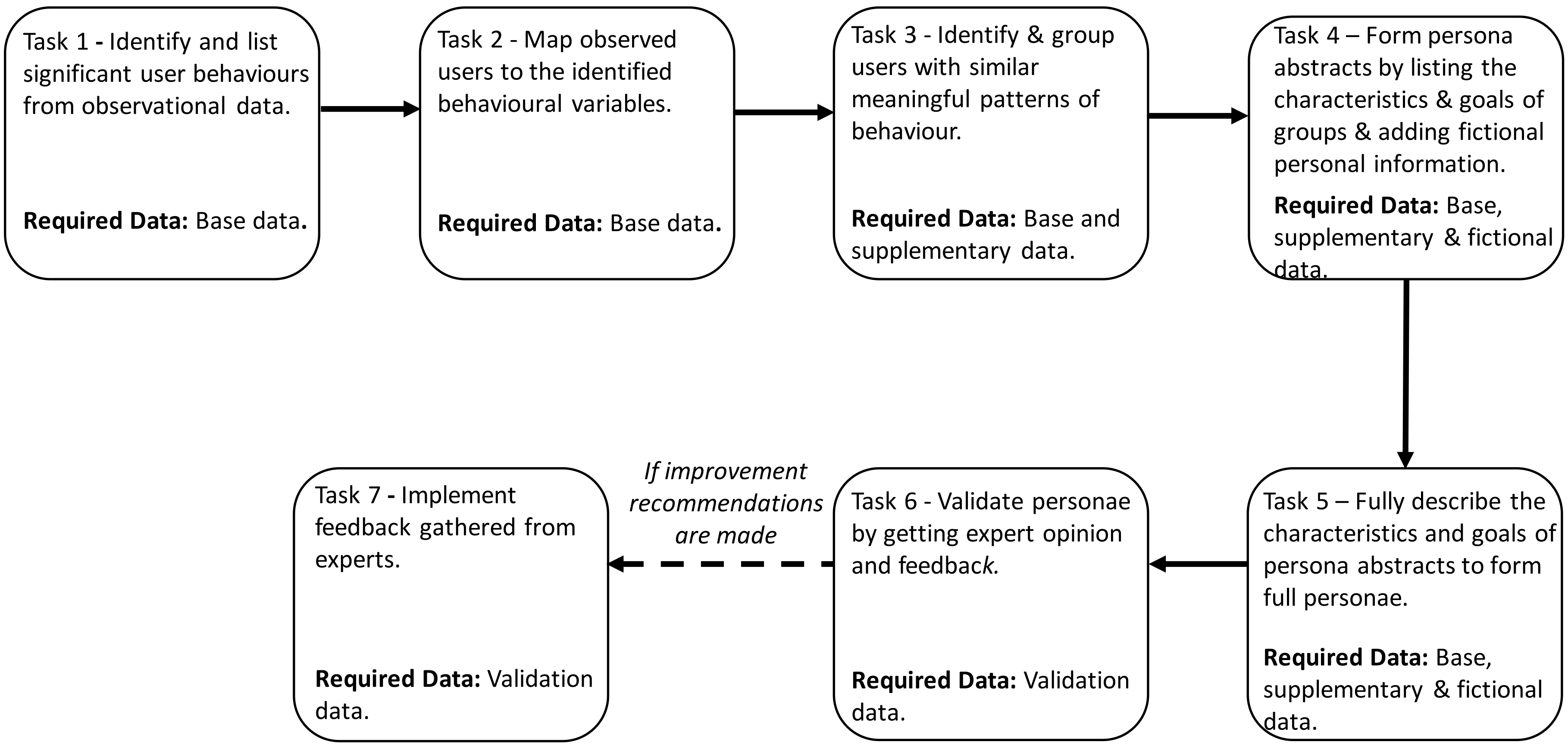
This chapter presented a novel method for creating personae for children with ASC, the results of applying the method to create a set of personae describing children with ASC for the design of accessible VPTs, and a revised and improved version of the method.

The proposed method was inspired by the existing data-grounded approaches (Cooper et al, 2007; Adlin and Pruitt, 2010). The data used in applying the method to create personae for children with ASC include observational data and video screen captures of children with ASC using Scratch, data from expert interviews and a set of existing personae for children with ASC gathered from the literature. After following the tasks specified by the method, three personae were created. Although it was hoped that one or more of the existing personae would be extended to create new personae, all the resulting personae were based purely on gathered data. The created personae had to be validated by experts as required by the method to ensure that they accurately described users with ASC and their characteristics and goals while using VPTs. Results from the validation showed that experts mostly agreed with the accuracy of the personae and provided recommendations for their improvement in areas that they did not agree on. Recommendations received from experts were reviewed and applied where appropriate to improve the quality of the personae.

Finally, a revised and improved version of the persona creation method was presented. The revisions and improvements were based on observations, insights and lessons learnt from applying the initially proposed method to create a set of personae. The improved version of the method emphasizes the creation of personae solely from data, stresses the need to utilize feedback from experts and makes data requirements at each stage explicit.

The contributions to the knowledge presented in this chapter include a method for the creation of data grounded personae for children with ASC and a set of three personae for children with ASC that can be used for designing VPTs and other interactive applications for children with ASC.

Figure 5.6. Revised and improved method of creating personae for children with ASC, its methods and required data



Chapter 6: Proposing Recommendations for Designing Accessible VPTs for Children with ASC

6.1. Introduction

Chapters 3 and 4 showed that children with ASC are likely to face accessibility difficulties when using existing VPTs, even those created specifically for children. This chapter will present the proposal of a set of recommendations for designing accessible VPTs for children with ASC. This was done by interviewing experts to gather data that led to the derivation of an initial set of recommendations and conducting a second interview with experts to validate and update the derived recommendations, thus, proposing the set of validated recommendations. Thematic analysis (Braun and Clarke, 2006) was used to analyse data and identify broad accessibility recommendation themes that contain one or more recommendations.

6.2. Method

The participants, procedure, data collection and analysis conducted for the process of gathering initial recommendations and the process of validating them are discussed below:

6.2.1. Participants

Seven experts, E1 - E7, consisting of two SEN teachers and five researchers (see Section 5.3.2 for their recruitment process and Table 5.2 for their brief profiles) participated in the interview for gathering initial recommendations. However, only three experts, E1, E4 and E6 agreed to participate in the interviews conducted for validating recommendations.

6.2.2. Data Collection

Semi-structured interviews were used both to gather data for deriving recommendations and for validating recommendations (see Appendix G and Appendix I). Six out of the seven of the first set of interviews were conducted face to face, while one was done using video conferencing (Skype).

The second set of interviews lasted between 30 - 45 minutes each and were all conducted face to face. All interviews were audio-recorded with the permission of the interviewee and were later transcribed for analysis.

6.2.3. Procedure

At the beginning of each interview conducted for gathering initial recommendations, the interviewee was shown an example of a VPT (Scratch) and how it can be used to create a simple animation program. Then data was collected by discussing behaviours, especially those related to difficulties associated with using VPTs faced by children with ASC and potential design recommendations for resolving or avoiding those difficulties. The behaviours and difficulties used to guide the interviews were those identified as the set of behavioural variables and mapped to five children with ASC as presented in Chapter 5 (see Figure 5.2).

Using a semi-structured interview approach, the researcher was flexible and opportunistic in following up on relevant and interesting points as they arose, and by using the points raised by experts to decide the sequence in which behaviours and difficulties were discussed. In some cases, experts suggested mitigating or avoidance approaches for difficulties and approaches for encouraging positive behaviours without being asked. In other cases, the researcher asked for recommendations by following up on a point made about the behaviour or difficulty. The complete set of gathered data were analysed to derive a set of initial recommendations for designing accessible VPTs for children with ASC.

Before the start of each interview conducted for validating recommendations, each interviewee was presented with the initial recommendations. At the start of the interview, an example of a VPT (Scratch) was shown to the interviewee. Then each recommendation theme was discussed together with its member recommendation(s) by asking the interviewee's opinion on its validity and usefulness. Based on the interviewee's response, more questions were asked to validate or correct existing recommendations, or even to derive new ones. Data collected from these interviews were analysed and the findings used to improve and create a set of proposed recommendations.

6.2.4. Thematic Data Analysis

Analysis of the data gathered from interviewing experts for this study was conducted using thematic analysis. "Thematic analysis is a method of identifying, analysing and reporting patterns within data" (Braun and Clarke, 2006). This method has been used previously in HCI research to extract themes that inform the design of interactive systems (e.g. Brown and Stockman, 2013; Gkatzidou et al., 2015; Tanaka et al., 2012)

Thematic analysis has been described as a tool used in different qualitative research methods e.g. grounded theory. However, Braun and Clarke (2006) argue that it should be considered as a method in its own right. Similar to grounded theory, thematic analysis is not restricted by a strict set of instructions guiding its applications. This flexibility makes it compatible with a wide range of approaches and research questions and research areas. It should be noted though that flexibility does not mean a lack of standardisation and structure.

Braun and Clarke (2006) have provided a six-step guide for conducting and validating thematic analysis in a methodically sound manner, whilst avoiding restrictions that will compromise the method's flexibility. The first step involves familiarizing yourself with the data to be analysed by reading, rereading, and making notes of observations, thoughts or ideas about the data. After getting familiar with the data, the next step involves creating initial codes from the data. Codes are used to denote basic parts of the data that are interesting and relevant to the issue being researched. The process of coding can be "data-driven" i.e. depending on the contents of the data, or "theory-driven" i.e. depending on some questions asked of the data. Step three involves constructing themes by reviewing the created codes to identify patterns of similar or overlapping codes. By clustering together similar codes, a theme that describes a meaningful pattern in the data is created. Themes are reviewed in step four to ensure that all extracts are relevant to each theme (level 1) and to ensure that themes are true to the content of the overall data set (level 2). Step five of thematic analysis asks researchers to name their themes with appropriate names that inform readers about the content of each theme. After naming themes, descriptions should be created that capture the essence of the themes. Finally, a report that describes the analysis and the findings is created in step six.

In the first phase of this study, all audio records of the interviews were first listened to while making notes of interesting observations within the data, then the recordings were transcribed, and then the transcripts read. This ensured that familiarity with the data and its contents has been established even before the start of the analysis.

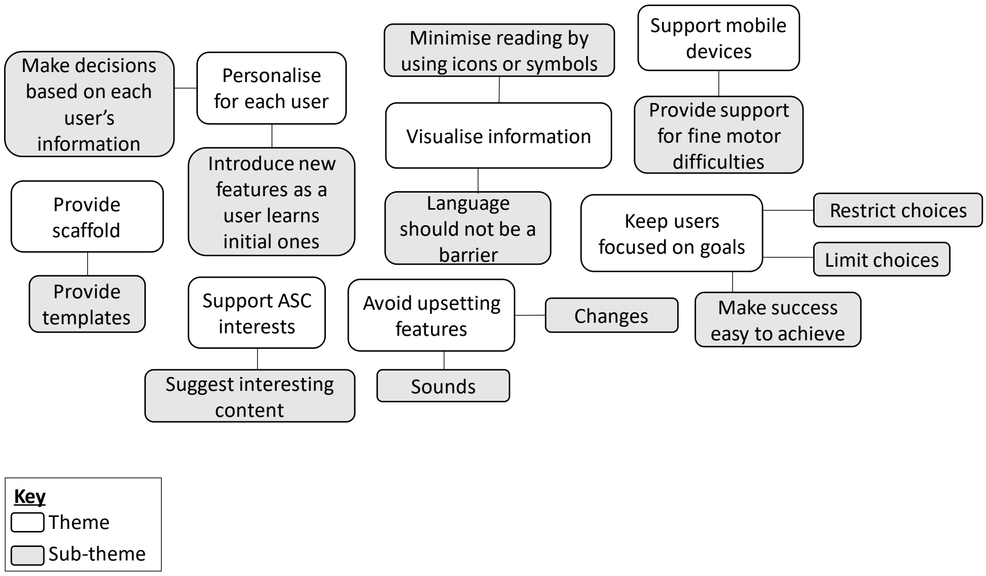
Then "theory-driven" coding was conducted by asking two questions, they are: "What features should VPTs have to ensure that they are accessible, usable and engaging for children with ASC?" and "What features should VPTs avoid to ensure that they are accessible, usable and engaging for children with ASC?". All parts of the interview transcripts were given full and equal attention during this coding process to ensure all relevant segments have been coded. On completion, 33 codes were created that denote segments of the data that provided useful information regarding the two questions asked of the data. To further clarify this process, table 6.1 provides a couple of excerpts from the interview transcripts and the codes that were created and assigned to them.

Table 6.1. Examples of phase one interview transcript excerpts and their codes

Excerpt	**Code(s)**
"I think restrictions could be really helpful to some people because if somebody is struggling to inhibit their enjoyment of adding new characters, like that is obviously a very satisfying thing, you do something and there's a character. So, I can understand why people get stuck in that because it's easy and it's very rewarding."	Restrictions can be good
"So I can imagine that you then lose that, you know, the excitement about it because if it becomes a chore to make it do anything, there will be people who just lose concentration. And not because they don't want to do it, but because it just becomes too hard for them to actually do it."	Make success easy to achieve Work at the pace of each user

After examining the created codes to identify similarities or overlaps, seven main themes and twelve subthemes were identified. One code did not fit into any of the created themes, and therefore it was discarded. A thematic map showing all the created themes and subthemes is shown in Figure 6.1.

Figure 6.1. Thematic map showing created themes and subthemes



The entire transcripts were then reread to ensure the validity of the created themes and sub-themes with respect to the entire data. This led to the realisation that some themes have within them subthemes representing key accessibility concerns or recommendations. To ensure that all key accessibility recommendations and concerns are given equal emphasis, a new thematic map was created representing them as themes (see Figure 6.2). The updated thematic map has nine main themes compared to the seven main themes of the previous thematic map.

Themes were then named to highlight the concept or ideas of the recommendations (codes) each contains. For example, the created theme "personalise for each user" has content that emphasizes the importance of personalisation in making VPTs accessible, therefore it was named "Personalisation". The complete list of themes with their initial and final names is presented in Table 6.2.

Figure 6.2. An updated thematic map showing updated themes and subthemes.

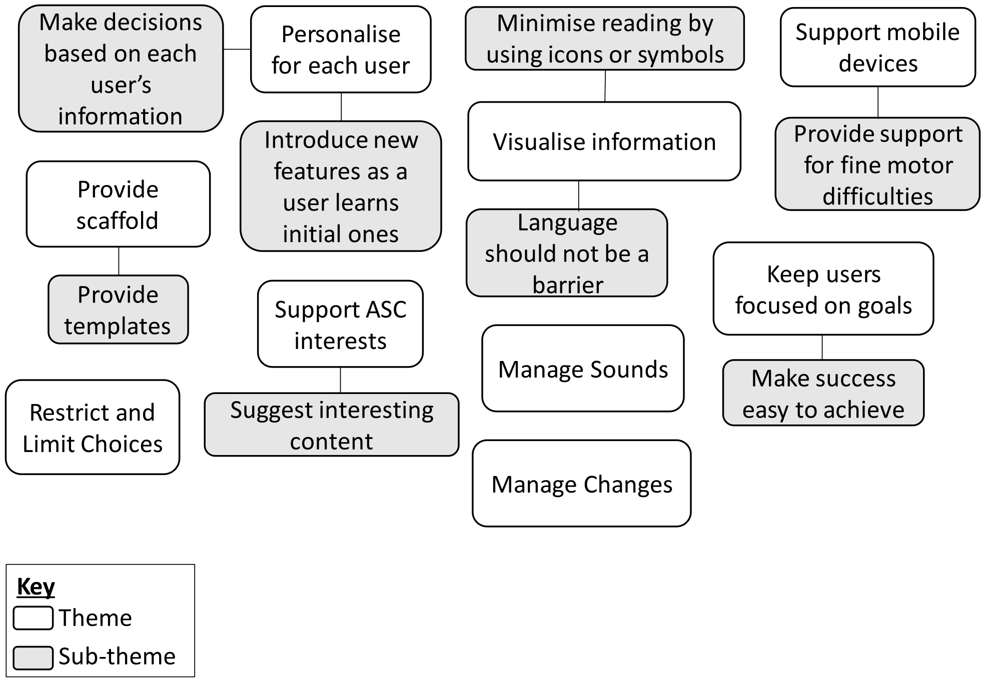


Table 6.2. Themes and their initial and final names

Initial Name	**Final Name**
Support mobile devices	Mobile device compatibility
Support ASC interests	Engaging users
Visualise information	Information presentation and visualisation
Manage sounds	Managing sounds
Manage changes	Managing changes
Provide scaffold	Scaffolding
Personalise for each user	Personalisation
Keep users focused on goals	Goal orientation
Restrict and limit choices	Restrictions and Limitations

The themes are described in the detailed report created as part of step six of conducting thematic analysis. The process of analysis of this study has been presented in this section, and a detailed account of the findings is presented in the next section with data excerpts used to describe the contents (recommendations and concerns) within each theme.

The second phase of this study aimed to validate the derived recommendations and make improvements where necessary. The analysis of the interviews conducted in this phase was also done following Braun and Clarks (2004) six phases of thematic analysis. Interviews were first listened to, then transcribed and read. During these steps, the researcher became familiar with the data and made notes about interesting concepts within it.

Then the data were coded using a theory-driven approach by asking the questions “What are the opinions of experts on the proposed recommendations?” and “What suggestions do experts have to improve the proposed recommendations?”. The created codes were then categorised into themes by assigning each code to the recommendations theme (created during the analysis of the first interview) it is concerned with (no code was found that did not ft any of the existing recommendation themes). For example, a code representing an opinion of an expert on the importance of a restriction and limitations recommendation is assigned to the restrictions and limitations theme, and a code representing concern shown by an expert about a personalisation recommendation is assigned to the personalisation theme. However, to add a layer of patterns, codes in each theme were grouped into subthemes based on what sort of opinion they are representing e.g. subthemes of codes showing experts’ concerns, experts’ agreement, experts’ suggestions etc. Table 6.3 shows examples of transcript excerpts with their codes named to show their theme (recommendation theme) and subtheme (opinion type).

Table 6.3. Examples of phase two interview transcript excerpts and their codes

Excerpt	**Code(s)**
"I think [using restrictions and limitations] is a good thing. I think it's very necessary with some of these some children because they just get so stuck and they don't want to be repeating the same thing forever."	Restrictions and Limitations: agreement
"It may well be that in their profile their you get a question about their resistance to new information. I can imagine scenarios where if you're really into Thomas the Tank Engine and	Engaging Users (suggesting popular content): suggestion

somebody said that you should use my little pony, then it won't go down very well."	Engaging Users (suggesting popular content): concern

Coded extracts were reread and compared to the themes and subthemes to ensure that they are compatible, and then the whole data was reread to ensure that the codes and themes are representative of the data. No changes to the codes or themes were made at the end of this phase.

It should be noted that one recommendation theme name was changed based on the findings of this process. The report of this analysis, which is presented in section 6.3.2, presents the relevant findings related to each recommendations theme .i.e. agreement, concerns or improvement suggestions from experts.

6.3. Findings

6.3.1. Initially Gathered Recommendations (Phase 1 Findings)

The nine themes created covered areas of concerns ranging from the type of hardware platform recommended for children with ASC, to the type of content that should be provided within a VPT and how it should be presented. For each theme discussed in this section, relevant excerpts from the transcripts are provided to highlight the opinions of experts. The complete list of initially derived recommendations organised by themes and their descriptions is also provided in Table 6.4. These recommendations include those that were explicitly recommended by the experts and identified as codes (e.g. integrate content known to interest children with ASC) and those that were proposed by the researcher to address concerns raised by experts (e.g. keep track of changes applied for a user).

Table 6.4. Recommendation themes, derived recommendations and their descriptions

Theme	**Recommendation**	**Description**
Mobile Device Compatibility	Make sure VPT is compatible with mobile devices	VPTs should be compatible with and accessible on mobile devices, especially smartphones and tablets in order to allow easier access and interactions for children with ASC including those with motor difficulties.
Engaging Users	Integrate content known to interest children with ASC	Provide users with a diverse set of media and templates covering as many topics known to interest children with ASC as possible. For example, provide templates and media related to various forms of transportation e.g. a space rocket launch project template, sprites and models of planets, astronauts etc.
	Suggest popular content to unmotivated users	Content suggestions should be made to users (especially those barely interacting with the VPT) by suggesting content that is popular among other users with similar profiles.
Information Presentation and Visualisation	Present information visually using icons/symbols	Information within VPTs should be presented or supported with visual symbols/icons. For example, visual symbols or icons should be used to label objects or to support the objects' text labels throughout the user interface. This should include labels on buttons, tabs, panes, programming elements (blocks, bricks) etc.
Managing Sounds	Sound should be optional	The VPT should be usable with or without sounds. Sounds (including feedback sounds and program sounds) should not be audible unless explicitly turned on by the user, and volume control should be provided for users to adjust their sound level.
Restrictions and Limitations	Limit the choices of media elements available to users	Users should be provided with a manageable and relevant subset of media items (e.g. characters, backgrounds etc.) to work with, based on the goal of their project. For example, when creating a "space racing

	to a relevant and manageable set	game", the choice of background images or landscapes options can be limited to only those related to outer space.
	Limit the choices of programming elements available to users to a usable, manageable and relevant set	Provide users with a usable, manageable and relevant subset of programming elements (blocks, bricks etc.) for their projects. For example, only a small subset of basic programming blocks should be available to a user with ASC and severe learning disabilities and ensuring that only blocks that reposition objects are available when the user is creating a script for moving an object.
	Limit the features available to the user to those required to achieve the user's goal and are within the user's cognitive abilities	VPTs usually have numerous tools and features for performing various tasks. Only those features that the user is capable of using and support the achievement of the user's goal should be available to the user. For example, a user that requires constant scaffolding should be restricted from using the 'create blank/empty project' feature. Features that become subjects of obsessive behaviour to the extent that they stand in the way of goal achievement should also be restricted to allow the user to move on to achieve their goal.
Scaffolding	Provide templates for projects	VPTs should provide templates for creating a wide range of projects (e.g. games and animated stories). The templates should provide a visual structural scaffold for users by guiding them through the various stages of creating a project. For example, templates for a story should guide users to choose characters, backgrounds, and actions for each character. They should also allow users to view a potential version of their end product.
	Provide programming elements at higher levels of abstraction	VPTs should provide programming elements at different levels of abstractions for users with different abilities. For example, visual programming elements for 'move along x' and 'move along y' can exist at the low level. However, for those users that may be unable to create a script using these two programming elements to

		represent jumping, high-level programming elements ‘jump forwards‘ and ‘jump backwards‘ should be made available.
Goal Orientation	Design to ease, support and encourage success and goal achievement	Personalisation, restrictions, limitations, visualisations and scaffolding, should all be applied in a way that helps and encourages users to achieve their goal(s) without having to perform unnecessary/inaccessible actions or tasks.
Personalisation	Use profiles to store information about users	VPTs should have user profiles for storing relevant personal information about users (e.g. interests, capabilities and difficulties) and the users‘ interaction history (e.g. frequency of programming blocks’ usage, properties of programs created). User profiles should be automatically updated with each use of the tool.
	Personalise based on user profile and interaction history	VPTs should configure their user interface, apply the right restrictions, limitations, choose the right level of programming abstraction etc. based on users’ profiles. As the user’s profile evolves, the tool should also reconfigure itself to keep up with the changing needs of the user.
Managing Changes	Notify users before making any changes	Users should be made aware of any change or changes due to personalisation that will affect the way the VPT looks or functions before said changes are made. The notifications should be subtle and simple to comprehend.
	Implement changes in small and manageable steps	Changes should be made in small manageable steps that can be handled by users. Drastic changes with major impacts should not be implemented at once.
	Keep track of changes applied for a user	The VPT should keep a history of changes made to a user’s configuration. This should be available for a user to view visually as a form of journey tracker

6.3.1.1. Mobile Device Compatibility

The use of VPTs requires constant and continuous interaction with visual representations of programming logic (e.g. blocks and bricks), and objects that are being programmed (e.g. character and background images). These interactions, as pointed out by E6, may not be straightforward for all users with ASC, especially using a mouse as an input device.

> *They need to be learning the link between what they're doing... some of them play video games and they're very clear that what they do with their hands has an effect on what happens on the screen, but with other children, making that link, particularly if they're going to use a mouse can be difficult.* - E6

A potential solution to this problem is making VPTs compatible with and accessible on mobile touch screen devices such as smartphones and tablets. This could greatly reduce the distress caused by difficulties using less intuitive input techniques, especially for those children with ASC and fine motor skills difficulties. In addition, E4 points out that most young people including those with ASC own and use smartphones and tablets and are comfortable interacting with objects on a touch screen.

> *A lot of young people use iPads obviously, and they get used to controlling things with their finger. And that conceptual link between you touching it and it doing something is a much shorter jump isn't it, it's much easier to understand what's happening there. Whereas with the mouse when you have to do the double click on things, some of that will be difficult for some children. Even if you tell them they have to click twice, they leave it so long that it does not work as a double click.* - E4

The need for an accessible interaction method cannot be overstated because as explained by E5, interaction difficulties can cause a ripple effect leading to difficulties in other areas.

> *For example, if you have difficulty performing mouse operations then maybe you're also going to have difficulty structuring and sequencing, not because you fundamentally have difficulty structuring and sequencing but because you can't click the mouse in order to tell the computer what to do.* - E5

6.3.1.2. Engaging Users

Individuals with ASC are known to have restrictive interests; these interests may seem random, peculiar and sometimes strange. However, experts believed some core areas of interest are common among individuals with ASC, and integrating content related to these areas of interest within VPTs could potentially lead to higher engagement levels and motivate users to create programs around their areas of interest. E3 and E6 had this to say on the subject:

> *I mean there are some things that sort of generally floats their boats in terms of ASC. I'm sort of being very generalistic here. For example, Thomas the Tank Engine, you know, they like the repetition, they like that it's not unpredictable and it's a very closed world.* - E3

> *So, there are people who have weird and wonderful interests but there are some things that a lot of young people are interested in and it's a bit different for boys and girls. So, for younger children, we know Thomas the Tank Engine is you know. .. they actually love Thomas. For older boys, a lot of boys still like trains but not Thomas. With girls, they tend to love animals, you know. There are probably a number of core things that you could perhaps say: 'we know that a lot of boys like these things and a lot of girls like these things and maybe we'll focus on integrating those'.* - E6

In addition to providing content related to known core areas of interests of children with ASC, another suggestion made by E3 is to use content receiving high levels of interest from users within a VPT as potential choices (to build projects around) for other users that are not motivated.

> *If a child is motivated by one character, maybe you could take that and get rid of the others and use it as a choice for somebody that is less motivated.* - E3

6.3.1.3. Information Presentation and Visualisation

The use of visual icons and symbols instead of text, or to support text, was a key suggestion by experts. This is due to the reading and reading comprehension difficulties, and preference for visual means of communication associated with children with ASC. E6 expressed concern about having more text labels than visual labels in VPTs:

> *I mean there is the issue of having to be able to read for meaning, it's not just reading the words, it's reading and understanding what it is, you know. If I read that, what will I have to do? So, you have to have a certain level of reading comprehension, don't you? I know there are other online programs that are directed at young people with a certain level of intellectual ability and reading ability. So, if it's something that's supposed to be accessible to everyone perhaps there needs to be a bit less writing and more visual kind of representations.* - E6

E4 also shared similar concerns about users needing to read and comprehend textual labels to use a VPT. To illustrate the difficulty of the task, E4 compared it to reading a foreign language that one cannot speak:

> *Think of it as if you were a native Italian speaker looking at this (scratch interface in English) and didn't know any English how much of it could you understand?* - E4

Therefore, as E6 mentioned, just like other applications targeted at children with disabilities in general, VPTs for children with ASC should present information visually, with as many visual symbols and icons as possible to make it easy for users to understand without the need to read text or text labels. E1 also made the same recommendation as seen in the excerpt below:

> *You could have a version that minimized the need to read or eradicated the need to read by putting symbols on it. You can have a run icon; you can have a jump icon and lots of other things.* - E1

6.3.1.4. Managing Sounds

ASC is commonly associated with high sensory sensitivities, and affected children can be highly sensitive to sounds. Therefore, E4 expressed concern over the use of sounds in VPTs:

> *Is auditory feedback necessary? Because I don't think at the moment that's a good idea, it may well be that the auditory system could be overloaded for some people with ASC.* - E4

Since sounds may not cause distress for all children with ASC and could be useful in content creation and program execution, the recommendation proposed here is to make sounds optional for the use of VPTs and only played when turned on. Therefore, feedback should also be provided through other means e.g. visual feedback for those that are sensitive to sounds and therefore have sounds turned off.

6.3.1.5. Restrictions and Limitations

Experts unanimously believed that the numerous choices (e.g. sprites, backgrounds, sounds, blocks) and open-ended scenarios (e.g. blank projects) presented by VPTs can be overwhelming for children with ASC. This is true even in their everyday activities as explained by E3:

> *When you are working with autistic students and you ask them an open question they struggle with that. So for example, if I was to say 'how do you feel?' there are sort of many different answers you can give. But if I say 'do you feel happy or sad today?' it sort of closes it down.* - E3

According to E4, another negative effect of having this level of choice comes in the form of children with ASC performing repetitive tasks as a way of controlling their arousal levels.

> *There's a lot of theory around arousal levels and emotional disengagement in autism. A lot of the things observed [by the researcher] are attempts by the person to control their level of arousal. You are confronting somebody with a lot of information [within the VPT], and their return to doing repetitive tasks or something else is their attempt in saying 'I can do this, let's just carry on doing this'.* - E4

Therefore, experts suggested the use of restrictions or limitations (when and where appropriate) as a way of providing safe and manageable options for children with ASC. This could potentially lead to them being comfortable enough to try out new things without getting overwhelmed. E6 suggests how this approach can be applied to providing a manageable number of media elements (e.g. story characters) to use in projects within a VPT:

So, you wouldn't make 50 characters available, you maybe make five available, so they'd just pick from a really small number so that they're not getting overwhelmed by the sheer number and not knowing what to pick. If there's a small number, they can pick on what they like the look of and then quickly get into doing something with it. - E6

In addition to media elements such as characters, limitations or restrictions can also be applied to other aspects of VPTs such as tools, features, programming elements etc. However, E1 cautioned that there might be a downside to this as having too many restrictions may prevent engagement.

So, the educator in me thinks I wouldn't want the restrictions to be there all the time, because I would be wanting to support them to do something more, but I would also want to be having it open enough so that they can get engaged in the first place - E1

Therefore, a balance should be struck where restrictions exist to prevent users from getting overwhelmed and reacting negatively, but not too much to prevent users from engaging with the VPT.

6.3.1.6. Scaffolding

Experts believed that children with ASC may have difficulties with creativity and imagination, sequencing events, understanding and using programming elements (even if they are visual). They recommended the use of scaffolding to guide the users through the various stages of program creation, from media selection to program logic specification. As E6 explains below, individuals that require scaffolding to perform tasks that require sequencing and structuring (e.g. writing a story) without the use of a VPT will surely require scaffolding from the VPT if they are to use it to perform the same task independently.

Sequencing and structuring may well be things that those children have difficulty with when they're writing a story by hand in a book, you know, some children have that difficulty. So again, there might be a need for a bit more scaffolding for children who might have that difficulty. If you just sit them in front of a piece of software and ask them to create a story, that will be really difficult. - E6

Children with ASC also find it difficult to visualise imaginary things, settings or situations as pointed out by E3:

> *A lot of students struggle with imagination. [Creating content using VPTs] is equivalent to say role-play, unless you've actually got something in front of them, some props, then they will struggle just to make a story out the sky.* - E3

Scaffolds can also help children with ASC avoid this difficulty by showing them what a possible outcome can look like.

> *Having a sense of direction in the sense of reward, not reward but a clear idea of what an outcome might look like... I think sometimes young learners in general, but especially autistic groups, if you show them what the end goal is going to look like, they can better see the journey. And I think if you can provide scaffolding, thus enabling better structure and sequencing and things like that. I think that will better enable them to stay on track.* - E2

Another potential benefit of having a scaffold as seen in the extract above is keeping users on track to achieve their goal and preventing them from getting lost in unrelated tasks. Based on insights gathered from experts, we recommend the use of templates that can guide users through program creation, as well as programming specific scaffolds through the provision of highly abstracted programming blocks that represent scripts for performing popular actions.

6.3.1.7. Goal Orientation

Findings show that experts believe designing VPTs with specific goals in mind can make it easier to identify the aspects of VPTs that need to be eliminated, restricted, automated or greatly simplified to allow children with ASC to focus on achieving goals and obtaining feedback. For example, E6 had this to say about eliminating reading activities to get users to focus on programming:

> *You want them to try and do something quickly you know, so you don't want them to have to read things and be concentrating, it's not a reading exercise it's a programming exercise. So if they're trying to read and work out what they have to do, it slows things down to the extent that they lose interest, and then you have lost purpose... If the purpose of the activity is to learn*

programming using the program then it needs to be easily accessible so they can do it quickly because then they'll get feedback, "wow I can make that work" and then they will want to do something more complicated. - E6

This approach could be a way of reducing frustration, increasing motivation and goal achievement, and encouraging actual visual programming. This, in turn, can lead to continued use of the VPT. However, success needs to be achieved quickly for this to occur as E4 mentions below:

If you don't understand [visual programming], more exposure is going to help you with that. But then you're not going to get more exposure unless you get some degree of success. One thing we tried to do when we were designing stuff was trying to make sure that people could actually get something done, there will always be some degree of challenge but they always got some degree of success because if they don't, they just give up. - E4

6.3.1.8. Personalisation

Children with ASC face varying degrees of difficulties, and experts stressed the need to acknowledge this when designing VPTs: "*you need some differentiation built-in*" (E2). For example, when discussing the appropriate application of limitations and restrictions, E1 suggested making decisions based on the needs of each child: *"If I knew a child I would make different decisions according to the child."* (E1). E6 also made a similar recommendation:

You have to work at the pace of the child because for some children they might stick at only having five symbols (programming blocks) for quite a long time whereas another child might get it straight away and the next week they want to be writing a story. So you might have to make more available for them more quickly. - E6

Personalisation can also be applied in prioritising the child's interest when providing content to create programs with. E7 believed that this can help increase engagement:

I think if it's following their interest a bit more I think that's going to make it more interesting to them, isn't it? It's picking up on something they know about and want to learn about. I think that's another additional problem with probably all of them, is finding the things that float their boat, which is a *massive issue, which is why you know personalizing it is probably going to help with that difficulty.* - E7

For personalisation to be successful, a VPT would require a knowledge of the characteristics of the child using it, and make decisions based on the characteristics and needs of the child. Therefore, the recommendations proposed here are to have user profiles for storing user information and then to personalise based on the contents of the profile.

6.3.1.9. Managing Changes

Most of the recommendations discussed in the themes above propose some form of modification to the user interface or logic of VPTs to improve accessibility. Implementing these modifications will undoubtedly produce changes that will be noticeable by the user. Although children with ASC are known for their difficulties with dealing with changes, experts suggested informing them about modifications to VPTs before they occur as a way of reducing the difficulty:

> *A characteristic of people with autism is that change can be something that's really challenging but if they know it's going to come and the connotations of the change are good ones then they can find it easy to cope with it.* - E4

> *Some children will hate it if you change it from the way it was originally but actually in my experience you can, you can warn them, you can explain why, you can present it as a good thing. So, I wouldn't say that it would be wrong to do it, but I think it's how you present it.* - E1

It can be seen from the excerpts above that although children with ASC characteristically do not respond well to unexpected changes, they deal well with changes that they are made aware of and understand the benefit of. Therefore, making changes slowly and not drastically can make it easier for children with ASC to accept the changes as explained by E2:

> *If you can scaffold it and gently move things from one to two to three to four, you know, be clear about where they are in the journey, I think that the expectations can be managed well enough that it shouldn't represent a major problem.* - E2

The recommendations proposed for helping children with ASC handle changes made to VPTs as a result of personalisation are: to present notifications whenever a change is due to be made; to avoid making major changes at an instance; and to have a feature that keeps track of changes applied for each child and presents it visually when requested.

6.3.2. Validated Recommendations (Phase 2 Findings)

Findings from the second phase of this study are presented in the sections that follow. Excerpts from the interview transcripts are used to show experts' opinions about the initial recommendations in their own words. The changes made to the proposed recommendations as a result of the findings are presented in Table 6.5. Newly added information such as recommendations and their descriptions, and updated descriptions for initial recommendations are presented in *italics*. It should be noted that in the case of recommendations under "Personalisation", a previously derived recommendation had to be broken down into two recommendations. During the validation interviews, it was realised that extensive explanations had to be provided before experts understood the full extent of the recommendation. Therefore, it was broken down to make it easier to understand and implement. Additionally, the name of the recommendations theme was updated to reflect the addition of a new customisation recommendation.

6.3.3.1. Mobile Device Compatibility

There was a general agreement by experts on the need for VPTs to be available on mobile devices:

> *It would be fantastic if it could be very portable, for children who can engage on phones that would be great. I think as a minimum it should be on some kind of tablet.* - E1

> *If you can give them the opportunity to create something where they haven't got to be holding a pen or a mouse and they can create an animation or whatever it's going to be, I think that would be really important because we don't want to set up an alternative means of doing something that still has challenges for them. I think most children understand drag and drop because they do it all the time in games and things.* - E6

Table 6.5. Changes to themes, recommendations and descriptions as a result of validation.

Theme	Recommendation	Description
Engaging Users	Integrate content known to interest those with ASC	In addition to the initial description: *Where possible, make use of such media items on splash screens, lock screens etc. to capture the attention of users.*
	Suggest popular content to unmotivated users	In addition to the initial description: *This should only be applied for users that are not resistant to new information.*
Information Presentation and Visualisation	Represent information visually using icons/symbols	In addition to the initial description: *Existing symbol/icon sets should be used where possible, otherwise a new, easy to understand set of symbols/icons can be created and used.*
Goal Orientation	*Provided templates should scaffold towards projects appropriate for teaching relevant skills to children with ASC*	*Templates should be designed for projects that teach children with ASC relevant skills such as communication and collaboration*
Personalisation *and Customisation*	*Store personal user information and preferences.*	*VPTs should have user profiles for storing relevant personal information about users (e.g. interests, capabilities and difficulties). An automated user*

		modelling test can be used to collect user data for initialising the user's profile, otherwise, the data can be entered manually by a teacher
	Record users' interaction history for personalisation	*VPTs should record the users' use of the tool (e.g. frequency of programming blocks' usage, properties of programs created). This record should be automatically updated with each use of the tool*
	Support user customisation, i.e. manual selection of preferences	*The VPT should also allow manual setting of preferences as a way of overriding automatic personalisation. For example, a user should be able to choose font size and colour*
Restrictions and Limitations	Limit the features available to the user to those required to achieve the user's goal and are within the user's cognitive abilities	In addition to the initial description: *Restrictions should focus on features and not media content or programming elements, even if the user is fixated on them.*

6.3.3.2. Engaging Users

Experts welcomed the recommendation for integrating content that is known to interest children with ASC within VPTs. E6 also suggested making the most out of this type of content to capture the attention of users:

> *Make sure that some of their favourite things are on the first screen that they see, I think that would be really important. If it's sharks or rainbows or unicorns you know, whatever their thing is 'my favourite thing is going to be behind the screen, so I need to keep going'.* - E6

However, with regards to making popular content suggestions to unmotivated users, E4 warned that this might not be suitable for those that have highly restrictive interests:

> *It may well be that in their profile you get a question about their resistance to new information. I can imagine scenarios where if you're really into Thomas the Tank Engine and somebody keeps saying you should use my little pony, then it won't go down very well.* - E4

Considering these findings, the descriptions for the recommendations related to the integration of engaging content were modified.

6.3.3.3. Information Presentation and Visualisation

Although all experts agreed on the need for visualisation using icons/symbols, concerns over the choice of using new or existing symbols/icons sets were raised:

> *Regardless of what they've been used to, some children will be able very quickly to pick up a new [visual] language, a new set of icons, they'll just quickly figure it out. And others obviously might want it to be something more familiar.* - E1

E4 believed that using existing sets will be best since children with ASC will already be familiar with them, and if they are not, then they get the chance to learn a symbol set that will be useful to them in other contexts. This also avoids putting the children through the unnecessary task of learning to understand the visual language to be able to use the tool. However, the use of an existing symbol set might come with certain Intellectual Property and Rights restrictions, and different children might be experienced in the use of different sets, which may mean having

VPTs support multiple sets and record individual preferences within profiles. Therefore, E6 favoured the idea of having new sets created and used for VPTs, and argued that as long as the children are interested, they will be able to learn the new symbol set:

> *I found when we have introduced..., whether it's for communication devices or programming, you know when kids started getting into the Lego programming and model making things because they're engaged with it and they are enthused, they can quite quickly learn the rules and the symbols that go with it. So I think if you have a new set and they're excited to use it, they will be able to learn.* - E6

Considering these findings, we propose the use of existing visual/iconic languages where possible and only use new ones in cases where the use of existing ones is not possible due to financial, legal or other constraints.

6.3.3.4. Managing Sounds

The need for making all sounds optional for the use of VPTs and allowing the user to choose whether they want sounds was also agreed on by experts. Sounds "*could be really great for some, but upset others"* according to E4. E1 also voiced approval for the recommendation, saying: *"I agree with making sounds optional".*

6.3.3.5. Restrictions and Limitations

Experts all agreed on the need to put restrictions and limitations to ensure users are focused and not overwhelmed:

> *I think it's really important because when you give too many choices, it might look great, but they just don't know where to begin. It's linked to their executive function challenges, being able to differentiate between what's important and not important, and how to organize things.* - E6

However, when imposing restrictions to help users get out of repetitive cycles, E4 advised against imposing them on content used to create programs even if the user is fixated on that content:

I think if they are only fixated on some topics then you should exploit that and remember that you are trying to get them to move up the levels of coding. - E4

The corresponding recommendation was updated to reflect the additional information gathered.

6.3.3.6. Scaffolding

All experts agreed on the need for structure using templates and the provision of scaffolds, to ensure children with ASC with different needs and abilities can program using VPTs:

It's an opportunity to really engage in a different way with something they've never done and it might..., it should be highly motivating especially if it scaffolds at the right level. - E1

The use of templates is a good idea, particularly for the children having moderate or severe learning disabilities. - E6

6.3.3.7. Goal Orientation

This recommendation was also well received by experts. E6 mentions that this design approach can also serve as a way of giving caregivers ideas on how VPTs can be used by children with ASC, thus encouraging them to introduce the use of the tools at home or in class:

I mean people pick out particular programs and tools because they think it will help with a particular goal. So this would be another way of getting the caregivers interested in picking this software. - E6

E6's insight led to the addition of a new recommendation for ensuring VPTs support the achievement of goals that lead to learning skills useful to children with ASC.

6.3.3.8. Personalisation

Recommendations concerning personalisation were greatly supported by all experts. However, a concern was raised by both E6 and E1 regarding the time and precision required to accurately set up profiles:

The user profile presumably is something that a teacher or parent or someone else might be able to put in as opposed to the child themselves, right? So all of these things will take a certain amount of setting up. - E6

To tackle this issue and to improve the accuracy of the information within profiles, E1 suggested using a user modelling test for children with ASC to automatically generate their profiles. Additionally, E1 suggested the provision of a feature that allows teachers or the users themselves to make customise VPTs in addition to the automatic personalisation. This is useful especially in cases where the applied automatic personalisation is not producing the expected positive results.

6.3.3.9. Managing Changes

Experts all agreed that these recommendations are necessary for managing the frustrations that children with ASC face when dealing with changes. E1 had this to say on the recommendation to notify users before making changes:

In terms of managing children's frustration, if they're going to be locked out, I think it should warn them that they're going to be locked out. I just sort of feel like that's a kind of an ethical thing to do. And it's quite good teaching because it's giving them a chance to change. - E1

6.4. Discussion

The set of validated recommendations proposed in this chapter aim to guide the design and development of accessible VPTs for children with ASC. The first recommendation in the proposed set suggests making VPTs compatible with mobile touch screen devices. This recommendation aims to take advantage of the widespread ownership and use of such devices by the target group. Experts believe that the familiarity that most children have with this mode of interaction would ease ASC children’s understanding of the interactions required to make use of VPTs. This could also reduce the difficulties associated with clicking and dragging objects using a mouse and other less intuitive input devices faced by those with fine motor skills difficulties.

Although making VPTs accessible on mobile devices will make it easier for children with ASC to access and use them, access does not always imply usage. One way of getting the attention of children with ASC is by taking advantage of their interests (Boyd et al., 2007), and experts claimed that some interests are common amongst children with ASC. Therefore, the experts recommended integrating content related to the topics known to interest children with ASC within VPTs, and in clear sight of users, to encourage interaction and programming of projects.

VPTs are known for visually representing programming constructs and program execution. However, for these tools to be accessible for children with ASC, visualisation must be extended to the labelling of all user interface elements. Findings from this study show that experts were concerned about the accessibility of VPTs depending on the abilities of children with ASC to read and understand textual information. To address this, experts recommended the use of visual icons/symbols in place of text, or together with text to convey the purpose of user interface elements including visual programming elements (blocks or bricks).

Avoidance of default audio feedback and playback within VPTs was also recommended, as some individuals with ASC have auditory hypersensitivity. However, complete elimination of sounds from VPTs is not recommended since audio feedback might be useful and even entertaining to some children. The recommendation is to have all sounds off by default, make the VPT usable without sound, and only play sounds when a user explicitly declares that preference.

VPTs targeted at children offer collections of media objects, visual programming elements, and in some cases, additional tools/features for editing, creating, storing and sharing media, programming elements and projects. While this may be advantageous for encouraging creativity in neurotypical children, experts warned that children with ASC might find having numerous choices overwhelming. This can affect their ability to pick out programming elements as well as media objects to program. Therefore, limiting these choices to a set that is manageable and useful (given the user's goals) reduces the possibility of overwhelming the user and makes it easier for them to make choices. Although meaningful usage of VPTs requires a subset of VP elements and media objects, other tools/features available within the VPT may not be entirely necessary depending on the nature of the project being created. Those can be removed from the user interface to reduce its clutter and provide fewer options for the user to deal with.

Experts believed that users with ASC might require scaffolding their programming within VPTs. An important observation made by one expert (E6) is that users that require scaffolding to perform a task without the use of technology will not be able to perform that same task with the use of interactive technology unless the technology provides scaffolding. The use of templates within VPTs is recommended to provide guidance and structure to build projects around. To further scaffold the users' programming experience, the provision of higher abstract level programming elements is also recommended. For example, some users might be able to create a script that makes a character jump using visual programming elements for moving along the x and y-axis. However, not all users can accomplish this, in which case, the provision of a "jump" visual programming element that abstracts the movement along the x and y-axis will be more suitable

Designing VPTs to be goal-oriented instead of "sandbox" in nature is also recommended. This will allow users to quickly access and use features that are relevant to their goal, program an executable project, obtain feedback, and become more motivated. Without providing goal-oriented focus, VPTs may become platforms where children with ASC spend most of their time on secondary or low-level tasks.

Support for each individual user's unique characteristics, interests and goals should be offered within VPTs. The use of profiles is recommended for storing user information as a route to personalisation. The user profile should be a live data store created and updated either manually or automatically by logging relevant user interactions. The VPT should then make decisions based on the contents of the user profile on how other recommendations should be applied e.g. the restrictions to apply to programming elements. Recommendations also exist for allowing the user or a teacher to explicitly specify preferences for overriding those automatically set by the tool, in cases where the changes made by the tool do not suit the user.
Personalising to meet and subsequently keep up with changing needs, interests and capabilities of users will undoubtedly lead to changes that affect how the tool looks and functions. Individuals with ASC are characterised as being resistant to change, and by their preference for consistency and predictability. Therefore, experts suggested ensuring that users are made aware of any changes that are going to happen due to personalisation beforehand. Additionally, the provision of a feature that presents a visual history of personalised changes applied for a user is recommended. The complete set of validated recommendations for designing accessible VPTs for children with ASC is presented in Table 6.6

Table 6.6. Validated recommendations for designing accessible VPTs for children with ASC

Theme	Recommendation	Description
Mobile Device Compatibility	Make sure VPT is compatible with mobile devices	VPTs should be compatible with and accessible on mobile devices, especially smartphones and tablets in order to allow easier access and interactions for children with ASC including those with motor difficulties.
Engaging Users	Integrate content known to interest children with ASC	Provide users with a diverse set of media and templates covering as many topics known to interest children with ASC as possible. For example, provide templates and media related to various forms of transportation e.g. a space rocket launch project template, sprites and models of planets, astronauts etc. Where possible, make use of such media items on splash screens, lock screens etc. to capture the attention of users.
	Suggest popular content to unmotivated users	Content suggestions should be made to users (especially those barely interacting with the VPT) by suggesting content that is popular among other users with similar profiles. This should only be applied for users that are not resistant to new information.
Information Presentation and Visualisation	Present information visually using icons/symbols	Information within VPTs should be presented or supported with visual symbols/icons. For example, visual symbols or icons should be used to label objects or to support the objects' text labels throughout the user interface. This should include labels on buttons, tabs, panes, programming elements (blocks, bricks) etc. Existing symbol/icon sets should be used where possible, otherwise a new, easy to understand set of symbols/icons can be created and used.

Managing Sounds	Sound should be optional	The VPT should be usable with or without sounds. Sounds (including feedback sounds and program sounds) should not be audible unless explicitly turned on by the user, and volume control should be provided for users to adjust their sound level.
Restrictions and Limitations	Limit the choices of media elements available to users to a relevant and manageable set	Users should be provided with a manageable and relevant subset of media items (e.g. characters, backgrounds etc.) to work with, based on the goal of their project. For example, when creating a "space racing game", the choice of background images or landscapes options can be limited to only those related to outer space.
	Limit the choices of programming elements available to users to a usable, manageable and relevant set	Provide users with a usable, manageable and relevant subset of programming elements (blocks, bricks etc.) for their projects. For example, only a small subset of basic programming blocks should be available to a user with ASC that has SLD and ensuring that only blocks that reposition objects are available when the user is creating a script for moving an object.
	Limit the features available to the user to those required to achieve the user's goal and are within the user's cognitive abilities	VPTs usually have numerous tools and features for performing various tasks. Only those features that the user is capable of using and support the achievement of the user's goal should be available to the user. For example, a user that requires constant scaffolding should be restricted from using the 'create blank/empty project' feature. Features that become subjects of obsessive behaviour to the extent that they stand in the way of goal achievement should also be restricted to allow the user to move on to achieve their goal. Restrictions should focus on features and not media content or programming elements, even if the user is fixated on them.

Scaffolding	Provide templates for projects	VPTs should provide templates for creating a wide range of projects (e.g. games and animated stories). The templates should provide a visual structural scaffold for users by guiding them through the various stages of creating a project. For example, templates for a story should guide users to choose characters, backgrounds, and actions for each character. They should also allow users to view a potential version of their end product.
	Provide programming elements at higher levels of abstraction	VPTs should provide programming elements at different levels of abstractions for users with different abilities. For example, visual programming elements for 'move along x' and 'move along y' can exist at the low level. However, for those users that may be unable to create a script using these two programming elements to represent jumping, high-level programming elements 'jump forwards' and 'jump backwards' should be made available.
Goal Orientation	Design to ease, support and encourage success and goal achievement	Personalisation, restrictions, limitations, visualisations and scaffolding, should all be applied in a way that helps and encourages users to achieve their goal(s) without having to perform unnecessary/inaccessible actions or tasks.
	Provided templates should scaffold towards projects appropriate for teaching relevant skills to children with ASC	Templates should be designed for projects that teach children with ASC relevant skills such as communication and collaboration

Personalisation	Store personal user information and preferences.	VPTs should have user profiles for storing relevant personal information about users (e.g. interests, capabilities and difficulties). An automated user modelling test can be used to collect user data for initialising the user's profile, otherwise, the data can be entered manually by a teacher
	Record users' interaction history for personalisation	VPTs should record the users' use of the tool (e.g. frequency of programming blocks' usage, properties of programs created). This record should be automatically updated with each use of the tool
	Personalise based on user profile and interaction history	VPTs should configure their user interface, apply the right restrictions, limitations, choose the right level of programming abstraction etc. based on users' profiles. As a user's profile evolves, the tool should also reconfigure itself to keep up with the changing needs of that user
	Support user customisation, i.e. manual selection of preferences	The VPT should also allow manual setting of preferences as a way of overriding automatic personalisation. For example, a user should be able to choose font size and colour
Managing Changes	Notify users before making any changes	Users should be made aware of any change or changes due to personalisation that will affect the way the VPT looks or functions before said changes are made. The notifications should be subtle and simple to comprehend.
	Implement changes in small and manageable steps	Changes should be made in small manageable steps that can be handled by users. Drastic changes with major impacts should not be implemented at once.
	Keep track of changes applied for a user	The VPT should keep a history of changes made to a user's configuration. This should be available for a user to view visually as a form of journey tracker

6.5. Conclusion

This chapter presented the derivation and validation of recommendations for designing accessible VPTs for children with ASC. Seven experts were interviewed, and the data analysed using thematic analysis to derive a set of initial recommendations. Three out of the seven experts were then interviewed to validate the initially derived recommendations. This allowed for the confirmation of the derived recommendations, deriving new recommendations and improving existing ones.

The contribution to knowledge made by this chapter is a set of recommendations for designing accessible VPTs. However, a limitation of the method used in their derivation is that the interviews used to gather data were guided by discussions around behaviours of, and difficulties faced by children with ASC while using Scratch. This means that accessibility issues that are not associated with those behaviours or difficulties may not have been discussed in the interviews, hence recommendations for fixing them may not have been derived.

Chapter 7: Extending Recommendations for Designing Accessible VPTs for Children with ASC

7.1 Introduction

Chapter 6 presented the proposal of a validated set of recommendations for designing accessible VPTs for children with ASC using interviews conducted with seven experts including SEN teachers and researchers. However, a limitation of the method used in the derivation is that the interviews used to gather data were guided by discussions around behaviours of, and difficulties faced by children with ASC while using Scratch. This means that accessibility issues that are not associated with the discussed behaviours and difficulties, or not applicable to Scratch, may not have been discussed in the interviews, hence recommendations for addressing them may not have been proposed. Consequently, this chapter presents the further validation and extension of the proposed recommendations by comparing them with existing recommendations for designing a wide range of interactive applications (including serious games, virtual reality and mobile applications), for children with ASC found through a final examination of the literature. Where overlaps exist, the recommendations proposed by this research were validated, and where not (for instance recommendations that exist for the wider range of interactive applications but not found in the analysis of this research's interviews with experts) the proposed recommendations were extended. This led to the definition of an extended set of recommendations for designing accessible VPTs for children with ASC informed both by experts, and literature, that address both accessibility issues unique to VPTs and those common to all interactive applications.

The sections that follow present the method used to validate and extend the set of proposed recommendations, the findings of the validation and extension exercises, a discussion of the findings, and a conclusion.

7.2 Method

To identify peer-reviewed literature that contains recommendations for designing accessible interactive applications for children with ASC, Scopus (2019), a database of abstracts and citations of peer-reviewed literature was queried. Keywords used for the query include ASC, Autism, ASD, Software, Games, Applications, Virtual Reality, Visual Programming, Accessibility, Recommendations and Guidelines. The search results were restricted only to those that were published between 2010 and 2019 to avoid including outdated recommendations. Other filters used to restrict the search including only results published in the English language, and only of types: journal articles, conference papers or book chapters. Seven relevant research papers were identified from the results of this search. Google Scholar was also queried using the same keywords that were used to query Scopus to identify additional relevant literature. This led to the identification of three additional research papers.

All recommendations found in the identified research papers were first extracted, listed and read. Then those that fitted into the recommendation themes identified by this research were categorised under the appropriate recommendation themes. In this context, any recommendation that concerns the main concept of a recommendation theme was considered fit for that theme. For each theme, its recommendations were categorised into those that are similar to the recommendations gathered by this research, those that contradict the recommendations gathered by this research, and those that have not been proposed by this research. Validation of this research's proposed recommendations was then conducted by comparing proposed recommendations to the similar and contradicting groups of recommendations identified from the literature.

Finally, recommendations from the literature that do not fit into any of the recommendation themes created by this research, and those that have been categorised into themes but were not proposed by this research were analysed to identify new recommendations that are relevant for the design of accessible VPTs. This was done to determine which of the recommendations were fit to be included as part of the extended set of proposed recommendations for designing accessible VPTs for children with ASC. Relevance was decided by the researcher based on experiences gathered from evaluating the accessibility of Scratch for children with ASC; creating personae for the design of VPTs for children with ASC; proposing recommendations for designing accessible VPTs for children with ASC.

7.3 Findings

Although all the research papers selected from the literature proposed recommendations for designing interactive applications for children with ASC, none of the recommendations was specifically for designing accessible VPTs. However, recommendations were found for designing serious games (Tsikinas and Xinogalos, 2019), websites (Britto and Pizzolato, 2016; Raymaker et al., 2019), mobile applications (Dattolo and L. Luccio, 2017), virtual reality applications (Bozgeyikli et al., 2018; Herrera et al., 2018), tangible user interfaces (Sitdhisanguan et al., 2012), and other interactive applications (Davis et al., 2010; Khowaja and Salim, 2015; Pavlov, 2014).

The identified research papers used varying methodologies in gathering their recommendations including literature reviews (Bozgeyikli et al., 2018; Britto and Pizzolato, 2016; Dattolo and Luccio, 2017; Tsikinas and Xinogalos, 2019; Herrera et al., 2018), engaging stakeholders (Raymaker et al., 2019), extending existing guidelines (Khowaja and Salim, 2015), combinations of literature review and stakeholder engagement (Pavlov, 2014), and using research experiences (Davis et al., 2010; Sitdhisanguan et al., 2012).

The findings of the validation exercise conducted by comparing this research's proposed recommendations with the recommendations from the identified research papers that fit into this research's recommendation themes are presented in Section 7.3.1. And the set of recommendations found in the identified research papers that were deemed suitable for designing accessible VPTs but did not fit into any of this research's recommendation themes are categorised into new themes and presented in Section 7.3.2.

7.3.1 Comparing Similar Recommendations

Similar to the recommendation proposed by this research to ensure mobile device compatibility, Dattolo and Luccio (2017) proposed recommendations for designing websites and mobile applications for those with ASC and made strong arguments for the suitability of mobile apps for children with ASC. Britto and Pizzolato (2016) did not recommend support for mobile devices but they recommended having the appropriate sensitivity on touch screens to prevent selection and accidental touch errors.

As recommended by this research, Bozgeyikli et al. (2018) also recommend taking advantage of the special interests of children with ASC to provide engaging and motivating content in virtual reality applications. Similarly, Davis et al. (2010) recommended accommodating special interests of children with ASC when designing interactive applications, they also recommended avoiding content relating to any fears the user may have. Another way of engaging children with ASC that lose interest and do not perform any interactions for a while is to gain their attention using a relevant stimulus e.g. sound or visual cue (Sitdhisanguan et al., 2012).

Visual presentation of information was recommended by this research, and it was also found to be a popular recommendation in the literature. Britto and Pizzolato (2016); Dattolo and Luccio (2017); Pavlov (2014); Raymaker et al. (2019) all recommend having visual objects as an alternative means of presenting information. When using icons or symbols, Britto and Pizzolato (2016); Khowaja and Salim (2015); and Raymaker et al. (2019) recommend using those representing concrete actions that can easily be recognised by users. Wherever text is used, recommendations suggest the use of an accessible font type (Pavlov, 2014; Tsikinas and Xinogalos, 2019; Raymaker et al., 2019; Britto and Pizzolato, 2016), and using simple straightforward language with no jargon, acronyms etc. (Khowaja and Salim, 2015; Britto and Pizzolato, 2016; Raymaker et al., 2019; Dattolo and Luccio, 2017). This research recommended making sounds optional to avoid irritating children with ASC that are sensitive to sounds. Although Bozgeyikli et al. (2018) noted that some studies have found positive impacts of the use of sounds to improve user motivation in virtual reality applications, they too recommended making sounds optional. Dattolo and Luccio (2017); Davis et al. (2010); and Pavlov (2014) do not recommend making sounds optional but they do recommend avoiding loud and unnecessary sounds.

Applying restrictions and limitations on VPTs is part of the recommendations proposed by this research, to achieve among other things, improved goal achievement and reduced repetitive tendencies. Bozgeyikli et al. (2018) and Davis et al. (2010) both recommend taking over control at certain times by preventing the user from performing certain tasks or accessing certain features.

Scaffolding experiences by providing structuring templates and highly abstracted programming elements may be a useful recommendation for designing VPTs, but not necessarily for other applications such as games, virtual reality applications and websites. Thus, other scaffolding approaches were found in the literature including providing multimedia instructions for interacting with interface objects (Britto and Pizzolato, 2016; Pavlov, 2014), and providing relevant examples (Raymaker et al., 2019).

Integrating personalisation and customisation capabilities were recommended by this research and they are highly supported by the recommendations found in the literature. Aspects that are recommended by the literature for personalisation and customisation include text size, colour and font (Britto and Pizzolato, 2016; Khowaja and Salim, 2015; Pavlov, 2014), characters and environments (Bozgeyikli et al., 2018; Tsikinas and Xinogalos, 2019), and the number of elements within the interface (Britto and Pizzolato, 2016).

In ensuring that children with ASC are focused on their goals, recommendations have been made to avoid displaying distracting elements on-screen (Britto and Pizzolato, 2016; Dattolo and Luccio, 2017; Khowaja and Salim, 2015; Pavlov, 2014) and to provide access only to features that help in goal achievement (Britto and Pizzolato, 2016; Davis et al., 2010; Khowaja and Salim, 2015). Both recommendations are in line with the recommendation proposed by this research for ensuring design encourages and supports goal achievement.

Only Khowaja and Salim (2015) made a recommendation that addressed the need to handle user interface changes in a step by step approach since children with ASC do not cope well with drastic changes. Another similar recommendation, not restricted to interface changes, proposed keeping users informed about the status of the system and providing constant feedback to users (Britto and Pizzolato, 2016).

Table 7.1 presents the recommendations proposed by this research and identifies which of the recommendations have also been proposed by the research papers identified from the literature.

Table 7.1. Proposed recommendations and their occurrence in the literature

Themes	Recommendations	Application Types and Recommendations									
		General			Web		Mobile Apps	Serious Games	Virtual Reality		Tangible User Interface
		Pavlov (2014)	Khowaja and Salim (2015)	Davis et al. (2010)	Britto and Pizzolato (2016)	Raymaker et al. (2019)	Dattolo and Luccio (2017)	Tsikinas and Xinogalos (2019)	Bozgeyikli et al. (2018)	Herrera et al. (2018)	Sitdhisanguan et al. (2012)
Mobile Device Compatibility	Make sure VPT is compatible with mobile devices						**x**				
Engaging Users	Integrate content known to interest children with ASC			**x**					**x**		
	Suggest popular content to unmotivated users										
Restrictions and Limitations	Limit the choices of media elements available to users to a relevant and manageable set										
	Limit the choices of programming elements available to users to a usable, manageable and relevant set										
	Limit the features available to the user to those required to achieve the user's goal and are within the user's cognitive abilities			**x**					**x**		

Themes	Recommendations	Application Types and Recommendations									
		General			Web		Mobile Apps	Serious Games	Virtual Reality		Tangible User Interface
		Pavlov (2014)	Khowaja and Salim (2015)	Davis et al. (2010)	Britto and Pizzolato (2016)	Raymaker et al. (2019)	Dattolo and Luccio (2017)	Tsikinas and Xinogalos (2019)	Bozgeyikli et al. (2018)	Herrera et al. (2018)	Sitdhisanguan et al. (2012)
Information Presentation and Visualisation	Present information visually using icons/symbols	**x**	**x**		**x**	**x**	**x**				
Managing Sounds	Sounds should be optional								**x**		
Scaffolding	Provide templates for projects										
	Provide programming elements at higher levels of abstraction										
Goal Orientation	Design to ease, support and encourage success and goal achievement	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
	Provided templates should scaffold towards projects appropriate for teaching relevant skills to children with ASC										

Themes	Recommendations	Application Types and Recommendations									
		General			Web		Mobile Apps	Serious Games	Virtual Reality		Tangible User Interface
		Pavlov (2014)	Khowaja and Salim (2015)	Davis et al. (2010)	Britto and Pizzolato (2016)	Raymaker et al. (2019)	Dattolo and Luccio (2017)	Tsikinas and Xinogalos (2019)	Bozgeyikli et al. (2018)	Herrera et al. (2018)	Sitdhisanguan et al. (2012)
Personalisation and Customisation	Store personal user information and preferences		**x**				**x**	**x**		**x**	
	Record users' interaction history for personalisation		**x**	**x**							
	Support user customisation, i.e. manual selection of preferences	**x**	**x**	**x**	**x**	**x**				**x**	
	Personalise based on user profile and interaction history		**x**				**x**	**x**		**x**	
Managing Changes	Notify users before making any changes				**x**						
	Implement changes in small and manageable steps		**x**								
	Keep track of changes applied for a user										

7.3.2 New Relevant Recommendations

Analysis of recommendations for designing various types of interactive applications for those with ASC from the identified research papers also resulted in the identification of recommendations overlooked by this research that could be useful in the design of accessible VPTs for children with ASC. Some of these recommendations fit into the recommendation themes created by this research, and they have been discussed in Section 7.3.1. However, others do not fit into any of the recommendation themes, thus were grouped into new themes, and discussed in the sub-sections below. Table 7.2 presents the new recommendations discussed in Section 7.3.1, those discussed in the sub-sections to follow, and identifies their sources in the literature.

7.3.2.1 User Interface and Navigation

The user interface should be designed with simple, predictable structures and no distracting secondary content (Pavlov, 2014; Khowaja and Salim, 2015; Davis et al., 2010; Raymaker et al., 2019; Dattolo and Luccio, 2017; Tsikinas and Xinogalos, 2019; Bozgeyikli et al., 2018). Mild colours should be used, and bright colours should be avoided (Pavlov, 2014; Bozgeyikli et al., 2018). There should also be a clear differentiation between background and foreground elements (Pavlov, 2014; Britto and Pizzolato, 2016; Bozgeyikli et al., 2018; Sitdhisanguan et al., 2012).

Icons and buttons should look clickable and be big enough to be clickable (Pavlov, 2014; Britto and Pizzolato, 2016). User interfaces should also include consistent navigation with no automatic redirects or time limit before a page should be exited (Pavlov, 2014; Britto and Pizzolato, 2016; Raymaker et al., 2019; Dattolo and Luccio, 2017).

7.3.2.2 System Status

Visual indicators should be used to inform users about the duration or waiting period associated with any time-consuming actions (Pavlov, 2014).

7.3.2.3 Control

Actions should be easily cancelled, reverted, undone or confirmed to resolve errors quickly and to encourage exploration without the fear of consequences (Khowaja and Salim, 2015; Britto and Pizzolato, 2016).

7.3.2.4 Low Latency

All actions should be handled quickly, and feedback for the actions should be provided. Latency should be avoided as it can easily frustrate children with ASC (Khowaja and Salim, 2015).

7.3.2.5 Accessible Documentation

Documentation designed with children with ASC in mind should be easily retrievable and accessible at any time to provide relevant multimedia help aimed at helping them complete their current task (Khowaja and Salim, 2015).

Table 7.2. New recommendations and their sources in the literature

Themes	Recommendations	Application Types and Recommendations									
		General			Web		Mobile Apps	Serious Games	Virtual Reality		Tangible User Interface
		Pavlov (2014)	Khowaja and Salim (2015)	Davis et al. (2010)	Britto and Pizzolato (2016)	Raymaker et al. (2019)	Dattolo and Luccio (2017)	Tsikinas and Xinogalos (2019)	Bozgeyikli et al. (2018)	Herrera et al. (2018)	Sitdhisanguan et al. (2012)
Mobile Device Compatibility	Touch screen interactions should have the appropriate sensibility and prevent errors in selections and accidental touch in interface elements				x						
Engaging Users	Stimulate users after a period of inactivity										X
Information Presentation and Visualisation	Use a clear accessible font for text	x			x	x		x			
	Language used should be simple, consistent, precise, with no jargon and with concepts and phrases familiar to users		X		x	x	X				
Managing Sounds	Avoid disturbing and explosive sounds or any other unnecessary sounds			x	x		X		x		X

Themes	Recommendations	Application Types and Recommendations									
		General			Web		Mobile Apps	Serious Games	Virtual Reality		Tangible User Interface
		Pavlov (2014)	Khowaja and Salim (2015)	Davis et al. (2010)	Britto and Pizzolato (2016)	Raymaker et al. (2019)	Dattolo and Luccio (2017)	Tsikinas and Xinogalos (2019)	Bozgeyikli et al. (2018)	Herrera et al. (2018)	Sitdhisanguan et al. (2012)
User Interface and Navigation	The user is who should control navigation and time to perform a task				x						
	Always differentiate between background colour and foreground objects	x			x				x		x
	Use mild colours and avoid bright colours	x							x		
	The design and structure should be simple, clear and predictable with no secondary content that could distract the users.	x	x	x		x	X	x	x		
	Navigation should be consistent and similar throughout.	x			x	x	X				
	Clickable icons, buttons and form controls should be big enough to provide appropriate click/tap areas and they should be designed to appear clickable.	x			x						

Themes	Recommendations	Application Types and Recommendations									
		General			Web		Mobile Apps	Serious Games	Virtual Reality		Tangible User Interface
		Pavlov (2014)	Khowaja and Salim (2015)	Davis et al. (2010)	Britto and Pizzolato (2016)	Raymaker et al. (2019)	Dattolo and Luccio (2017)	Tsikinas and Xinogalos (2019)	Bozgeyikli et al. (2018)	Herrera et al. (2018)	Sitdhisanguan et al. (2012)
Scaffolding	Provide concrete examples where applicable, to accommodate difficulties in understanding concepts					**x**					
	Present appropriate instructions to interact with interface elements	**x**			**x**						
System Status	Visual indicators should be used to inform users about time-consuming actions	**x**									
Control	Allow critical actions to be reverted, cancelled, undone or confirmed		**x**		**x**						
Low Latency	Avoid the frustration of users by avoiding latency of supported actions		**x**								
Accessible Documentation	Documentation, help or instructions should be visible or easily retrievable whenever appropriate, focus on the user's task, provide a multimedia demonstration of tasks, and not be too large.		**x**								

7.4 Discussion

To address the limitations associated with the recommendations proposed in Chapter 6, this chapter presented a final examination of the literature for research to validate and extend the proposed recommendations. The validation exercise ensured that the proposed recommendations are in line with recommendations for designing other interactive applications for children with ASC proposed elsewhere in the literature. The extension exercise ensured that all existing recommendations for designing accessible interactive applications for children with ASC that are relevant for designing VPTs and not included in the proposed recommendations are included in the extended set of proposed recommendations.

The recommendations found in the literature supported all the identified recommendation themes, but not all recommendations within the themes. However, 5 out of the 7 recommendations that are not supported by the literature are specific to VPTs e.g. the recommendation that project templates should be provided. Of the gathered and validated recommendations that are supported by the literature, 4 are supported by only 1 set of recommendations from the literature, 3 are supported by 2 sets of recommendations from the literature, 2 are supported by 4 sets of recommendations from the literature, 1 is supported by 5 sets recommendations from the literature, 1 is supported by 6 sets recommendations from the literature, and a final 1 supported by all 10 sets recommendations found in the literature. It should be noted that being supported by a higher number of sets of recommendations does not indicate a greater degree of confidence in a derived recommendation. It only indicates that the recommendation applies to a higher number of domains.

It should also be noted that some recommendations found in the literature appeared to contradict the ones proposed by this research. This is because the recommendations are specifically suitable for the type of interactive application they are being recommended for, and not for VPTs. An example is the recommendation by Tsikinas and Xinogalos (2019) to support the repetition of tasks within serious games so that children with ASC can enjoy this repetition and also master the task. While this makes sense in the context of serious games, which are used to master a particular skill, it does not fit VPTs well since they are used to encourage learning through exploration and creation of interactive media products.

Therefore, intentionally supporting repetition will defeat the purpose of using VPTs within this learning context. A more suitable recommendation is the one proposed by this research, which suggests restricting the features available to children with ASC and allowing them to explore and create within a more structured environment but still with some degree of freedom depending on their needs.

There were also recommendations from the literature that were suitable for designing accessible VPTs for children with ASC but were not covered by this research's initial recommendations. Each of these additional recommendations was added either into an appropriate existing theme or into a newly created theme if an appropriate one does not exist. Seven new recommendations were added to existing themes, and 9 new recommendations were added into 5 new themes.

The complete extended set of proposed recommendations are provided in Table 7.3 (the recommendations informed by the literature are presented in italics).

Table 7.3. Extended set of recommendations for designing accessible VPTs for children with ASC

Theme	**Recommendation**	**Description**
Mobile Device Compatibility	Make sure VPT is compatible with mobile devices	VPTs should be compatible with and accessible on mobile devices, especially smartphones and tablets in order to allow easier access and interactions for children with ASC including those with motor difficulties.
	Touch screen interactions should have the appropriate sensibility and prevent errors in selections and accidental touch in interface elements	*VPTs should be designed to support use by children with fine motor skill difficulties by having appropriate sensibility and preventing errors associated with the condition.*
Engaging Users	Integrate content known to interest children with ASC	Provide users with a diverse set of media and templates covering as many topics known to interest children with ASC as possible. For example, provide templates and media related to various forms of transportation e.g. a space rocket launch project template, sprites and models of planets, astronauts etc. Where possible, make use of such media items on splash screens, lock screens etc. to capture the attention of users.
	Suggest popular content to unmotivated users	Content suggestions should be made to users (especially those barely interacting with the VPT) by suggesting content that is popular among other users with similar profiles. This should only be applied for users that are not resistant to new information.

	Stimulate users after a period of inactivity	*VPTs should be able to attract the attention of users that lose interest and do not perform any interactions for a while using a relevant stimulus e.g. sound or visual cue, this may vary depending on the preference and interest of the child.*
Information Presentation and Visualisation	Present information visually using icons/symbols	Information within VPTs should be presented or supported with visual symbols/icons. For example, visual symbols or icons should be used to label objects or to support the objects' text labels throughout the user interface. This should include labels on buttons, tabs, panes, programming elements (blocks, bricks) etc. Existing symbol/icon sets should be used where possible, otherwise a new, easy to understand set of symbols/icons can be created and used.
	Use a clear accessible font for text	*VPTs should support the use of fonts that are accessible and easy to read by those with ASC e.g. Arial.*
	Language used should be simple, consistent, precise, with no jargon and with concepts and phrases familiar to users	*VPTs should support language that is easily understandable by children with ASC, and avoid using technical jargon, abbreviations etc.*
Managing Sounds	Sound should be optional	The VPT should be usable with or without sounds. Sounds (including feedback sounds and program sounds) should not be audible unless explicitly turned on by the user, and volume control should be provided for users to adjust their sound level.

	Avoid disturbing and explosive sounds or any other unnecessary sounds	*Any loud or disturbing sound should be avoided, especially as feedback sounds. Explosions, sirens etc., should only be played when chosen by the user.*
Restrictions and Limitations	Limit the choices of media elements available to users to a relevant and manageable set	Users should be provided with a manageable and relevant subset of media items (e.g. characters, backgrounds etc.) to work with, based on the goal of their project. For example, when creating a "space racing game", the choice of background images or landscapes options can be limited to only those related to outer space.
	Limit the choices of programming elements available to users to a usable, manageable and relevant set	Provide users with a usable, manageable and relevant subset of programming elements (blocks, bricks etc.) for their projects. For example, only a small subset of basic programming blocks should be available to a user with ASC that has SLD and ensuring that only blocks that reposition objects are available when the user is creating a script for moving an object.
	Limit the features available to the user to those required to achieve the user's goal and are within the user's cognitive abilities	VPTs usually have numerous tools and features for performing various tasks. Only those features that the user is capable of using and support the achievement of the user's goal should be available to the user. For example, a user that requires constant scaffolding should be restricted from using the 'create blank/empty project' feature. Features that become subjects of obsessive behaviour to the extent that they stand in the way of goal achievement should also be restricted to allow the user to move on to achieve their goal. Restrictions should focus on features and not media content or programming elements, even if the user is fixated on them.

Scaffolding	Provide templates for projects	VPTs should provide templates for creating a wide range of projects (e.g. games and animated stories). The templates should provide a visual structural scaffold for users by guiding them through the various stages of creating a project. For example, templates for a story should guide users to choose characters, backgrounds, and actions for each character. They should also allow users to view a potential version of their end product.
	Provide programming elements at higher levels of abstraction	VPTs should provide programming elements at different levels of abstractions for users with different abilities. For example, visual programming elements for ’move along x’ and ’move along y’ can exist at the low level. However, for those users that may be unable to create a script using these two programming elements to represent jumping, high-level programming elements ‘jump forwards‘ and ‘jump backwards‘ should be made available.
	Provide concrete examples where applicable, to help in understanding concepts	*Provide a library of examples of projects, and how concepts are used, for users to learn from.*
	Present appropriate instructions to interact with interface elements	*Instructions should be available to guide users on how to use the various interface elements available in VPTs, and ideally, this should also be visual and accessible for children with ASC.*

Goal Orientation	Design to ease, support and encourage success and goal achievement	Personalisation, restrictions, limitations, visualisations and scaffolding, should all be applied in a way that helps and encourages users to achieve their goal(s) without having to perform unnecessary/inaccessible actions or tasks.
	Provided templates should scaffold towards projects appropriate for teaching relevant skills to children with ASC	Templates should be designed for projects that teach children with ASC relevant skills such as communication and collaboration
Personalisation	Store personal user information and preferences.	VPTs should have user profiles for storing relevant personal information about users (e.g. interests, capabilities and difficulties). An automated user modelling test can be used to collect user data for initialising the user's profile, otherwise, the data can be entered manually by a teacher
	Record users' interaction history for personalisation	VPTs should record the users' use of the tool (e.g. frequency of programming blocks' usage, properties of programs created). This record should be automatically updated with each use of the tool
	Personalise based on user profile and interaction history	VPTs should configure their user interface, apply the right restrictions, limitations, choose the right level of programming abstraction etc. based on users' profiles. As a user's profile evolves, the tool should also reconfigure itself to keep up with the changing needs of that user

	Support user customisation, i.e. manual selection of preferences	The VPT should also allow manual setting of preferences as a way of overriding automatic personalisation. For example, a user should be able to choose font size and colour
Managing Changes	Notify users before making any changes	Users should be made aware of any change or changes due to personalisation that will affect the way the VPT looks or functions before said changes are made. The notifications should be subtle and simple to comprehend.
	Implement changes in small and manageable steps	Changes should be made in small manageable steps that can be handled by users. Drastic changes with major impacts should not be implemented at once.
	Keep track of changes applied for a user	The VPT should keep a history of changes made to a user's configuration. This should be available for a user to view visually as a form of journey tracker
User Interface and Navigation	*The user should be able to control navigation and time to perform a task*	*VPTs should avoid automatic redirects and allow users to have total control over navigation. No time limit should be used to determine how long a user stays in a section of a VPT.*
	Always differentiate between background colour and foreground objects	*Contrasting colours should be used to differentiate between the background and objects in the foreground. For example, colours of programming elements should be used to differentiate them from their background.*
	Use mild colours and avoid bright colours	*Bright colours should be avoided to ensure that the sensitivities experienced by children with ASC connected to bright colours are not triggered.*

	The design and structure should be simple, clear and predictable	*The overall design of VPTs should be easy to learn to use, navigate and should not contain any surprises. It should be predictable and consistent in all aspects.*
	Clickable icons, buttons and other interactive elements should be big enough to provide an appropriate click/tap area	*Clickable icons, buttons etc. in VPTS should be designed to appear clickable to the users, and they should be big enough to be easily clicked or tapped by users even those with fine motor skills difficulties.*
Low Latency	*Avoid the frustration of users by avoiding latency of supported actions*	*Children with ASC can be easily distracted or frustrated during periods of inactivity, or while waiting for actions to be complete. Therefore, VPTs designed for them should be quick in executing actions and providing feedback.*
System Status	*Visual indicators should be used to inform users about time-consuming actions*	*VPTs may perform actions that take some time to be completed e.g. compiling a program before executing or downloading graphic assets. Whenever these actions are performed, visual indicators should be used to inform the user about their corresponding status.*
Control	*Allow critical actions to be reverted, cancelled, undone or confirmed*	*To avoid frustrations and to encourage exploration and creativity, VPTs should allow children with ASC to easily cancel, revert or undo their actions.*
Accessible Documentation	*Documentation, help or instructions should be visible*	*VPTs' documentation should be visible to users or should be easily retrievable when needed, should focus on the user's task, and provide a multimedia demonstration of tasks.*

7.5 Conclusion

This chapter presented the validation and extension of the proposed recommendations for designing VPTs for children with ASC presented in Chapter 6. This was done through the examination of the literature to identify recommendations for designing accessible interactive applications for children with ASC, comparing the identified recommendations with the proposed recommendations for similarities and contradictions, and identifying final additional recommendations suitable for designing VPTs that were not proposed initially by this research. The result of these exercises is an extended set of recommendations for designing accessible VPTs for children with ASC.

The limitation associated with this extended set of recommendations is that newly added recommendations have not (as yet) been validated by experts. However, the researcher's experience and knowledge gathered from conducting studies on evaluating the accessibility of a VPT for children with ASC; creating personae for the design of VPTs for children with ASC; and proposing recommendations for designing accessible VPTs for children with ASC, were used to judge their suitability to be part of the proposed recommendations.

Chapter 8: Conclusions

8.1. Introduction

The research presented in this thesis contributes to knowledge on the accessibility of Visual Programming Tools (VPTs) by answering three main research questions. The questions, the research studies that allowed them to be answered, and the contributions to knowledge made, as a result, are all presented in the section that follows. Limitations, future studies and closing remarks are then presented.

8.2. Research Questions and Contributions

A brief summary of the method, findings and contributions associated with each of the three research questions answered in this thesis is provided in sections 8.2.1 – 8.2.3. Finally, section 8.2.4 provides a visual summary of the research processes and contributions to knowledge that make up this thesis.

8.2.1 RQ1 - How accessible are existing VPTs for children with learning disabilities?

This question was answered in two phases. In the first phase, a formative evaluation of accessibility was conducted on the most popular VPT for children, Scratch, with children with learning disabilities. Due to the challenges faced by children with learning disabilities in communication, especially those that also have ASC (APA, 2013), special needs teachers were interviewed as part of this evaluation to provide information that could not be gathered by user evaluations with the children alone (Lazar et al, 2017). Grounded theory research methodology (Corbin and Strauss, 2015; Devkar et al., 2015; Gasson and Waters, 2013) was used as the methodological framework for this evaluation.

Findings from this study, in the form of a theoretical model, provide an overall insight into the use of Scratch by children with learning disabilities within a classroom setting to achieve a goal e.g. create animated stories. The theoretical model identified difficulties faced by children with learning disabilities while using Scratch, the features of Scratch that cause these difficulties, the strategies employed by the children when facing difficulties, and how they are assisted to navigate the difficulties. By identifying difficulties faced by children with learning disabilities while using Scratch, this evaluation answered, although partially, the question of whether existing VPTs are accessible for children with learning disabilities by showing that Scratch, the most popular VPT, is not fully accessible to the target group. It also provided data in the form of the identified 'causes of difficulties' that can be used to derive heuristics for the evaluation of other VPTs to completely answer the research question.

The second phase of answering this research question started by deriving a set of heuristics from the 'causes of difficulties' identified in the first phase. A heuristic evaluation (Petrie and Bevan, 2009) of accessibility was then conducted on three additional VPTs. The evaluated VPTs were selected based on several factors including their popularity, their use in research for children, and having features with potential accessibility benefits to children with learning disabilities. The findings from this evaluation showed that all three VPTs are not fully accessible for children with learning disabilities. Although each satisfied at least one of the heuristics, none addressed all. Thus, all three VPTs have one or more design features in common with Scratch that caused difficulties for children with learning disabilities.

Contribution to knowledge: the findings of this research contribute to knowledge on the accessibility of VPTs by showing that popular existing VPTs have design features that have been found to cause difficulties for children with learning disabilities. Although some of these VPTs might have more of the 'difficulty causing' features than others, none is fully accessible for children with learning disabilities. In the process of answering this research question, another contribution to the knowledge was made in the form of a grounded theory based method for conducting accessibility evaluations of VPTs for children with learning disabilities that involve the children themselves as participants. This is an important contribution as children with learning disabilities are reported to be underrepresented in research (Grynszpan et al., 2014; Standen et al., 2014). This method provides a way to efficiently include them in technological evaluations. Part of these findings were presented at a conference and published as part of the conference proceedings (Zubair et al., 2018).

Another contribution to knowledge from the findings presented above is a set of heuristics for assessing the accessibility of VPTs for children with learning disabilities. Although target user inclusion in HCI research is of great importance, the difficulty in securing the participation of children with learning disabilities needs to be acknowledged. Therefore, in cases where user participation is not always possible (e.g., small population size, illness, competing demands on time), this set of heuristics can be used in assessing the accessibility of VPTs.

8.2.2 RQ2 - How can the requirements and goals of children with ASC associated with the use of VPTs be gathered and represented using personae?

The literature review identified personae as tools that can be used as part of the UCD approach to describe users, their requirements and their goals. The literature review also identified the successful uses of personae for children with ASC when used as design targets by designers. However, the literature review did not yield methods for designing personae specifically for children with ASC. Therefore, this question was answered by proposing a method for creating personae for children with ASC based on Coopers et al.'s (2007) method. The proposed method was used to create a set of three personae for children with ASC for designing accessible VPTs for the target group. Additionally, the lessons learnt from the application of the proposed method were used to improve the personae creation method.

Contribution to knowledge: in answering this question, a method for gathering and representing the requirements and goals of children with ASC was created. A set of 3 personae that describe the needs and goals of children with ASC of varying severity was also created. These personae can be used as part of a UCD approach to both inform the design of accessible VPTs (McCrickard et al., 2015; Vieira et al., 2017) and to evaluate the accessibility of VPTs (Friess, 2015; Kneale et al., 2017).

The persona creation method was published as a peer-reviewed article (Zubair et al., 2019).

8.2.3 RQ3 - What design recommendations should be followed in designing a VPT that meets the requirements of children with ASC?

This question was answered by the proposal of a set of recommendations for designing accessible VPTs for children with ASC. These recommendations are a result of a two-phased process of experts' consultation.

In the first phase, experts were interviewed to gather recommendations for designing accessible VPTs. The data collected from this phase was used to derive a set of initial recommendations. In the second phase, the derived recommendations were validated through another round of expert interviews. This led to the improvement of some initial recommendations and the addition of new recommendations.

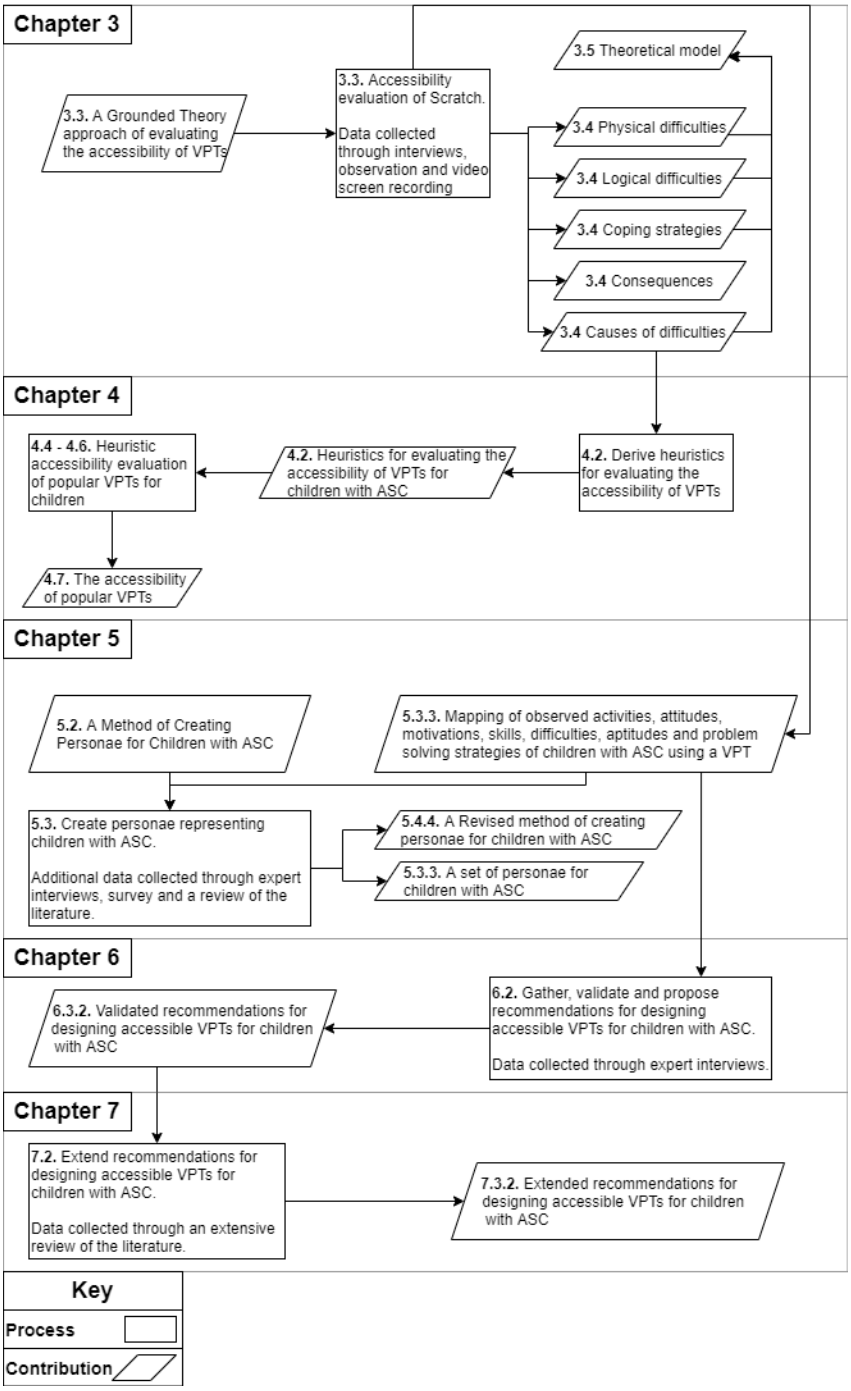
However, the interviews used to gather data to derive the initial recommendations were guided by discussions around behaviours of, and difficulties faced by children with ASC while using Scratch. This means that accessibility issues that are not associated with the discussed behaviours and difficulties, or not applicable to Scratch, may not have been discussed in the interviews, hence recommendations for addressing them may not have been proposed. Therefore, a concluding validation of the recommendations was conducted through a final examination of the literature to identify recommendations for designing a larger set of interactive applications for children with ASC. This process further validated the initial set of recommendations and also extended the set to include recommendations influenced by the design of other interactive applications that were considered useful and not identified in the interviews.

Contribution to knowledge: the contribution to the knowledge made in answering this question is an extensive set of recommendations for designing accessible VPTs for children with ASC. In addition to designing accessible VPTs, these recommendations can also be used in evaluating accessibility (Petrie and Bevan, 2009). An article that presents these findings is currently being reviewed for publication by the International Journal of Human-Computer Studies (IJHCS) (Zubair et al., 2019).

8.2.4 Visual Summary of Conducted Research

Figure 8.1 provides a chapter by chapter (starting from chapter 3) breakdown of the research procedures conducted as part of this research, their inputs, and resulting contributions. The figure is divided into five sections, each representing a chapter of this thesis. Within each chapter's section are the research processes (represented as rectangles) reported within the chapter and the resulting contributions to knowledge (represented as parallelograms). Contributions can also serve as input to research processes. Processes and contributions are labelled with descriptions as well as the section in which they are presented in the thesis. Thus, the figure provides a clear and complete picture of the contributions to knowledge that make up this thesis and how they were achieved.

Figure 8. 1. A visual summary of the research processes and contributions to knowledge that make up this thesis



8.3. Limitations

This section presents the limitations associated with the individual studies conducted as part of this research.

8.3.1 Evaluating the accessibility of Scratch for children with learning disabilities – Low number of participating children with learning disabilities

The low number of participating children that took part in the user evaluation of Scratch is a potential criticism of this research. The study's sample size is not large or diverse enough to be considered representative of the population of children with learning disabilities. As a result, the findings of the research can be considered as not generalizable, or as simple case studies. The difficulty in getting access to special schools to work with those with disabilities, especially children, contributed to the small sample size of participants. These access difficulties and the lack of time (due to competing demands experienced by students) to conduct user-based evaluations for all other VPTs represented the rationale for conducting heuristic evaluations to assess the accessibility of other VPTs.

However, due to the difficulties associated with recruiting and working with participants within this group, other researchers have stated that it is acceptable to work with 5 – 10 participants (Lazar et al, 2017). Additionally, the evaluation was a formative one, which can be conducted with between five to eight users (Petrie and Bevan, 2009). Therefore, although the findings of the study cannot be generalised across all children with learning disabilities, the study has shown that accessibility issues exist for some and therefore Scratch is not completely accessible to all children with learning disabilities.

8.3.2 Evaluating the accessibility of Scratch for children with learning disabilities – Absence of a control group

It could be argued that the use of a control group made up of atypical users in this research's accessibility evaluation of Scratch could have been used to differentiate between general usability issues and accessibility issues associated with this research's target group. While that would have been a valid additional contribution to knowledge, the primary aim of the study was to identify whether Scratch was accessible to the target group or not.

8.3.3 Evaluating the accessibility of Scratch for children with learning disabilities – Absence of programming lessons

Another limitation is that the participating children were not taught programming before or during the user-based evaluation, and it could be argued that this also caused difficulties. While this could be true, programming was not taught because Scratch, and most VPTs, are designed to provide an easy platform for learning programming through exploration (Maloney et al., 2010, 2008). Thus, if children with learning disabilities find it difficult to learn while exploring, this implies a lack of accessibility to this group of users.

8.3.4 Evaluating the accessibility of Scratch for children with learning disabilities – Creation of only animated stories

A final limitation associated with user evaluation of Scratch is that only one type of content (animated stories) was created by participants during the evaluation. Therefore, it can be argued that the difficulties found may be specific to the content type.

The choice of creating stories as part of the evaluation was made due to the recommendation made by participating teachers. They argued that stories could address areas where the participating children needed to improve and that the participants have already shown interest in creating stories using other mediums.

Due to the unavailability of additional participants, there was no other opportunity to conduct the accessibility evaluation with participants creating content other than stories.

Further insights could have been derived from the data collected by this study through analysing the stories created by users, however, this was not part of the research scope.

8.3.5 Heuristic accessibility evaluation of VPTs – Selection of evaluated VPTs

Another limitation is the set of VPTs chosen for evaluation by this research. Although the findings of this research would have been more generalised if all VPTs were evaluated, there was simply not enough time to perform these evaluations. Therefore, the popularity of VPTs, their reported use in research, and their features with accessibility potential for the research's target audience were factors that were considered when choosing the VPTs to be evaluated by this research.

8.3.6 Heuristic accessibility evaluation of VPTs – Single evaluator and unvalidated heuristics

Another limitation that could be pointed out here is that only one evaluator conducted the heuristic evaluation, and the heuristics used have not been validated to confirm their ability to identify all accessibility issues. However, it should be noted that the objective of the evaluation was not to identify all accessibility issues. The objective was to confirm whether children with learning disabilities are likely to face difficulties when they use the evaluated VPTs. Therefore, in this context these heuristics and a single evaluator are sufficient.

8.3.7 Creating personae and proposing accessibility recommendations – Lack of target user involvement

A limitation of the studies conducted in the second phase of the research presented in this thesis is that they involved experts, but not target users. This is due to difficulties associated with communication faced by this group of users, which would have affected their ability to provide the type of data required. In situations such as this, experts become the appropriate participants due to their ability to provide the required information (Lazar et al, 2017). However, it should be noted that recorded data consisting of the recorded behaviours and difficulties of children with ASC associated with the use of VPTs were always used as a reference for experts during this phase of the research.

8.3.8 Proposed accessibility recommendations – Touch screens not explicit recommended

Although the use of a mouse as input was identified as a cause of accessibility issues in the accessibility evaluation of Scratch, touch screens were not explicitly recommended in this thesis's proposed recommendations. It should be noted however that mobile devices were recommended as the devices most suitable for VPTs targeted at children with ASC and learning disabilities, and modern mobile devices are known to utilise touch screens. Therefore, although not explicitly recommended, touch screens are recommended as part of the recommendation to utilise mobile devices.

8.3.9 Extending recommendations for designing accessible VPTs for children with ASC – Unvalidated recommendations

Finally, the extended set of recommendations for designing accessible VPTs for children with ASC presented at the end of this research consists of recommendations validated by experts, and some additional ones that have not been validated yet. Although this can be seen as a limitation, the additional recommendations gathered from the literature should be taken as a tentative extended set of recommendations gathered through an opportunistic examination of the literature for the existence of recommendations relevant for designing accessible VPTs for children with ASC that were not identified in the interviews with experts.

8.4. Future Work

This research has provided insights into the difficulties faced by children with learning disabilities when using VPTs, shown that these difficulties can be faced while using popular VPTs for children, and proposed tools and recommendations for designing accessible VPTs. However, there is still room for further understanding of how children with learning disabilities use VPTs, how they can use VPTs as learning tools, and how their overall experience can be improved.

8.4.1 Investigating the relationship between accessibility and the type of content being created

Future research could investigate the relationship between the type of content being created and the accessibility of VPTs for children with learning disabilities. Different content types might require different tools, programming concepts, structure and sequence, and may require a different approach to design altogether. For example, compared to the creation of stories, creating games requires the creation of levels, implementation of character controls, creation of rewards, creation of a scoring system etc. Future research can investigate whether accessibility changes with the content being created or accessibility is fixed regardless of the content.

As part of this study, the content created by the participants of the accessibility evaluation of scratch could be analysed, as well as other types of content created in new studies. This could help understand not just the relationship between the accessibility of VPTs and the type of content being created, but also the programming concepts used by the target group and the complexity of their programs.

8.4.2 Investigating the impact of personalisation on accessibility

This research has provided brief examples of how personalisation could be used in improving the accessibility of VPTs for children with ASC. Further research could investigate the impact of these proposals.

As a starting point, personalisation recommendations can be implemented using predefined preferences created to meet the needs of the personae created by this research. A user can then experience a personalised VPT depending on the persona most similar to them, allowing the accessibility of the VPT to be evaluated with personalisation in place. To illustrate this implementation approach, Appendix J showcases a redesign of Pocket Code to meet the need of the 'Oliver' persona for creating animations without using 'confusing programming blocks'. To achieve this, the redesign applies 'Restriction and Limitation' recommendations by removing access to features that Oliver is likely to find confusing and applies the 'Goal Orientation' recommendation in selecting and adding features to help Oliver achieve his goal as easily as possible. The resulting redesign allows Oliver to create projects using existing templates but not blank projects; to replace or edit the sprites in a project but not add or remove sprites; to create and customise animations using templates without viewing, adding, removing or editing a projects programming blocks. This redesign received positive feedback from experts during informal presentations held after conducting validation interviews for the recommendations presented in Chapter 6.

8.4.3 A comparative study with children with high functioning ASC

The studies conducted as part of this thesis focused on children with ASC and learning disabilities. As a future study, similar studies could be conducted with and on children of a similar age diagnosed with high functioning ASC, i.e those with ASC and no learning disabilities. The study will be aimed at understanding the differences and similarities between the experiences of children with low functioning and high function ASC, and how accessible VPTs can be designed for both groups.

8.4.4 A comparative study with other visual creation and learning tools

Since the start of this research, the use and popularity of creation tools for children has continued to increase. Tools for creating 3D worlds and environments, programming robots, creating games, creating augmented reality and virtual reality applications are now being used as learning tools for children. As part of a future study, studies similar to those conducted as part of this research could be conducted with the tools mentioned above. Finding from these studies will further shed light on the experiences of children with ASC and learning disabilities when using visual creation and learning tools, highlight differences and similarities to their experiences when using VPTs, and identify accessibility recommendations and guidelines for designing the tools.

8.5. Closing Remarks

VPTs are becoming increasingly more acceptable as tools for aiding children's learning within and outside of classrooms, and research studies are reporting the benefits of using VPTs in this context. This research makes several contributions to knowledge concerning the accessibility of VPTs including methods for evaluating the accessibility of VPTs for children with learning disabilities; a method for designing personae for children with ASC to describe their requirements and goals associated with the use of VPTs; a set of personae for children with ASC for designing accessible VPTs; and a set of design recommendations for designing accessible VPTs for children with ASC.

References

Abras, C., Maloney-Krichmar, D., Preece, J. and others. (2004), “User-centered design”, *Bainbridge, W. Encyclopedia of Human-Computer Interaction. Thousand Oaks: Sage Publications*, Citeseer, Vol. 37 No. 4, pp. 445–456.

Adams, A. and Cox, A.L. (2008), “Questionnaires, in-depth interviews and focus groups”, in Cairns, P. and Cox, A.L. (Eds.), *Research Methods for Human Computer Interaction*, Cambridge University Press, Cambridge, pp. 17–34.

Adlin, T. and Pruitt, J. (2010), *The Essential Persona Lifecycle : Your Guide to Building and Using Personas*, Morgan Kaufmann Publishers, San Francisco.

Akcaoglu, M. (2014), “Learning problem-solving through making games at the game design and learning summer program”, *Educational Technology Research and Development*, Vol. 62 No. 5, pp. 583–600.

Al-Wabil, A., Drine, S., Alkoblan, S., Alamoudi, A., Almozaini, M. and Rawan, A.-A. (2012), “The Use of Personas in the Design of an Arabic Auditory Training System for Children”, *Proceedings of the 13th International Conference on Computers Helping People with Special Needs*, Linz, Austria, pp. 199–205.

Alcorn, A., Pain, H., Rajendran, G., Smith, T., Lemon, O., Porayska-Pomsta, K., Foster, M.E., et al. (2011), “Social Communication between Virtual Characters and Children with Autism”, pp. 7–14.

Alper, S. and Raharinirina, S. (2006), “Assistive Technology for Individuals with Disabilities: A Review and Synthesis of the Literature”, *Journal of Special Education Technology*, Vol. 21 No. 2, pp. 47–64.

APA. (2013), *Diagnostic and Statistical Manual of Mental Disorders (DSM-5®)*, American Psychiatric Pub.

Aslam, S., Standen, P.J., Shopland, N., Burton, A. and Brown, D. (2016), “A Comparison of Humanoid and Non-humanoid Robots in Supporting the Learning of Pupils with Severe Intellectual Disabilities”, *2016 International Conference on Interactive Technologies and Games (ITAG)*, IEEE, pp. 7–12.

Baron-Cohen, S., Scott, F.J., Allison, C., Williams, J., Bolton, P., Matthews, F.E. and Brayne, C. (2009), “Prevalence of autism-spectrum conditions: UK school-based population study", *British Journal of Psychiatry*, Vol. 194 No. 6, pp. 500–509.

Bekele, E., Crittendon, J., Zheng, Z., Swanson, A., Weitlauf, A., Warren, Z. and Sarkar, N. (2014), "Assessing the Utility of a Virtual Environment for Enhancing Facial Affect Recognition in Adolescents with Autism", *Journal of Autism and Developmental Disorders*, Vol. 44 No. 7, pp. 1641–1650.

Benton, L., Johnson, H., Ashwin, E., Brosnan, M. and Grawemeyer, B. (2012), "Developing IDEAS: Supporting children with autism within a participatory design team", *Proceedings of the 2012 ACM Annual Conference on Human Factors in Computing Systems - CHI '12*, ACM Press, New York, New York, USA, p. 2599.

Bernardini, S., Porayska-Pomsta, K. and Smith, T.J. (2014), "ECHOES: An intelligent serious game for fostering social communication in children with autism", *Information Sciences*, Vol. 264, pp. 41–60.

Blandford, A., Furniss, D. and Makri, S. (2016), *Qualitative Hci Research: Going Behind the Scenes*, Morgan & Claypool Publishers.

Bossavit, B. and Parsons, S. (2017), "From start to finish: teenagers on the autism spectrum developing their own collaborative game", *Journal of Enabling Technologies*, Vol. 11 No. 2, pp. 31–42.

Boyd, B.A., Conroy, M.A., Mancil, G.R., Nakao, T. and Alter, P.J. (2007), "Effects of Circumscribed Interests on the Social Behaviors of Children with Autism Spectrum Disorders", *Journal of Autism and Developmental Disorders*, Vol. 37 No. 8, pp. 1550–1561.

Bozgeyikli, L., Raij, A., Katkoori, S. and Alqasemi, R. (2018), "A Survey on Virtual Reality for Individuals with Autism Spectrum Disorder: Design Considerations", *IEEE Transactions on Learning Technologies*, IEEE, Vol. 11 No. 2, pp. 133–151.

Brajnik, G. (2008), "Beyond Conformance: The Role of Accessibility Evaluation Methods", *Web Information Systems Engineering – WISE 2008 Workshops*, Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 63–80.

Brandão, J., Cunha, P., Vasconcelos, J., Carvalho, V. and Soares, F. (2015), "An

Augmented Reality GameBook for Children with Autism Spectrum Disorders", *The International Conference on E-Learning in the Workplace 2015*, pp. 1–6.

Braun, V. and Clarke, V. (2006), "Using thematic analysis in psychology", *Qualitative Research in Psychology*, Vol. 3 No. 2, pp. 77–101.

Britto, T.C.P. and Pizzolato, E.B. (2016), "Towards Web Accessibility Guidelines for People With Autism Spectrum Disorder", *ACHI 2016 : The Ninth International Conference on Advances in Computer-Human Interactions*, available at:https://doi.org/10.13140/RG.2.1.4881.0321.

Brown, D., Burton, A., Boulton, H., Napoles, C.P., Gonzalez, M.A.B., Cobello, S., Mazzucato, A., et al. (2016), *Managing - D2.1 Formation of Stakeholder Groups V1.0*, available at: http://mathisis-project.eu/sites/default/files/mathisis/public/content-files/deliverables/MaTHiSiS D2.1 Formation of stakeholder groups.pdf (accessed 22 May 2018).

Brown, D.J., McHugh, D., Standen, P., Evett, L., Shopland, N. and Battersby, S. (2011), "Designing location-based learning experiences for people with intellectual disabilities and additional sensory impairments", *Computers and Education*, Elsevier Ltd, Vol. 56 No. 1, pp. 11–20.

Brown, D.J., Standen, P., Evett, L., Battersby, S. and Shopland, N. (2010), "Designing Serious Games for People with Dual Diagnosis", *Design and Implementation of Educational Games*, pp. 424–439.

Brown, N. and Stockman, T. (2013), "Examining the Use of Thematic Analysis As a Tool for Informing Design of New Family Communication Technologies", *Proceedings of the 27th International BCS Human Computer Interaction Conference*, British Computer Society, Swinton, UK, UK, pp. 21:1--21:6.

Burke, Q. and Kafai, Y.B. (2010), "Programming & storytelling", *Proceedings of the 9th International Conference on Interaction Design and Children - IDC '10*, ACM Press, New York, New York, USA, p. 348.

Burnett, M.M. (1999), "Visual Programming", *Wiley Encyclopedia of Electrical and Electronics Engineering*, Vol. 32, John Wiley & Sons, Inc., Hoboken, NJ, USA, pp. 218–220.

Calao, L.A., Moreno-León, J., Correa, H.E. and Robles, G. (2015), “Developing mathematical thinking with scratch an experiment with 6th grade students”, *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, Vol. 9307, Springer, Cham, pp. 17–27.

Card, S.K., Moran, T.P. and Newell, A. (1983), *The Psychology of Human-Computer Interaction*, edited by Card, S.K., CRC Press, available at:https://doi.org/10.1201/9780203736166.

Caro, K., Tentori, M., Martinez-Garcia, A.I. and Zavala-Ibarra, I. (2017), “FroggyBobby: An exergame to support children with motor problems practicing motor coordination exercises during therapeutic interventions”, *Computers in Human Behavior*, Vol. 71, pp. 479–498.

Chang, Y.-J., Kang, Y.-S., Chang, Y.-S., Liu, H.-H., Chiu, Y.-L. and Kao, C.C. (2016), “Designing a Kinect2Scratch Game to Help Teachers Train Children with Intellectual Disabilities for Pedestrian Safety”, *Proceedings of the 18th International ACM SIGACCESS Conference on Computers and Accessibility - ASSETS ’16*, ACM Press, New York, New York, USA, pp. 269–270.

Charmaz, K. (2014), *Constructing Grounded Theory*, Sage.

Choi, J.W. and Kimura, T.D. (1986), “A Compiled Picture Language on Macintosh”, *Proceedings of the 1986 ACM SIGSMALL/PC Symposium on Small Systems*, ACM, New York, NY, USA, pp. 72–80.

Cluley, V. (2018), “From ‘Learning disability to intellectual disability’-Perceptions of the increasing use of the term ‘intellectual disability’ in learning disability policy, research and practice”, *British Journal of Learning Disabilities*, Vol. 46 No. 1, pp. 24–32.

Cooper, A. (1999), *The Inmates Are Running the Asylum*, Sams, Indianapolis, IN, available at:https://doi.org/10.1007/978-3-322-99786-9_1.

Cooper, A., Reimann, R. and Cronin, D. (2007), *About Face 3: The Essentials of Interaction Design*, *Information Visualization*, Vol. 3, Wiley Pub, available at:https://doi.org/10.1057/palgrave.ivs.9500066.

Cooper, A., Reimann, R., Cronin, D. and Noessel, C. (2014), *About Face : The Essentials of Interaction Design*, John Wiley & Sons, Incorporated, Somerset, UNITED STATES, available at: http://ebookcentral.proquest.com/lib/ntuuk/detail.action?docID=1762072.

Cooper, S., Dann, W. and Pausch, R. (2000), "Alice : a 3-D Tool for Introductory Programming Concepts", *Orientations*, Vol. 5 No. 5, pp. 108–117.

Corbin, J.M. and Strauss, A.L. (2015), *Basics of Qualitative Research : Techniques and Procedures for Developing Grounded Theory*, available at: https://uk.sagepub.com/en-gb/eur/basics-of-qualitative-research/book235578 (accessed 16 November 2017).

Dattolo, A. and L. Luccio, F. (2017), "Accessible and UsableWebsites and Mobile Applications for People with Autism Spectrum Disorders: a Comparative Study", *ICST Transactions on Ambient Systems*, Vol. 4 No. 13, p. 152549.

Davis, M., Dautenhahn, K., Powell, S. and Nehaniv, C. (2010), "Guidelines for researchers and practitioners designing software and software trials for children with autism", *Journal of Assistive Technologies*.

Devkar, S., Lobo, S. and Doke, P. (2015), "A Grounded Theory Approach for Designing Communication and Collaboration System for Visually Impaired Chess Players", Springer, Cham, pp. 415–425.

Didehbani, N., Allen, T., Kandalaft, M., Krawczyk, D. and Chapman, S. (2016), "Virtual Reality Social Cognition Training for children with high functioning autism", *Computers in Human Behavior*, Vol. 62, pp. 703–711.

Diehl, J.J., Schmitt, L.M., Villano, M. and Crowell, C.R. (2012), "The clinical use of robots for individuals with Autism Spectrum Disorders: A critical review", *Research in Autism Spectrum Disorders*, Vol. 6 No. 1, pp. 249–262.

Dix, A. (2008), "Theoretical analysis and theory creation", *Research Methods for Human–Computer Interaction*, pp. 175–195.

Djajadiningrat, J.P., Gaver, W.W. and Fres, J.W. (2004), "Interaction relabelling and extreme characters", *Proceedings of the Conference on Designing Interactive Systems Processes, Practices, Methods, and Techniques - DIS '00*, ACM Press, New York, New York, USA, pp. 66–71.

Eiselt, K. and Carter, P. (2019), “Integrating Social Skills Practice with Computer Programming for Students on the Autism Spectrum”, *Proceedings - Frontiers in Education Conference, FIE*, Vol. 2018-Octob, IEEE, pp. 1–5.

Flannery, L.P., Silverman, B., Kazakoff, E.R., Bers, M.U., Bontá, P. and Resnick, M. (2013), “Designing ScratchJr”, *Proceedings of the 12th International Conference on Interaction Design and Children - IDC ’13*, ACM Press, New York, New York, USA, pp. 1–10.

Floyd, I.R., Cameron Jones, M. and Twidale, M.B. (2008), “Resolving Incommensurable Debates: a Preliminary Identification of Persona Kinds, Attributes, and Characteristics”, *Artifact*, Vol. 2 No. 1, pp. 12–26.

Fowler, A. (2017), “Engaging young learners in making games”, *Proceedings of the International Conference on the Foundations of Digital Games - FDG ’17*, ACM Press, New York, New York, USA, pp. 1–5.

Frauenberger, C., Makhaeva, J. and Spiel, K. (2017), “Blending Methods: Developing Participatory Design Sessions for Autistic Children”, *Proceedings of the 2017 Conference on Interaction Design and Children - IDC ’17*, ACM Press, New York, New York, USA, pp. 39–49.

Fridenson-Hayo, S., Berggren, S., Lassalle, A., Tal, S., Pigat, D., Meir-Goren, N., O’Reilly, H., et al. (2017), “‘Emotiplay’: a serious game for learning about emotions in children with autism: results of a cross-cultural evaluation”, *European Child & Adolescent Psychiatry*, Vol. 26 No. 8, pp. 979–992.

Friess, E. (2015), “Personas in Heuristic Evaluation: An Exploratory Study”, *IEEE Transactions on Professional Communication*, Vol. 58 No. 2, pp. 176–191.

Fung, R.H.Y., Chiu, D.K.W., Ko, E.H.T., Ho, K.K.W. and Lo, P. (2016), “Heuristic Usability Evaluation of University of Hong Kong Libraries’ Mobile Website”, *The Journal of Academic Librarianship*, Vol. 42 No. 5, pp. 581–594.

Ganz, J.B. (2015), “AAC Interventions for Individuals with Autism Spectrum Disorders: State of the Science and Future Research Directions”, *Augmentative and Alternative Communication*, Vol. 31 No. 3, pp. 203–214.

García-Redondo, García, Areces, Núñez and Rodríguez. (2019), “Serious Games and Their Effect Improving Attention in Students with Learning Disabilities”, *International Journal of Environmental Research and Public Health*, Vol. 16 No. 14, p. 2480.

Gasson, S. and Waters, J. (2013), "Using a grounded theory approach to study online collaboration behaviors", *European Journal of Information Systems*, Vol. 22 No. 1, pp. 95–118.

Gill, P., Stewart, K., Treasure, E. and Chadwick, B. (2008), "Methods of data collection in qualitative research: Interviews and focus groups", *British Dental Journal*, Nature Publishing Group, Vol. 204 No. 6, pp. 291–295.

Gkatzidou, V., Hone, K., Sutcliffe, L., Gibbs, J., Sadiq, S.T., Szczepura, A., Sonnenberg, P., et al. (2015), "User interface design for mobile-based sexual health interventions for young people: Design recommendations from a qualitative study on an online Chlamydia clinical care pathway", *BMC Medical Informatics and Decision Making*, BMC Medical Informatics and Decision Making, Vol. 15 No. 1, pp. 1–13.

Glaser, B. and Strauss, A.L. (1967), *Discovery of Grounded Theory Strategies for Qualitative Research.*, Taylor and Francis, available at: https://books.google.co.uk/books?id=GTMrDwAAQBAJ&dq=the+discovery+of+grounded+theory&source=gbs_navlinks_s (accessed 16 November 2017).

Goldsmith, T.R. and LeBlanc, L.A. (2004), "Use of technology in interventions for children with autism.", *Journal of Early and Intensive Behavior Intervention*, Vol. 1 No. 2, pp. 166–178.

Goodwin, S. (2005), "Using screen capture software for web site usability and redesign buy-in", edited by Muir, S.P.*Library Hi Tech*, Emerald Group Publishing Limited, Vol. 23 No. 4, pp. 610–621.

Gribble, J., Hansen, A., Harlow, D. and Franklin, D. (2017), "Cracking The Code: The Impact of Computer Coding on the Interactions of a Child with Autism Work in Progress/Late Breaking", *Proceedings of the 2017 Conference on Interaction Design and Children (IDC '17)*, No. June 27-30, pp. 445–450.

Grynszpan, O., Weiss, P.L. (Tamar), Perez-Diaz, F. and Gal, E. (2014), "Innovative technology-based interventions for autism spectrum disorders: A meta-analysis", *Autism*, Vol. 18 No. 4, pp. 346–361.

Guasch, D., Martín-Escalona, I., Macías, J.A., Moreno, L., Hervás, R. and Bautista, S. (2019), "Expert-based Assessment of an Augmentative and Alternative Communication Tool", *Proceedings of the XX International Conference on Human Computer Interaction - Interacción '19*, ACM Press, New York, New York, USA, pp. 1–8.

Hardy, C., Ogden, J., Newman, J. and Cooper, S. (2002), *Autism and ICT: A Guide for Teachers and Parents*, Routledge, available at:https://doi.org/10.4324/9781315069609.

Harrison, M., Stockton, C. and Pearson, E. (2008), "Inclusive, adaptive design for students with severe learning disabilities", *Proceedings - The 8th IEEE International Conference on Advanced Learning Technologies, ICALT 2008*, pp. 1023–1027.

Hayter, M., Cleary, M. and Horsfall, J. (2014), "Data collection and sampling in qualitative research: does size matter?", *Journal of Advanced Nursing*, Vol. 70 No. 473–475, pp. 2012–2014.

Herrera, G., Alcantud, F., Jordan, R., Blanquer, A., Labajo, G. and De Pablo, C. (2008), "Development of symbolic play through the use of virtual reality tools in children with autistic spectrum disorders", *Autism*, Vol. 12 No. 2, pp. 143–157.

Herrera, G., Vera, L., Sevilla, J., Portalés, C. and Casas, S. (2018), "On the Development of VR and AR Learning Contents for Children on the Autism Spectrum", *Augmented Reality for Enhanced Learning Environments*, IGI Global, pp. 106–141.

Holwerda, R. and Hermans, F. (2018), "A usability analysis of blocks-based programming editors using cognitive dimensions", *Proceedings of IEEE Symposium on Visual Languages and Human-Centric Computing, VL/HCC*, Vol. 2018-Octob, IEEE Computer Society, pp. 217–225.

International Standards Organization. (2019), "ISO/IEC 30071-1:2019(en), Information technology — Development of user interface accessibility — Part 1: Code of practice for creating accessible ICT products and services", available at: https://www.iso.org/obp/ui/fr/#iso:std:iso-iec:30071:-1:ed-1:v1:en (accessed 25 December 2019).

Isleyen, F., Gulkesen, K.H., Cinemre, B., Samur, M.K., Zayim, N. and Sen Kaya, S. (2014), “Evaluation of the Usability of a Serious Game Aiming to Teach Facial Expressions to Schizophrenic Patients”, *Studies in Health Technology and Informatics*, Vol. 205, IOS Press, pp. 662–666.

Jamal, R. and Wenzel, L. (2002), “The applicability of the visual programming language LabVIEW to large real-world applications”, pp. 99–106.

Jenkin, E., Wilson, E., Murfitt, K., Clarke, M., Campain, R. and Stockman, L. (2015), *Inclusive Practice for Research With Children With Disability : A Guide*.

John Clarkson, P. and Coleman, R. (2015), “History of Inclusive Design in the UK”, *Applied Ergonomics*, Vol. 46, pp. 235–247.

Kagohara, D.M., van der Meer, L., Ramdoss, S., O’Reilly, M.F., Lancioni, G.E., Davis, T.N., Rispoli, M., et al. (2013), “Using iPods® and iPads® in teaching programs for individuals with developmental disabilities: A systematic review”, *Research in Developmental Disabilities*, Vol. 34 No. 1, pp. 147–156.

Kahn, K. (1999), “A Computer Game to Teach Programming”, *NECC’99: Proc. Ntl. Educational Computing Conf.*, pp. 127–135.

Ke, F. and Lee, S. (2016), “Virtual reality based collaborative design by children with high-functioning autism: design-based flexibility, identity, and norm construction”, *Interactive Learning Environments*, Vol. 24 No. 7, pp. 1511–1533.

Khowaja, K. and Salim, S.S. (2015), “Heuristics to Evaluate Interactive Systems for Children with Autism Spectrum Disorder (ASD)”, edited by Suzuki, K.*PLOS ONE*, Vol. 10 No. 7, p. e0132187.

Khowaja, K. and Salim, S.S. (2019), “Serious Game for Children with Autism to Learn Vocabulary: An Experimental Evaluation”, *International Journal of Human–Computer Interaction*, Vol. 35 No. 1, pp. 1–26.

Kim, J. and Kimm, C.H. (2017), “Functional technology for individuals with intellectual disabilities: Meta-analysis of mobile device-based interventions”, *The Journal of Special Education Apprenticeship*, Vol. 6 No. 1, pp. 1–22.

Kneale, L., Mikles, S., Choi, Y.K., Thompson, H. and Demiris, G. (2017), “Using scenarios and personas to enhance the effectiveness of heuristic usability evaluations for older adults and their care team", *Journal of Biomedical Informatics*, Vol. 73, pp. 43–50.

Kölling, M. (2010), "The Greenfoot Programming Environment", *ACM Transactions on Computing Education*, Vol. 10 No. 4, pp. 1–21.

Lazar, J., Feng, J.H. and Hochheiser, H. (2017), *Research Methods in Human-Computer Interaction*, 2nd Editio., available at: https://www.sciencedirect.com/book/9780128053904/research-methods-in-human-computer-interaction (accessed 29 March 2019).

Leal, A., Teixeira, A. and Silva, S. (2016), "On the Creation of a Persona to Support the Development of Technologies for Children with Autism Spectrum Disorder", in Antona, M. and Stephanidis, C. (Eds.), *Universal Access in Human-Computer Interaction. Users and Context Diversity*, Springer International Publishing, Cham, pp. 213–223.

Lewis, C.M. (2010), "How Programming Environment Shapes Perception, Learning and Goals: Logo vs. Scratch", *Proceedings of the 41st ACM Technical Symposium on Computer Science Education*, ACM, New York, NY, USA, pp. 346–350.

Liss, M., Saulnier, C., Fein, D. and Kinsbourne, M. (2006), "Sensory and attention abnormalities in autistic spectrum disorders", *Autism*, Vol. 10 No. 2, pp. 155–172.

Lorah, E.R., Parnell, A., Whitby, P.S. and Hantula, D. (2015), "A Systematic Review of Tablet Computers and Portable Media Players as Speech Generating Devices for Individuals with Autism Spectrum Disorder", *Journal of Autism and Developmental Disorders*, Vol. 45 No. 12, pp. 3792–3804.

Mace, R. (1988), "Universal design: housing for the lifespan of all people", *The Center for Universal Design, Nort Carolina State University*.

MacLaurin, M.B. (2011), "The design of kodu", *ACM SIGPLAN Notices*, Vol. 46 No. 1, p. 241.

Maloney, J., Resnick, M., Rusk, N., Silverman, B. and Eastmond, E. (2010), "The Scratch Programming Language and Environment", *ACM Transactions on Computing Education*, ACM, Vol. 10 No. 4, pp. 1–15.

Maloney, J.H., Peppler, K., Kafai, Y., Resnick, M. and Rusk, N. (2008), "Programming by choice", *Proceedings of the 39th SIGCSE Technical Symposium on Computer Science Education - SIGCSE '08*, Vol. 24, ACM Press, New York, New York, USA, p. 367.

Mangowal, R.G., Yuhana, U.L., Yuniarno, E.M. and Purnomo, M.H. (2017), "MathBharata: A serious game for motivating disabled students to study mathematics", *2017 IEEE 5th International Conference on Serious Games and Applications for Health (SeGAH)*, IEEE, pp. 1–6.

Maor, D., Currie, J. and Drewry, R. (2011), "The effectiveness of assistive technologies for children with special needs: a review of research-based studies", *European Journal of Special Needs Education*, Vol. 26 No. 3, pp. 283–298.

McCrickard, D.S., Abel, T.D., Scarpa, A., Wang, Y. and Niu, S. (2015), "Collaborative design for young children with autism: Design tools and a user study", *2015 International Conference on Collaboration Technologies and Systems (CTS)*, pp. 175–182.

Miaskiewicz, T. and Kozar, K.A. (2011), "Personas and user-centered design: How can personas benefit product design processes?", *Design Studies*, Elsevier, Vol. 32 No. 5, pp. 417–430.

Millen, L., Cobb, S. and Patel, H. (2011a), "A method for involving children with autism in design", *Proceedings of the 10th International Conference on Interaction Design and Children - IDC '11*, pp. 185–188.

Millen, L., Cobb, S. and Patel, H. (2011b), "Participatory design approach with children with autism", *International Journal on Disability and Human Development*.

Modugumudi, Y.R., Santhosh, J. and Anand, S. (2013), "Efficacy of Collaborative Virtual Environment Intervention Programs in Emotion Expression of Children with Autism", *Journal of Medical Imaging and Health Informatics*, Vol. 3 No. 2, pp. 321–325.

Moreno-Leon, J. and Robles, G. (2016), "Code to learn with Scratch? A systematic literature review", *2016 IEEE Global Engineering Education Conference*

(EDUCON), IEEE, pp. 150–156.

Mota-Macias, J.M., Ruiz-Rube, I., Balcells, A.C., Dodero, J.M., Corral, J.M.R. and Morgado-Estevez, A. (2019), “A Study on the Suitability of Visual Languages for Non-Expert Robot Programmers”, *IEEE Access*, Vol. 7, pp. 17535–17550.

Muller, M. (2014), “Curiosity, Creativity, and Surprise as Analytic Tools: Grounded Theory Method”, *Ways of Knowing in HCI*, Springer New York, New York, NY, pp. 25–48.

Muller, M.J. (2007), “Participatory design: the third space in HCI”, *The Human-Computer Interaction Handbook*, CRC press, pp. 1087–1108.

Munoz, R., Barcelos, T., Noel, R. and Kreisel, S. (2012), “Development of Software that Supports the Improvement of the Empathy in Children with Autism Spectrum Disorder”, *2012 31st International Conference of the Chilean Computer Science Society*, IEEE, pp. 223–228.

Munoz, R., Barcelos, T.S., Villarroel, R. and Silveira, I.F. (2016), “Game design workshop to develop computational thinking skills in teenagers with Autism Spectrum Disorders”, *2016 11th Iberian Conference on Information Systems and Technologies (CISTI)*, IEEE, pp. 1–4.

Myers, B.A. (1990), “Taxonomies of visual programming and program visualization”, *Journal of Visual Languages and Computing*, Academic Press, Vol. 1 No. 1, pp. 97–123.

Newbutt, N., Sung, C., Kuo, H.J. and Leahy, M.J. (2017), “The Acceptance, Challenges, and Future Applications of Wearable Technology and Virtual Reality to Support People with Autism Spectrum Disorders”, pp. 221–241.

Nielsen, J. (1994), “Usability inspection methods”, *Conference Companion on Human Factors in Computing Systems - CHI ’94*, ACM Press, New York, New York, USA, pp. 413–414.

Nielsen, J. and Molich, R. (1990), “Heuristic evaluation of user interfaces”, *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems Empowering People - CHI ’90*, ACM Press, New York, New York, USA, pp. 249–256.

Norman, D. (2006), “Ad hoc personas & empathetic focus”, *The Persona Lifecycle:*

Keeping People in Mind during Product Design, Morgan Kaufmann Press, pp. 154–157.

Norman, D.A. and Draper, S.W. (1986), *User Centered System Design; New Perspectives on Human-Computer Interaction*, L. Erlbaum Associates Inc., Hillsdale, NJ, USA.

O'Brien, G. and Pearson, J. (2004), "Autism and learning disability", *Autism*, Vol. 8 No. 2, pp. 125–140.

de Oliveira Malaquias, F.F. and Malaquias, R.F. (2017), "The role of virtual reality in the learning process of individuals with intellectual disabilities", *Technology and Disability*, Vol. 28 No. 4, pp. 133–138.

Ouahbi, I., Kaddari, F., Darhmaoui, H., Elachqar, A. and Lahmine, S. (2015), "Learning Basic Programming Concepts by Creating Games with Scratch Programming Environment", *Procedia - Social and Behavioral Sciences*, Vol. 191, pp. 1479–1482.

Parsons, S. (2015), "Learning to work together: Designing a multi-user virtual reality game for social collaboration and perspective-taking for children with autism", *International Journal of Child-Computer Interaction*, Vol. 6, pp. 28–38.

Parsons, S. and Mitchell, P. (2002), "The potential of virtual reality in social skills training for people with autistic spectrum disorders", *Journal of Intellectual Disability Research*, Vol. 46 No. 5, pp. 430–443.

Pavlov, N. (2014), "User Interface for People with Autism Spectrum Disorders", *Journal of Software Engineering and Applications*, Vol. 07 No. 02, pp. 128–134.

Pennisi, P., Tonacci, A., Tartarisco, G., Billeci, L., Ruta, L., Gangemi, S. and Pioggia, G. (2016), "Autism and social robotics: A systematic review", *Autism Research*, Vol. 9 No. 2, pp. 165–183.

Persson, H., Åhman, H., Yngling, A.A. and Gulliksen, J. (2015), "Universal design, inclusive design, accessible design, design for all: different concepts—one goal? On the concept of accessibility—historical, methodological and philosophical aspects", *Universal Access in the Information Society*, Vol. 14

No. 4, pp. 505–526.

Petrie, H., & Bevan, N. (2009). "The Evaluation of Accessibility, Usability, and User Experience". *The universal access handbook*, *1*, pp. 1-16.

Prawira, G.S.A., Kaburuan, E.R. and Effendy, V. (2017), "User Interface (UI) Design of Scheduling Activity Apps for Autistic Children", *2017 International Conference on Orange Technologies (ICOT)*, pp. 129–133.

Putnam, C. and Chong, L. (2008), "Software and technologies designed for people with autism: What do users want?", *ASSETS'08: The 10th International ACM SIGACCESS Conference on Computers and Accessibility*, pp. 3–10.

Quezada, A., Juárez-Ramírez, R., Jiménez, S., Ramírez-Noriega, A., Inzunza, S. and Munoz, R. (2018), "Assessing the target' size and drag distance in mobile applications for users with autism", *Advances in Intelligent Systems and Computing*, Vol. 746, pp. 1219–1228.

Raymaker, D.M., Kapp, S.K., McDonald, K.E., Weiner, M., Ashkenazy, E. and Nicolaidis, C. (2019), "Development of the AASPIRE Web Accessibility Guidelines for Autistic Web Users", *Autism in Adulthood*, Mary Ann Liebert, Inc., publishers 140 Huguenot Street, 3rd Floor New~…, Vol. 1 No. 2, pp. 146–157.

Read, J.C., Horton, M., Clarke, S., Jones, R., Fitton, D. and Sim, G. (2018), "Designing for the 'at home' experience of parents and children with tablet games", pp. 441–448.

Repenning, A. (2013), "Making programming accessible and exciting", *Computer*, IEEE, Vol. 46 No. 6, pp. 78–81.

Repenning, A., Ioannidou, A. and Zola, J. (2000), "AgentSheets: End-User Programmable Simulations", *Journal of Artificial Societies and Social Simulation*, Vol. 3 No. 3.

Rocha, T., Bessa, M., Magalhães, L. and Cabral, L. (2016), "Performing universal tasks on the Web", pp. 1–7.

Rocha, T., Bessa, M., Melo, M., Barroso, J. and Cabral, L. (2017), "Evaluating selection, manipulation and navigation tasks by people with intellectual disabilities: Learning level comparison of user interaction performance with digital content", *2016 23 Encontro Portugues de Computacao Grafica e Interacao, EPCGI 2016*, available at:https://doi.org/10.1109/EPCGI.2016.7851193.

Roldán-Álvarez, D., Gomez, J., Márquez-Fernández, A., Martín, E. and Montoro, G. (2016), "Mobile Devices as Assistive Technologies for ASD: Experiences in the Classroom", in Marcus, A. (Ed.), *Design, User Experience, and Usability: Novel User Experiences*, Springer International Publishing, Cham, pp. 187–197.

de Sá, M. and Carriço, L. (2012), "Fear therapy for children – A Mobile Approach", *Proceedings of the 4th ACM SIGCHI Symposium on Engineering Interactive Computing Systems - EICS '12*, ACM Press, New York, New York, USA, p. 237.

Sáez-López, J.-M., Román-González, M. and Vázquez-Cano, E. (2016), "Visual programming languages integrated across the curriculum in elementary school: A two year case study using 'Scratch' in five schools", *Computers & Education*, Vol. 97, pp. 129–141.

Sarachan, J. (2012), "Virtual floortime: Using games to engage children with Autism Spectrum Disorder", *4th International IEEE Consumer Electronic Society - Games Innovation Conference, IGiC 2012*, IEEE, pp. 1–4.

Scassellati, B., Henny Admoni and Matarić, M. (2012), "Robots for Use in Autism Research", *Annual Review of Biomedical Engineering*, Vol. 14 No. 1, pp. 275–294.

Schlosser, R.W. and Koul, R.K. (2015), "Speech Output Technologies in Interventions for Individuals with Autism Spectrum Disorders: A Scoping Review", *Augmentative and Alternative Communication*, Vol. 31 No. 4, pp. 285–309.

Sengupta, P., Dickes, A., Farris, A.V., Karan, A., Martin, D. and Wright, M. (2015), "Programming in K-12 science classrooms", *Communications of the ACM*, Vol. 58 No. 11, pp. 33–35.

Shu, N.C. (1999), "Visual programming: Perspectives and approaches", *IBM Systems Journal*, Vol. 38 No. 2.3, pp. 199–221.

Sitdhisanguan, K., Chotikakamthorn, N., Dechaboon, A. and Out, P. (2012), "Using tangible user interfaces in computer-based training systems for low-functioning autistic children", *Personal and Ubiquitous Computing*, Vol. 16 No. 2, pp. 143–155.

Slany, W. (2014), "Pocket code: A Scratch-like integrated development environment for your phone", *Proceedings of the Companion Publication of the 2014 ACM SIGPLAN Conference on Systems, Programming, and Applications: Software for Humanity - SPLASH '14*, ACM Press, New York, New York, USA, pp. 35–36.

Smith, D.C., Cypher, A. and Spohrer, J. (1994), "KidSim: Programming Agents Without a Programming Language", *Commun. ACM*, ACM, New York, NY, USA, Vol. 37 No. 7, pp. 54–67.

Spieler, B., Schindler, C., Slany, W., Mashkina, O., Beltrán, M.E., Boulton, H. and Brown, D. (2017), "Evaluation of game templates to support programming activities in schools", *Proceedings of the 11th European Conference on Games Based Learning, ECGBL 2017*, Vol. 8, pp. 600–609.

Standen, P., Brown, D., Roscoe, J., Hedgecock, J., Stewart, D., Galvez Trigo, M.J. and Elgajiji, E. (2014), "Engaging Students with Profound and Multiple Disabilities Using Humanoid Robots", pp. 419–430.

Standen, P.J. and Brown, D.J. (2005), "Virtual Reality in the Rehabilitation of People with Intellectual Disabilities: Review", *CyberPsychology & Behavior*, Vol. 8 No. 3, pp. 272–282.

Standen, P.J. and Brown, D.J. (2006), "Virtual reality and its role in removing the barriers that turn cognitive impairments into intellectual disability", *Virtual Reality*, Vol. 10 No. 3–4, pp. 241–252.

Strawhacker, A., Lee, M., Caine, C. and Bers, M. (2015), "ScratchJr Demo: A coding language for Kindergarten", In *Proceedings of the 14th International Conference on Interaction Design and Children*, pp. 414-417.

Szatmari, P. (2000), "The Classification of Autism, Asperger's Syndrome, and Pervasive Developmental Disorder", *The Canadian Journal of Psychiatry*, Vol. 45 No. 8, pp. 731–738.

Tanaka, A., Parkinson, A., Settel, Z. and Tahiroglu, K. (2012), "A Survey and Thematic Analysis Approach as Input to the Design of Mobile Music GUIs", *NIME 2012 Proceedings of the International Conference on New Interfaces for Musical Expression*, pp. 2–5.

Thorsteinsson, G. and Page, T. (2007), “Piloting New Ways of Collecting Empirical Data”, *ICT in Education: Reflections and Perspectives*, available at: http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=DA40999D69FC1D04E751D4D8AC8B568F?doi=10.1.1.567.6029&rep=rep1&type=pdf (accessed 16 November 2017).

Tsikinas, S. and Xinogalos, S. (2019), “Design Guidelines for Serious Games Targeted to People with Autism”, in Uskov, V.L., Howlett, R.J., Jain, L.C. and Vlacic, L. (Eds.), , Vol. 99, Springer International Publishing, Cham, pp. 489–499.

Tsikinas, S., Xinogalos, S. and Satratzemi, M. (2016), “Review on serious games for people with intellectual disabilities and autism”, *Proceedings of the European Conference on Games-Based Learning*, Vol. 2016-Janua, pp. 696–703.

Utting, I., Cooper, S., Kölling, M., Maloney, J. and Resnick, M. (2010), "Alice, greenfoot, and scratch--a discussion". *ACM Transactions on Computing Education (TOCE)*, *10*(4), p.17.

Vazquez, V., Cardenas, C., Cibrian, F.L. and Tentori, M. (2016), “Designing a Musical Fabric-Based Surface to Encourage Children with Autism to Practice Motor Movements”, *Proceedings of the 6th Mexican Conference on Human-Computer Interaction - MexIHC’16*, ACM Press, New York, New York, USA, pp. 1–4.

Vieira, D., Leal, A., Almeida, N., Silva, S. and Teixeira, A. (2017), “‘Tell your day’: Developing multimodal interaction applications for children with ASD”, *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, Vol. 10277 LNCS, Springer, Cham, pp. 525–544.

Vissers, L.E.L.M., Gilissen, C. and Veltman, J.A. (2016), “Genetic studies in intellectual disability and related disorders”, *Nature Reviews Genetics*, Vol. 17 No. 1, pp. 9–18.

W3C. (2018), "Web Accessibility Evaluation Tools List", *Developed by the Education and Outreach Working Group*, available at: https://www.w3.org/WAI/ER/tools/#General (accessed 10 December 2019).

Walsh, L. and Barry, M. (2008), "Demystifying the interface for young learners with autism", *IADIS International Conference Interfaces and Human Computer Interaction 2008*, pp. 308–313.

Wehmeyer, M.L., Smith, S.J., Palmer, S.B. and Davies, D.K. (2004), "Technology Use by Students with Intellectual Disabilities: An Overview", *Journal of Special Education Technology*, Vol. 19 No. 4, pp. 7–21.

Werner, L., Campe, S. and Denner, J. (2012), "Children learning computer science concepts via Alice game-programming", *SIGCSE'12 - Proceedings of the 43rd ACM Technical Symposium on Computer Science Education*, pp. 427–432.

Whyatt, C.P. and Craig, C.M. (2012), "Motor Skills in Children Aged 7–10 Years, Diagnosed with Autism Spectrum Disorder", *Journal of Autism and Developmental Disorders*, Vol. 42 No. 9, pp. 1799–1809.

Whyte, E.M., Smyth, J.M. and Scherf, K.S. (2015), "Designing Serious Game Interventions for Individuals with Autism", *Journal of Autism and Developmental Disorders*, Vol. 45 No. 12, pp. 3820–3831.

Yaneva, V., Temnikova, I. and Mitkov, R. (2016), "Evaluating the Readability of Text Simplification Output for Readers with Cognitive Disabilities", *Proceedings of the Tenth International Conference on Language Resources and Evaluation ({LREC}'16)*, European Language Resources Association (ELRA), Portorož, Slovenia, pp. 293–299.

Yee, H.S.S. (2012), "Mobile technology for children with Autism Spectrum Disorder: Major trends and issues", *2012 IEEE Symposium on E-Learning, E-Management and E-Services*, IEEE, pp. 1–5.

Zakari, H.M., Ma, M. and Simmons, D. (2014), "A Review of Serious Games for Children with Autism Spectrum Disorders (ASD)", pp. 93–106.

Zhang, K. (2010), *Visual Languages and Applications*, *Springer Science & Business Media*.

Zubair, M.S., Brown, D., Hughes-Roberts, T. and Bates, M. (2018), "Evaluating the

Accessibility of Scratch for Children with Cognitive Impairments”, *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, Vol. 10907 LNCS, pp. 660–676.

Zubair, M.S., Brown, D., Hughes-Roberts, T. and Bates, M. (2019), “A method of creating personae for children with autism spectrum condition: application and revision”, *Journal of Enabling Technologies*, Vol. 13 No. 2, pp. 112–122.

Zubair, M.S., Brown, D.J., Bates, M. and Hughes-Roberts, T. (2019), “Designing Accessible Visual Programming Tools for Children with Autism Spectrum Condition”, *ArXiv Preprint ArXiv:1911.07624*.

Appendix A. Ethical approval for phase 1 of the research

NOTTINGHAM TRENT UNIVERSITY

COLLEGE OF SCIENCE AND TECHNOLOGY

ETHICAL COMMITTEE (HUMANS)

Application No:	**468**
Title:	Accessible Visual Programming for Game Making
Applicants:	Dr Misbahu Zubair
Date of Meeting:	4th November 2016

With regard to your application to the recent meeting of the Ethical Committee (Humans), the Committee have reviewed this and the following action has been decided:

- [x] Approved
- [ ] Approved, subject to the following information being provided/clarified.
- [ ] Decision deferred, pending further receipt of further information.
- [ ] Not approved

Professor Bob Rees
Chair
Ethical Review Committee (Humans)

Date: 5/1/17

Version - September 2016

Appendix B. Teacher interviews conducted for the accessibility evaluation of Scratch

The following questions were asked of the two teachers of the class that participated in the user evaluation of Scratch, in order to plan the user evaluation.

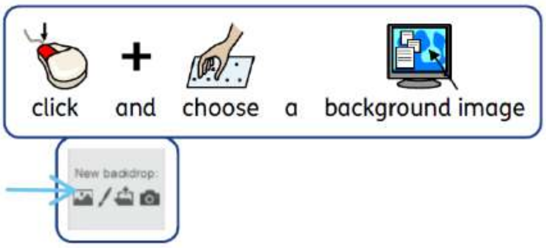
- What is your opinion of Scratch as a potential teaching tool in your class?
- How would you use Scratch in your class?
- Which learning objectives will you try to meet?

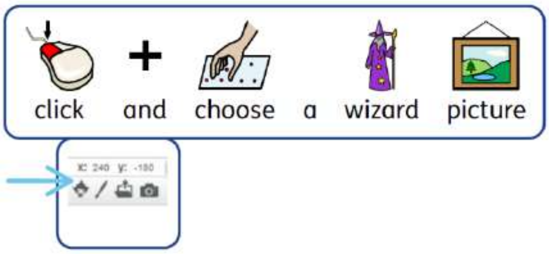
Questions from the list below were asked of all three participating teachers after concluding user evaluations with participating children.

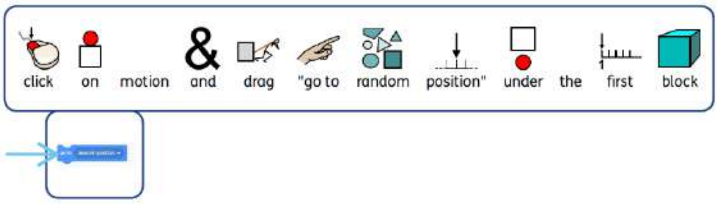
- What do you think about the accessibility of Scratch in general?
- What do you think caused the participating children to have difficulties finding buttons?
- What do you think caused the participating children to have difficulties identifying links?
- What do you think caused the participating children to have difficulties identifying blocks?
- What do you think caused the participating children to have difficulties switching areas?
- What do you think caused the participating children to have difficulties dragging objects?
- What do you think caused the participating children to have difficulties selecting objects?
- What do you think caused the participating children to have difficulties defining instructions?
- What do you think caused the participating children to have difficulties structuring and sequencing?
- What do you think caused the participating children to have difficulties staying on track?
- Are there any features of Scratch that you think will cause difficulties to your students?

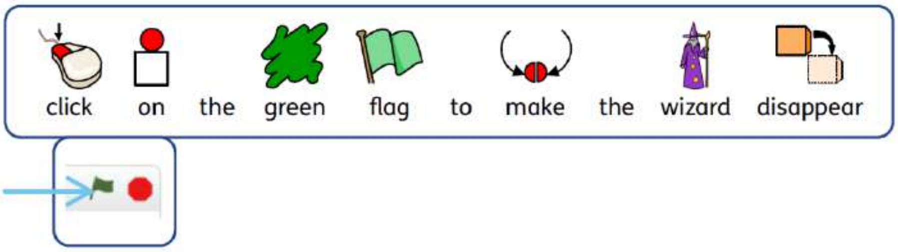
**Note: Additional follow-up questions were asked, as appropriate, with each participant.*

Appendix C. Sample guide for creating a disappearing wizard animation

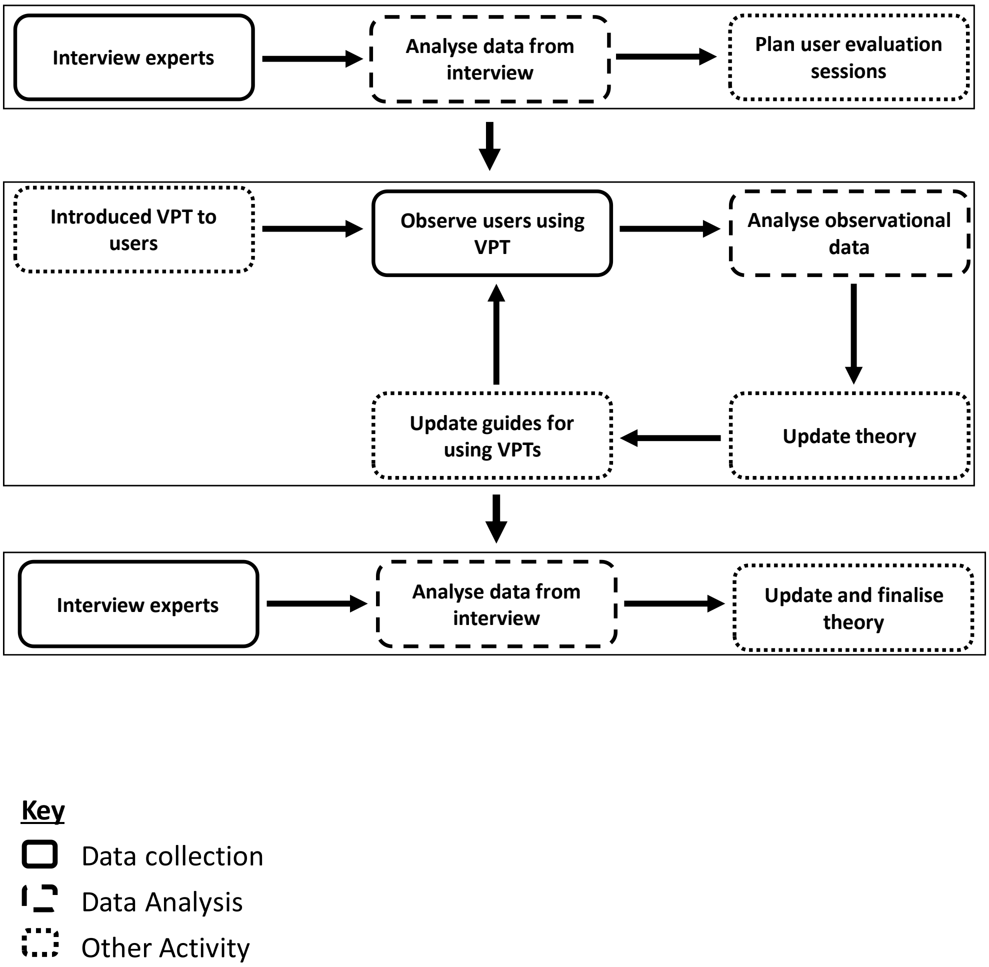








Appendix D. Grounded theory based method for formative evaluation of the accessibility of VPTs for children with learning disabilities



Appendix E. Ethical approval for phase 2 of the research

NOTTINGHAM TRENT UNIVERSITY

School of Science and Technology

Non-Invasive Human Ethics Committee

Notification of Decision– **17/18 – 76v2**

Date: 02.07.18

Student's Name	Misbahu Zubair
Supervisor's Name	David Brown
NTU ID	N0545420
Course	PhD RSCH282
Title	Creating Personas for Children with Autism
Start Date	May 2018
End Date	April 2019

Approved - you may commence your research as outlined in your application.

Points the applicant needs to address:	
Independent Reviewer 1:	**Approved**
Independent Reviewer 2:	**Approved**

You must discuss any untoward incident, during this project, which results in the completion of an accident claim form in the first instance to your supervisor as a matter of urgency and then via SST.ethics@ntu.ac.uk.

If you have any queries please do not hesitate to contact your project supervisor or alternatively e-mail SST.ethics@ntu.ac.uk.

Version 1 – 08.09.2016
Confidential

Appendix F. Existing personae gathered from the literature

Sample Persona 1: Mohammad

Background: Mohammad is twelve years old and has only just joined this school as his family has only recently moved to the area. He has Autistic spectrum disorder with severe ID and hearing loss with a short attention span. He does not speak but uses Makaton sign language having learnt quite a few new signs in the four months he has been at this school. Mobile and liable to run away seemingly without warning. Has violent tendencies and a preference for solitary play. He has no awareness of danger.

Learning needs: Staff want him to improve his communication and increase his attention span. The speech therapist believes he could learn a few single-word utterances but could increase his use of sign language both pictorial and signed.

Challenges: Hearing loss and inconsistent eye contact, short attention span and tendency to get distracted by a particular feature of the technical device with which he is working even though it may be irrelevant.

Learning style/likes and dislikes: Likes technology and Lego but is quick to break and dismantle things. Because of short attention span, he is better in an uncluttered environment. Also prefers to work on his own with his favourite teaching assistant.

Sample Persona 2: Angel

Background: Angel is 10 years old. He has just started using functional oral language, even though he still screams for attention. He stands up all the time and walks around the classroom. He exhibits many stereotypic movements - usually grabbing his ears and flapping his hands. He likes a regular routine and does not tolerate changes in routines very well. Sometimes he is "aggressive", and he is obsessed with another pupil that also cries, and screams, and to whom he gets close to in order to hit her. His teacher is his reference and acts as an "intermediary" between him and the rest of the world. Angel is obese due to his bad eating habits that his family cannot control. He has no awareness of danger.

Learning needs: To improve his functional oral language, develop his social skills, learn to control his "tantrums" (he uses aggressive behaviour to get what he wants) and to learn to eat healthier.

Capabilities: He is good at imitating people. He is very observant and a fast learner of things that interest him. He is also good at asking for help when he needs something but will use his own strategies to get things himself.

Technology use: He has good fine and gross motor skills, and can use a mobile, and tablet. He often uses smart boards. Challenges: He displays disruptive behaviours. Sometimes it is difficult to understand his speech. With unknown people, he will often try to run away from the classroom. He is stubborn and very obsessed about routine.

Learning style/likes and dislikes: He likes technology and Lego or other building games. He also loves Peppa Pig, Disney characters, shopping centres, cars, Donny Brook, and music.

Sample Persona 3: Jake

Background: Jake is 12 years old and attends a special school for students with autism. At school, his preferred activity is flicking water from the tap or repetitively running his fingers through sand or other small substances. He does not speak but will try to make his needs known through vocalisations and gestures. He is physically active, strong and can push staff away or try to hit them in order to be left alone. He usually resists any attempts to bring him into a class activity.

Learning needs: To be able to point to indicate a choice. He will select a symbol from a small choice when prompted but needs to develop independence. He also needs to learn to follow an adult choice of activity.

Technology use: Has used a laptop but without apparent purpose or direction.

Challenges: Jake resists the efforts of staff to engage him or demonstrate how he can do things.

Learning style/likes and dislikes: Jake appears to just want to be alone and in control of how he spends his time. Occasionally he likes to look at a book.

Sample Persona 4: Archie

Background: Archie is 11 years old and attends a special school for children with autism. He is non-verbal, shows little variation of facial expression and has no communication system, caregivers have to recognise body language to anticipate needs. He is generally very passive, will allow himself to be lead around the school but takes very little active part in activities. When alone he will rock in his chair, tap the table, and make repetitive sounds.

Learning needs: Archie needs to develop a means of communication so that teachers can begin to find ways to work with him. He resists looking at books and shows little interest in any materials.

Technology use: Has been shown cause and effect games on the iPad and will show some interest when physically guided to engage in them.

Challenges: Archie's level of passivity and inaction. He does not appear to have functional use of his hands beyond repetitive tapping.

Learning style/likes and dislikes: Archie really enjoys music and singing. He will respond to an adult when they engage physically with him, taking his hands to be guided through gestures accompanying songs.

Sample Persona 5: Susanna

Background: Susanna is 11 years old, she attends the first year of secondary education, with the help of an assistant teacher and an educator for the majority of the school time. In September she started a new class at school and, as in all previous times she encounters a new environment or situation, this caused the worsening of some behaviours (e.g. she will run away from the classroom without any warning signs). Susanna talks a lot and she likes to play with her peers in one-to-one relationships.

Learning needs: Since she is curious (in her own peculiar way) about the others, she needs to improve her capacity to tolerate the frustrations in her relationships.

Technology use: She plays videogames on her tablet.

Challenges: Susanna can suddenly act in aggressive and violent way when she doesn't reach her goals. She also has a short attention span.

Learning style/likes and dislikes: Susanna is very creative, spends a lot of time drawing, painting, cutting, pasting…, where she can use her imagination.

Sample Persona 6: Nuno

Background: Nuno Rocha, born in 2005, in Aveiro district, Portugal, lives with his father, mother and a 13-year-old sister. At the age of 3, he was diagnosed with Autism Spectrum Disturbance (level 2 in the scale of severity), with associated cognitive deficits. He currently attends the 4th grade in a Basic School, where he benefits from a specific individual curriculum, including Special Education support, using a structured learning model (TEACCH), and Speech Therapy sessions

Technology use: At home, he prefers to watch TV and play computer games. He only uses his ability to play computer games. He is not able to research information on any search engine, nor does he use the social networks for communication

Challenges: As far as it concerns reading, he recognizes all the letters from the alphabet, but he seems to struggle on the reading process, mostly syllabic, associated to a loss of purpose and hesitations]. He writes with orthographic correction, but he needs support on the structuring of small texts and in answering questions. He makes requests in his areas of interest but has difficulties in answering questions, sharing daily experiences, and beginning and keeping a conversation. He shows difficulties in keeping eye contact, respecting interaction shifts and adjusting to the context and to the interlocutor. In some situations, he verbalizes incoherent phrases and out of context (delayed echolalia).

Appendix G. Personae creation and initial recommendations gathering interview

Questions for personae creation

Participating experts were asked questions from the list below, after they were provided with the mapping of observed children with ASC to behavioural variables, and a set of sample personae for children with ASC.

- Would you describe any combination of the observed children as having similar characteristics?
- Can you classify the observed children according to the similarities in their patterns of behaviours?
- What are the characteristics that lead to the patterns of observed behaviours?
- What do you think the children with the characteristics you have mentioned would have as goals while using VPTs?
- Do you think the sample personae accurately and consistently describe any of the groups of children with similar behaviours?
- What other behaviours or variations of the observed behaviours are likely to be exhibited by other children with ASC while using VPTs?

Questions for gathering recommendations

- How can VPTs be designed to ensure that children with ASC do not face difficulties similar to those recorded in the list of behavioural variables?
- How can VPTs support and encourage the motivations, interests and activities of children with ASC?
- How can VPTs be designed to be easy to learn and use by children with ASC?

**Note: Additional follow-up questions were asked, as appropriate, with each participant*

Appendix H. Persona validation questionnaire

The questionnaire was created using Google Forms and was sent via email to participants. It consists of an instruction, the personae to be validated, and five questions. Questions 1, 2 and 3 require a response that expresses the participants' agreement within the range of 1 – 4, 1 being ‘strongly disagree’ and 4 ‘strongly agree’. Questions 4 and 5 require a response in the form of written text. The instruction and questions are provided below.

Instruction

Thank you for taking the time to complete this survey. Please read all three sections of the persona described below and answer the questions that follow.

Questions

1) Do you agree that the description provided in the "Background" section of the persona described above is consistent with typical behaviours of children with autism spectrum condition?

2) Do you agree that the description provided in the "Use of VPTs" section of the persona described above is consistent with typical behaviours of children with autism spectrum condition?

3) Do you agree that the description provided in the "Goals" section of the persona described above is consistent with typical behaviours of children with autism spectrum condition?

4) Examining the persona as a whole, do you find any of its sections inconsistent in relation to other sections? If yes, please explain.

5) Is there anything else that you would like to add, remove or modify to make the persona more accurate and/or consistent? If yes, please explain.

Appendix I. Recommendations validation interview

Participating experts were asked questions from the list below, after being provided with the set of proposed recommendations.

- Do you think mobile device support will improve the accessibility of VPTs for children with ASC?
- Do you think integrating content that interests children with ASC and making popular suggestions will improve the accessibility of VPTs for children with ASC?
- Do you think visualising information will improve the accessibility of VPTs for children with ASC?
- Do you think managing sounds will improve the accessibility of VPTs for children with ASC?
- Do you think implementing restrictions and limitations will improve the accessibility of VPTs for children with ASC?
- Do you think implementing scaffolding will improve the accessibility of VPTs for children with ASC?
- Do you think making VPTs goal-oriented will improve their accessibility?
- Do you think adding personalisation support will improve the accessibility of VPTs for children with ASC?
- Do you think managing changes will improve the accessibility of VPTs for children with ASC?
- Are there any recommendations that are missing from the provided list of recommendations that you think can improve the accessibility of VPTs for children with ASC?

**Note: Additional follow-up questions were asked, as appropriate, with each participant*

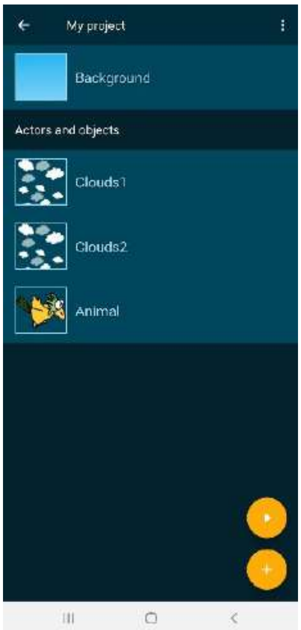
Appendix J. Pocket Code Redesign

Screen 1

Pocket Code:
User can create a new blank project or a project from an example template

Pocket Code Redesign:
User can only create a project from available templates

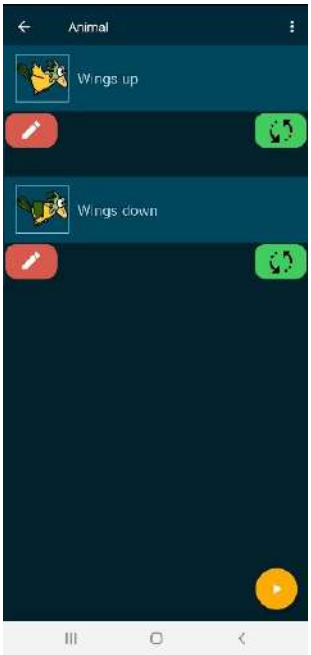
Screen 2



Pocket Code:
User can add objects to template project, as well as run project.

Pocket Code Redesign:
User cannot add new objects to template project, but can run the project.

Screen 3



Pocket Code:
User has access to and can add, remove or edit each object's programming blocks, sprites, and sounds.

Pocket Code Redesign:
User does not have access to an object's programming blocks and sounds, however the user can edit or replace an object's sprite(s) to create a customised animation.