THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

Neon Chalk: Designing Software to Support Drawing as Play for Children with Autism Spectrum Disorders

Grant Shannon

This thesis is submitted in partial fulfillment of the requirements for the Degree of Master of Science at the University of Waikato.

March 2009

Abstract

Neon Chalk is a prototype piece of software designed to support drawing as play, for children with Autism Spectrum Disorders (ASD). It incorporates a minimalist interface to reduce distraction while drawing, compelling colours and sound that are configurable for each user, and an interaction design that makes the stimulus reward outputted by the software contingent on input from the child drawing.

The design and development of the Neon Chalk prototype has motivated and informed the assessment of *user-centred* data gathering techniques. Six children with ASD were involved in this research. The techniques used within this studied are evaluated based on their suitability of use with this challenging user population.

Keywords: autism spectrum disorders, user-centred design, digital environments, interaction, interface.

Acknowledgements

I would like to thank the following individuals:

Sally Jo Cunningham, my ever-suffering supervisor. My use of tense will forever fear the verdant swish of your quill.

Bill Rogers, an XNA aficionado whose knowledge and understanding of just about everything is almost as humbling as it is useful.

Professor Mary Foster, Dr. James McEwan and Dr Eric Messik. Thanks for the loan of your expertise – it's a different flavour of mental ice cream than my own.

The children and staff at Patricia Avenue School, without you this thesis wouldn't exist and the last year wouldn't have been nearly as interesting.

My all-forgiving and ever helpful house elf Tenille. One day I'll give you a sock.

My stolen cat.

Apocalyptica, for being not too heavy and not too soft.

All the other people I like...

Table of Contents

List of Figures

1.0 Introduction

Children with Autism Spectrum Disorders (ASD) don’t play in the same way as other children. They often use toys and objects in an inflexible way or become fixated on a certain aspect of the toy they are playing with. For example, a child with ASD may be preoccupied with the spinning wheels on a car, rather than playing a racing or driving game. Some children with ASD do not give any indication that they want to play with other children, preferring to play by themselves; other children with ASD would like to but they can have great difficulty in letting other children know that they want to.

Looking at software designed for children, are the play activities and games that such software offers appropriate for a population of users that have different play routines and exhibit alternative behaviours during play? Even if the activities and games modelled within this software are appropriate, are the interfaces suitable for children with ASD, or do these children require an interface that has been tailored to their specific needs?

With regard to the development of software tailored to the specific requirements that children with ASD have, which software design methodologies are useful? Once a software methodology has been identified as promising, will the development process it defines and the data gathering techniques it promotes be useful ‘as is’ or will they have to be adapted to the characteristics of this highly varied and idiosyncratic user population?

After pondering the questions posed above, this focus of this thesis coalesced into the following two aims:

1. The first aim was to develop a piece of prototype software that would support a play activity for children with ASD. This first goal was engineered as a way of both providing a means of answering the question posed below, and as a way of applying the answers discovered in a practical fashion that would in turn be subject to evaluation.

2. The second aim was to explore user-centred data gathering techniques as a means of involving children with autism spectrum disorders in the design and development of software tailored for their use.

With reference to the satisfaction of the second goal of this thesis, it was recognised that the question it posed would be difficult to answer in isolation, on a purely theoretic basis. At this point, the first goal of this thesis was born, and it was decided that through the process of designing and developing a piece of prototype software to support a play activity for children with ASD that the data gathering techniques and participant involvement processes suggested by a user-centred design methodology could be accessed for this user population.

The sections within this thesis contribute to the resolution of the two goals presented above in the following ways:

Section 2 outlines current research and understanding of autism spectrum disorders, with specific attention paid to the sensory sensitivity, language, communication and social deficits experienced by the population. It provides justification for the goal of supporting play for children with ASD through a description of the relationship between autism, play and learning. The three leading cognitive models of autism are discussed and the role they played in the research undertaken during this thesis is outlined. Finally, the role that computing and software plays, and has the potential to play, in the lives of children with ASD is discussed. The section concludes with a discussion of user-centred design and its suitability as a design methodology for the software development embarked upon during this thesis.

Section 3 is a literature review that considers five research papers that had an impact on the research and investigations that occurred during this thesis. Similarities and differences between the studies and the one undertaken during this thesis are discussed, with emphasis placed on their influence on this thesis.

Section 4 discusses which data gathering techniques conventionally employed by a user-centred design strategy were used during this thesis (and which were not) and why. Adaptations to the techniques that were necessary given the specific autistic characteristics possessed by the participants involved are discussed.

Section 5 describes the first investigation undertaken during this thesis, Investigation 1, in which the day-to-day routine of the participants within the classroom environment was observed. From this observation the 'zeitgeist' within the classroom was sampled and the effect that this had on the role of play within that environment was also glimpsed. From the observations made during this period, *drawing* was selected as the form of play that would be supported by the prototype software developed for this thesis.

Section 6 describes two investigations that explored how the participants involved in this thesis interacted with software. The first of these, Investigation 2, focused on computer game software that the children were familiar with and enjoyed. The second investigation, Investigation 3, focused on the drawing/art package Kid Pix Studio 4 (an internationally best-selling package for children).

Section 7 describes the Neon Chalk software prototype that was developed for this thesis. The first half provides a series of walkthroughs from the perspective of the users that Neon Chalk was designed to support, and the second half focuses on a discussion of the key features within the prototype and their development.

Section 8 describes Investigation 4, where the participants involved in this thesis had the opportunity to interact with the Neon Chalk software prototype developed as part of this thesis. In doing so, their interaction served as a short evaluation of the prototype and its features.

Section 9 pulls together the findings of the four investigations undertaken during this thesis, along with insights sourced from alternative sources that were consulted during this thesis. These findings are interpreted with regard to the two goals of this thesis and the contribution this thesis makes to the greater understanding of software design and development for children with ASD.

2.0 Background

Children with autism spectrum disorders possess a number of characteristics that separate them from their neurotypical peers. Within this section autism spectrum disorders are discussed with reference to the characteristics that are attributed to individuals upon the spectrum, but also with regard to play, learning, the role of computing and suitable methodologies for the design of software tailored to their specific needs.

2.1 Autism Spectrum Disorders

Autism Spectrum Disorders or ASD are a subset of three of the five disorders that make up the Pervasive Developmental Disorders or PDD (Lord et al., 2000; Strock, 2007). All three of the disorders are characterised by qualitative abnormalities in social interactions and patterns of communication, as well as severely restricted interests and highly repetitive, stereotyped behaviour (World Health Organisation, 1992).

The three disorders are autism, Asperger's syndrome and PDD-NOS (Pervasive Developmental Disorder Not Otherwise Specified). The following is given as the diagnostic criteria for autism or code 299.00 (Autistic Disorder) within the DSM-IV-TR (American Psychological Association, 2000):

A. A total of six (or more) items from (1), (2), and (3), with at least two from (1), and one each from (2) and (3):
   1. qualitative impairment in social interaction, as manifested by at least two of the following:
      1. marked impairment in the use of multiple nonverbal behaviors such as eye-to-eye gaze, facial expression, body postures, and gestures to regulate social interaction
      2. failure to develop peer relationships appropriate to developmental level

3. a lack of spontaneous seeking to share enjoyment, interests, or achievements with other people (e.g., by a lack of showing, bringing, or pointing out objects of interest)
4. lack of social or emotional reciprocity

2. qualitative impairments in communication as manifested by at least one of the following:

1. delay in, or total lack of, the development of spoken language (not accompanied by an attempt to compensate through alternative modes of communication such as gesture or mime)
2. in individuals with adequate speech, marked impairment in the ability to initiate or sustain a conversation with others
3. stereotyped and repetitive use of language or idiosyncratic language
4. lack of varied, spontaneous make-believe play or social imitative play appropriate to developmental level

3. restricted repetitive and stereotyped patterns of behaviour, interests, and activities, as manifested by at least one of the following:

1. encompassing preoccupation with one or more stereotyped and restricted patterns of interest that is abnormal either in intensity or focus
2. apparently inflexible adherence to specific, non-functional routines or rituals
3. stereotyped and repetitive motor mannerisms (e.g., hand or finger flapping or twisting, or complex whole-body movements)
4. persistent preoccupation with parts of objects

B. Delays or abnormal functioning in at least one of the following areas, with onset prior to age 3 years: (1) social interaction, (2) language as used in social communication, or (3) symbolic or imaginative play.

C. The disturbance is not better accounted for by Rett's Disorder or Childhood Disintegrative Disorder.

As can been seen from the breadth of the criteria outlined above, there can be a distinct difference in degree and form even between individuals diagnosed with the same disorder upon the spectrum. It is this heterogeneity amongst individuals diagnosed upon spectrum that has lead to anecdotes such as, “If you’ve seen one child with autism, you’ve seen one child with autism”.

Asperger’s syndrome is nearest to autism in symptoms and probable causes (Lord et al., 2000), although unlike autism, there is no significant delay in language development, no qualitative impairments in communication and no lack of varied, spontaneous make-believe play or social imitative play (American Psychiatric Association, 2000). Pervasive developmental disorder not otherwise specified (PDD-NOS) is diagnosed when the criteria are not met for a more specific disorder amongst those specified within the set of pervasive developmental disorders (Lord et al., 2000; Strock, 2007; American Psychiatric Association, 2000).

High-functioning autism (HFA) is an informal term applied to autistic individuals who are in some sense able (Frith, 2004). One definition is that individuals with HFA have an IQ above some cut-off value such as 85 (Baron-Cohen, 2006). There is no consensus as to the definition, although its use implies a high level of ability to function within society, in comparison to others diagnosed upon the spectrum.

The extent of the overlap between HFA and Asperger’s syndrome is unclear (Klin, 2006). ‘High-functioning’ or ‘low functioning’ autism are not recognised diagnoses in the DSM-IV-TR (American Psychological Association, 2000) or the ICD-10 (World Health Organisation, 1992), although, as mentioned above, they are commonly used informal references for an individual’s position on ‘the spectrum of ability’.

Most recent investigations estimate a prevalence of 1–2 cases diagnosed per 1,000 for autism and at least 6 per 1,000 for ASD overall (Newschaffer et al., 2007). There has been some concern however, that due to inadequate data, these figures may underestimate the true prevalence of ASD cases (Caronna et al., 2008). Boys are affected with ASDs more frequently than are girls, with an average male-to-female ratio of 4.3:1 (Fombonne, 2005 in Newschaffer et al., 2007).

2.2 Sensory Sensitivity

Sensory sensitivity is a characteristic that is not included in either of the two leading diagnostic definitions (ICD-10 and DSM-IV-TR), but is included in alternative sources (National Autistic Society, 2008; Williams, 1996).

The National Autistic Society provide the following description of sensory sensitivity within individuals with ASD:

> This can occur in one or more of the five senses - sight, sound, smell, touch and taste. A person's senses are either intensified (hypersensitive) or under-sensitive (hypo-sensitive).
>
> For example, a person with autism may find certain background sounds, which other people ignore or block out, unbearably loud or distracting. This can cause anxiety or even physical pain.
>
> People who are hypo-sensitive may not feel pain or extremes of temperature. Some may rock, spin or flap their hands to stimulate sensation, to help with balance and posture or to deal with stress.
>
> People with sensory sensitivity may also find it harder to use their body awareness system. This system tells us where our bodies are, so for those with reduced body awareness, it can be harder to navigate rooms avoiding obstructions, stand at an appropriate distance from other people and carry out 'fine motor' tasks such as tying shoelaces. (National Autistic Society, 2008).

The likelihood of sensory sensitivity amongst children with ASD was taken into account during the investigations of this thesis (during the researcher's classroom interactions with child participants; see Sections 5.0, 6.0, and 8.0). It was also a factor that affected the design of the software prototype developed during this thesis (see Section 7.0).

2.3 Language, Communication and Social Deficits

As can be seen in Section 2.1 above, language delay is one the key diagnostic features of those with autism (American Psychological Association, 2000). "It is estimated that around half of individuals with autism will not be able to use language in any meaningful way, with the remainder showing, at the very least, significant delays in social communication (Parisse, 1999 in Whitehouse, 2006). Although this population's language delay is well established, the exact nature of the language disorder remains, at present poorly understood" (Whitehouse, 2006, p. 38).

Individuals with ASD who have verbal language often have bizarre linguistic output, with frequent pronoun reversal, limited social reciprocity, and scripted or echolalic speech. Social skills deficits include lack of eye-to-eye gaze and inappropriate facial expressions, body posture and gestures (American Psychological Association, 2000). Many individuals with ASD also experience anxiety during social interactions, which can result in an increase in abnormal social behaviours (Kuusikko et al., 2008).

The effect that the language, communication and social deficits experienced by many children with ASD has on software design is expanded upon below, in Section 2.7. In relation to how such deficits directly affected the investigation methodology and data gathering techniques used in this thesis, see Section 4.0.

2.4 Autism, Play and Learning

Play augments social, communicative, and linguistic ability, all of which are impaired in children with ASD (Bruner, 1986 in Preissler, 2006). As can be seen within the section of DSM-IV-TR reprinted in Section 2.1, "a lack of varied, spontaneous make-believe play or social imitative play appropriate to developmental level" is one of the criteria used to diagnose autism. This criterion is notably missing from the diagnostic criteria for Asperger's syndrome, but could be present in an individual diagnosed with PDD-NOS (American Psychological Association, 2000).

This diagnostic acknowledgement of deficit, in the forms of make-believe and social play mentioned above, is supported by a significant body of research (Leslie, 1987; Jordan, 2003; Rutherford & Rogers, 2003; Herrera et al., 2008). Additionally, research also exists that shows that children with ASD experience qualitative abnormalities in earlier forms of play, i.e. sensorimotor and functional play (Morgan, 1986; Losche, 1990; Williams et al., 2001).

Play allows children to learn many skills, such as decision-making, turn taking, and significantly, language skills and social interaction, monitoring and reciprocity (Preissler, 2006). Both Piaget (1962) and Vygotsky (1966, 1978 in Preissler, 2006) acknowledged the significance of symbolic play for normal development. According to Vygotsky, play is not parallel to development, but rather one of the forces that drive it.

According to Piaget, there are distinct stages of play throughout a child's development. Initially, young children display and engage in sensorimotor play. In this kind of play, infants and toddlers experiment with the interaction of their bodies with people and the environment. This ranges from early behaviours such as thumb sucking and grasping activities to more advanced behaviours such as exploring toys by mouthing them or smashing two toys together. During this time, children learn cause-and-effect relationships. While not symbolic, this kind of play serves as a basis for more sophisticated skills.

Symbolic play requires imagination, as children learn to substitute one object for another, such as using a banana as a telephone. More advanced stages include the ability to dynamically switch from reality to make-believe. At its latter stage, children can engage in games that require turn taking and rule following. Symbolic play is a crucial foundation for normal social growth.

The activity of drawing, which as a result of Investigation 1 (see Section 5.0) was selected as the form of play that was supported in the software prototype developed during this thesis, traverses both the sensorimotor and symbolic stages of play described above. At its earlier stages, when a child is developing their drawing abilities and has not set him- or herself a task of attempting to represent any particular thing, the child experiences drawing as sensorimotor play (they ‘play with the act of drawing’; Dailey, 1984). As their abilities with drawing develop, the activity becomes integrated into their burgeoning symbolic play.

Given the importance of play as a source of developmental growth, and the deficits in its execution that are experienced by children with ASD, the support of play for children with ASD has the potential to augment crucial areas of development, areas where acknowledged impairments exist.

2.5 Cognitive Models of Autism

Within the literature three cognitive models of autism have become especially dominant (Volkmar et al., 2004). The ‘theory of mind’ hypothesis concentrates on the difficulty that individuals with autism have in assigning mental abilities to others and themselves. This deficit leads to a difficulty in understanding individuals as people with intentions (Baron-Cohen, 2000).

A second cognitive model focuses on ‘weak central coherence’, a failure to incorporate local details into a global whole. Within this frame of reference, individuals with autism focus on individual elements rather than the composition of those elements. As a result of this, individuals with autism have difficulty in extracting overall meaning from a situation (Happe & Frith, 2006).

The last of the dominant cognitive models, the ‘executive dysfunction’ hypothesis, suggests that individuals upon the spectrum have difficulty in self-organising cognitive functions toward the accomplishment of a predetermined goal. According to this theory, individuals with autism have difficulty learning new skills due to a cognitive style that is characterised by uncontrollable repetition, reduced forward planning and poor self-regulation (Hill, 2004).

It was this last cognitive model of autism, the ‘executive dysfunction’ hypothesis, that was directly useful during this thesis. Section 4.8 details the review of a problem classification scheme originally designed for use in classifying the problems encountered during the evaluation of computer games for children. The executive dysfunction hypothesis was used as a comparison during this review, to see if the classification could be applied, in a similar role, to children with ASD (see Section 4.8 for details of the review and Sections 5.0 and 6.0 for instances where the classification was used).

2.6 Computing, Children and Autism

The issue of technology use with young children is controversial. The argument against is based primarily on the detrimental effects on health and learning caused by possible cognitive exhaustion (Healy, 1998). On the other end of the spectrum, advocates such as Plowman and Stephen (2003) have conducted a multitude of investigations which favour a guided interaction with the technology and involve the social sharing of the experience with others. Papert (1996) has argued that computers can act as a environment in which social and intellectual development can occur, contingent on playful exploration forming the foundation of task. Levin and Rosequest (2001) directly oppose this line of reasoning, suggesting that individualised and open-ended opportunities for play are discouraged by the constrained and repetitive interactions offered by technological artefacts. A lot of this debate however, focuses on the aspects of traditional hardware, peripherals and interfaces that separate a child's interactive experience with technology (and computers in particular) from the less constrained, more developmentally appropriate form found in a low-tech setting, e.g. the game of catch presented in the opening paragraph of (Levin & Rosequest, 2001).

Some children with ASD exhibit self-injurious behaviours. The most common forms of these behaviours include: head banging, hand biting, and excessive self-rubbing and scratching. In more extreme cases, this tendency towards self-injurious behaviour can severely restrict the toys and artefacts that parents/caregivers feel are safe to provide the child with, especially with regard to unsupervised play. Software can offer an alternate in these situations, allowing the child to experience play activities similar to those that use prohibited artefacts or aids, while at the same time reassuring the parents/caregivers that access to such activities hasn't increased the potential for harm to come to the child.

The sensory sensitivity experienced by many children with ASD (see Section 2.2) can adversely affect the types and number of play activities that are available to them. The ability to control the form and aspect of a variety of stimuli (colour, sound, motion etc.) within a software environment makes it uniquely suited to such individuals, and can offer them the opportunity to engage in activities that they would otherwise find intolerable.

As suggested by the diagnostic criteria presented in Section 2.1, and with specific focus on the sensory sensitivity discussed within Section 2.2, children with ASD can vary widely in terms of the specific autistic characteristics and sensory sensitivities they possess. This can often mean that the same play activity, while suitable for one child with ASD, is unsuitable for another. Software offers the opportunity to support a play activity for multiple children with ASD by customising aspects of the activity to their individual needs.

Many children with ASD become anxious when exposed to novel situations, and can be distressed by what they perceive as the random occurrences they commonly associate with such situations. The predictable environment that can be created with software can offer a sanctuary of sorts to such individuals, an environment in which they can relax and feel reassured in the knowledge that they can predict the outcome of their interactions.

Given the deficits in play experienced by children with ASD (see Section 2.4), and the multitude of factors that can restrict the play activities available to those children (see above), the safe, controllable, customisable and predictable environment that is possible to create with software seems uniquely suited to offer support to this group of users in their play activities.

2.7 A Suitable Design Methodology

User-centred design is a design philosophy and a process in which the *needs, wants, and constraints* of the end user of a system or piece of software are given extensive attention at every stage of the design process (Noyes & Barber, 2001). User-centred design is a multiple stage problem solving process, that not only requires designers to analyse and predict how users are likely to use a system or piece of software, but also to *test the validity of their assumptions of user behaviour* with *real world tests* with *actual users*.

The chief difference from other interface design philosophies is that user-centred design attempts to *optimize the user interface* around how people can, want, or need to work, rather than *forcing the users to change* how they work to accommodate the system or software.

Participatory design is an approach to design that attempts to actively involve the end users in the design process to help ensure that the product designed meets their needs and is usable (Muller, 2003). It is important to understand that this approach is focused on process and is not a design style. Participatory design can be viewed as user-centred design, with an additional component of *active user participation* within the *design process*.

The design methodology used during development of the software prototype produced during this thesis was *user-centred*, but not *participatory*. To see why this was the case, the role that the users, a group of children with ASD (see Section 4.1), played during the development process can be classified using definitions borrowed from Allision Druin's paper, *The Role of Children in the Design of New Technology* (Druin, 2002). The definitions of the roles depicted in the paper are described below:

- "In the role of *user*, children contribute to the research and development process by using technology, while adults may observe, videotape, or test for skills. Researchers use this role to try to understand the impact existing technologies have on child users, so future technologies can be changed or future educational environments enhanced." (Druin, 2002, p. 4)
- "In the role of *tester*, children test prototypes of technology that have not been released to the world by researchers or industry professionals. As a tester, children are again observed with the technology and/or asked for their direct comments concerning their experiences. These testing results are used to change the way future iterations of the pre-released technology are developed." (Druin, 2002, p. 4)
- "In the role of *informant*, children play a part in the design process at various stages, based on when researchers believe children can inform the design process. Before any technology is developed, children may be observed with existing technologies, or they may be asked for input on

design sketches or low-tech prototypes. Once the technology is developed, children may again offer input and feedback." (Druin, 2002, p. 4)

- "In the role of *design partner*, children are considered to be equal stakeholders in the design of new technologies throughout the entire experience. As partners, children contribute to the process in ways that are appropriate for children and the process." (Druin, 2002, p. 4)

During the investigations undertaken during this thesis, the children involved served as *informants*, as defined by the above classification. They were observed within their work and play environment (Investigation 1), as well as while interacting with existing technologies (Investigation 2 and 3). All of the information collected from these three investigations was used to inform the software design process. Finally, once a software prototype had been developed, the children were observed testing it (Investigation 4), with data gathered offering feedback and informing the development of future iterations of the prototype.

For the design methodology used during this thesis to have been classed as *participatory*, the end users of the software prototype that was developed, a group of children with ASD, would have had to have played the role of *design partners* during that development. They did not. While Druin's definition of *design partner* does include the phrase "appropriate for children and the process" (Druin, 2002, p. 4) the deficits in language, communication and social functioning (see Section 2.3) possessed by the children involved meant that it was not possible or appropriate for them to play that role. As discussed in Section 4.4 and 4.5, verbalisation and direct inquiry techniques were not possible due to the aforementioned language, communication and social deficits. In the same vein, the conversation and active collaboration that children as *design partners* should participate in (as described in *The role of children in the design of new technology*) during the development of the target software was not possible with this group of children.

This finding contradicts the experience of Wendy Keay-Bright et al., as described in her paper The Reactive Colours Project: Demonstrating Participatory and Collaborative Design Methods for the Creation of Software for Autistic Children

(Keay-Bright, 2007a). Within this paper she describes her and her teams experience with a group of children with ASD, working with the children as design partners to help develop the ReacTickles suite of software. As can been seen from the title and content of the paper, Keay-Bright classifies the design methodology that they used as not just user-centred, but participatory. She and her team may have been working with children with different characteristics from those who participated in this study, and their participant group was larger as well; these factors may have allowed the Reactive Colours Project to apply a fully participatory design methodology. For the research project described in this thesis, participation as design partners was beyond the capabilities of the children involved.

2.8 Conclusions

This section gave a brief review of the current research and information available on ASD (Autism Spectrum Disorders). Areas such as the diagnostic criteria, sensory sensitivity, and the language, communication and social deficits experienced by many children with ASD were discussed, with specific mention of their impact on the investigations undertaken during this thesis. The role of play within learning was discussed with regard to the development of a child with ASD. The impact this had on the choice of supporting drawing as a form of play within the software developed during this thesis was described. The leading three cognitive models of autism were outlined, and the ‘executive dysfunction hypothesis of autism’ was highlighted as being directly useful in reviewing a prospective classification scheme. The issue of computing and children was discussed, both in general terms and with specific reference to children with ASD. Finally, the design methodology that guided the design and implementation of the investigations and software development undertaken during this thesis was described.

3.0 Related Work

Five research papers that influenced the design and implementation of the research undertaken during this thesis are discussed below. Aspects of the findings from those papers that were used as justification for design decisions or for the development of working hypotheses are emphasised. The ways in which these five studies differ from the research undertaken during this thesis are also highlighted and the reasons for these differences are discussed.

3.1 The Reactive Colours Project and ReacTickles Software

Wendy E. Keay-Bright et al. have developed a suite of recreational software (the ReacTickles Project) that promotes natural interactions in the form of 'tapping, smoothing, and circling' rather than keyboard an mouse interaction; their goal is to develop software that allows children on the autistic spectrum to explore the technology rather than be dominated by it (Keay-Bright, 2007b). This embracing of embodied or untethered technology provides an environment that is more developmentally appropriate for young children as well while side stepping the issues that arise from incompatibilities with more invasive interface technologies for children with ASD (such as environments that use VR helmets (Strickland, 1996) or custom harnesses (Ramloll et al., 2004)).

Within the work of Keay-Bright et al. the benefits which the tangible interface, such a Smartboard interactive whiteboard, has for enhancing the learning capacities of autistic children are discussed and promoted. The results of the deployment of ReacTickles software to tangible interfaces, and the rationale Keay-Bright provides for that deployment, inspired (along with the work of Deautenhahn, discussed below) a similar use of such interfaces within the research described in this thesis.

Keay-Bright demonstrates the importance to the design process of participation with end-users and interdisciplinary collaboration with experts. The context of the Reactive Colours Project is the interaction between autistic children and computers in education. Whereas computers in education are conventionally associated with task-based learning, her research uses the computer as a tangible interface for embodied play activities. The importance Keay-Bright places on end-user participation and interdisciplinary collaboration is mirrored within the work presented within this thesis, with specific discussion on the role of experts during this project presented in Section 4.5.3.

Keay-Bright makes two claims with regard to the participatory design process. The first is that there is an important relationship between the participatory design process and the design of play for autistic children. End-user participation in this context allows the highly particular responses and reactions of autistic children to be recorded and included in the evolutionary design process. While, the experience and findings of the research undertaken during this thesis support this claim, the specific *level of participation* Keay-Bright claims that she and her colleagues experienced with children with ASD as end-users was not experienced during this thesis (see Section 2.7).

The second claim Keay-Bright makes is that the interdisciplinary approach to collaboration presents a challenging paradox for designers, as it requires both imaginative and empirical design methods. Whilst it is often critical to have a quantitative aspect to research to satisfy scientific approaches, it is of equal importance, within this area of research, to understand the idiosyncratic behavioural patterns of individuals on a spectrum of autistic difference. This paradox was experienced directly by the researcher during this thesis, specifically, whilst determining a suitable method for analysing the video data gathered during Investigation 2 to 4. This process is described and the outcome discussed in Section 4.7 and 4.8.

3.2 The AURORA Project

The AURORA project of Dautenhahn et al., aims to develop an autonomous, mobile robot as a therapeutic tool for children with autism. Within her paper, *Design Issues on Interactive Environments for Children with Autism* (Dautenhahn, 2000), Dautenhahn describes the benefits of interaction scenarios that allow children to move freely and interact using the whole body and that do not constrain them by requiring them to sit at a desk or wear special devices.

Kerstin Dautenhahn suggests that the ‘embodied interaction’ facilitated within environments such as these can provide new aspects to learning, “helping children with autism to explore their bodies and how the body interacts with the environment. Thus, the bodily interaction itself can be as therapeutically relevant as the ‘content’ of the interaction.” (Dautenhahn, 2000, p. 6).

The scenario presented within Dautenhahn’s paper, of a child interacting with a floor dwelling robot, put forth an argument as to the benefits of ‘untethered interaction’ that was extremely compelling. “Children with autism often show a distorted and usually ‘indifferent’ attitude towards their body. Self-injurious behaviour, abnormal complex behaviours of the body and eating disorders can be observed. These indications of body image distortions might contribute to their problems in relating to other people” (Dautenhahn, 2000, p. 5-6). The argument presented within Dautenhahn’s paper was that through the use of ‘untethered’ interfaces, the learning experience could also become a therapeutic one, where the child is given further opportunity to reconcile their body with the interactions that occur around them.

The ‘untethered’ principal can be applied to software that runs on platforms other than robots. Keay-Bright et al. reach a similar conclusion based on their work. Observations undertaken during this thesis (see Section 5.0) support this principal, and the direct evidence those observations provide was the basis for the implementation of an untethered interface via the deployment of the Neon Chalk prototype to a Smartboard (see Section 7.0).

3.3 The MEDIATE Project

The MEDIATE project of Pares et al. seeks to promote creativity, exploration and enjoyment in low functioning autistic children who have no verbal communication. Within their paper, Pares et al. propose that MEDIATE, an interactive environment that generates real time visual, aural and vibrotactile stimuli, is a safe environment in which such children can experiment with interaction.

The design of MEDIATE was guided by the objectives of giving low functioning children with ASD a sense of agency and enhancing their non-repetitive actions. The hope was to foster natural interaction through the use of non-invasive technology and non-representational visuals. This focus on the interactions that children with ASD could have within software, and the effect that the nature of those interactions would have, was mirrored within the software development undertaken during this thesis.

Two key facets of the interaction design of MEDIATE, the low level of latency between input from the child and output from the software, and the use of non-representational visuals, were transferred across to the software design undertaken during this thesis.

3.4 Developing Symbolic Play Through Virtual Reality

Herrera et al. have undertaken two case studies with a VR tool they have developed to explore the use of virtual reality environments in supporting symbolic play amongst children with ASD. According to Herrera et al., "VR offers the advantage, for teaching pretend play and for understanding imagination, of it being possible to show these imaginary transformations explicitly" (Herrera et al., 2008, p. 143).

They examined the effectiveness of using a VR tool specifically designed to work on teaching understanding of pretend play. During part of the intervention implemented by Pares et al., the transformation of one object within the environment into another object is used as a method of describing the concept of symbolism, i.e. that one object 'is like' another object. The results they present showed a significant advance in pretend play abilities after the intervention period in both participants, and an increase in the ability of one participant to generalise the skills learnt to situations other than those explicitly encountered during the intervention.

The VR tool developed by Herrera et al. used representational graphics, which was a direct contrast to the non-representational graphics used in the ReacTickles software of Keay-Bright et al. and the MEDIATE project of Pares et al. The rationale behind the use of these representational graphics by Herrera et al. was that it was necessary to depict the objects within the VR environment as realistically as possible, to avoid confusing the participants as to what each object was. The fact that during part of the intervention these objects were transformed meant that it was even more important that the participants understood what the object was before the transformation and what it had become after the transformation had occurred.

The refined goal and specific research aims that Herrera et al. had during this research separates it quite distinctly from the research undertaken during this thesis. They were concerned with supporting symbolic play specifically, through the intervention of a task-oriented tool, while the software prototype developed during this thesis (see 7.0) was designed to support a play activity and not a stage of play (see Section 2.4). The nature of the activity supported in the software prototype, drawing, leant itself toward an open-ended assignment of task by the user, in stark contrast to the task-driven assignment of goal described within the work of Herrera et al.

3.5 TouchStory

TouchStory is a software game developed by Davis et al. that aims at improving the understanding of narrative by children with autism. In addition to specific investigation with TouchStory, Davis et al. intend to investigate to what extent the understanding of narrative of children with ASD have can be improved through the introduction of simple game-like tasks that address primitive components of narrative. Their design goal to 'keep things simple', introducing features only if necessary to provide each individual child with a focussed and enjoyable game, is very similar to design goals that emerged during the development of the software prototype for this thesis (see Section 7.0). As well as this broad design goal, Davis et al.'s focus on issues of reward, feedback, and opportunities for reasoning (about the task and/or their own performance) that the software provides the children is mirrored in the investigations and software development undertaken during this thesis. During all the investigations undertaken during this thesis (see Sections 5.0, 6.0 and 8.0), observations were made with regard to the effectiveness of rewards provided by the interactions the children were involved in and the relationship reward had with those interactions.

The major point of difference between the development of TouchStory and the development of the software prototype created during this thesis, was the focus of that development. Davis et al.'s research is focused on improving an aspect of the cognitive process that is acknowledged as deficient within children with ASD, i.e. narrative. As discussed at the end of Section 3.4, the research undertaken during this thesis explores the user-centred design process by developing prototype software that supports drawing for children with ASD, not with investigating a *specific* deficiency that the population is acknowledged to possess.

3.6 Conclusions

All five of the research projects discussed within this section contributed to the research undertaken during this thesis. The Reactive Colours Project of Keay-Bright et al, served as the inspiration for this thesis, and as such had much in common with the goals and practice undertaken during it. However, as outlined in Section 2.7, Keay-Bright's claim that a fully participatory design methodology was used during the development of the ReacTickles suite of software, is contrary to the experience the researcher had of working with the children with ASD who participated in this thesis.

Dautenhahn et al.'s paper describing their AURORA project supported the case made within Keay-Bright et al.'s research for the use of 'untethered interfaces' for use with children with ASD. Although the AURORA project dealt with the interaction of children with ASD with robots, the observations recorded and the lessons learnt by the Dautenhahn et al. were equally applicable to the design of software for children with ASD.

The MEDIATE project, while it focused specifically on 'low functioning' children with ASD, contained material relevant to this thesis. Design focused on the interactions that were possible within software, and the impact that those interactions would have on the children with ASD, was mirrored within the development of the software prototype created during this thesis.

The last two projects examined within this section, Herrera et al.'s and the work of Davis et al. with TouchStory, demonstrated that while the focus of the these two research initiatives was narrower than that of this thesis, that similar design techniques were being applied across the studies.

4.0 Adaptations to User Centred Data Gathering Techniques for use with Children with Autism Spectrum Disorders

This section discusses the difficulties encountered in the various software evaluations undertaken during the course of this project, and the adaptations to that process that were decided upon given these difficulties.

The two factors these difficulties arose from were part and parcel of the user population involved: children diagnosed on the autistic spectrum. Both the fact that they were children, as opposed to adults, and that they were possessed of an individually varied subset of the characteristics symptomatic of being diagnosed with ASD (see Section 2.0), meant that there were numerous challenges that needed to be overcome.

As a review of the current research and techniques available when evaluating software with children (especially game software) and the considerations that need to be made when using these techniques, Wolmet Barendregt's Ph.D. thesis *Evaluating fun and usability in computer games with children* (Barendregt, 2006) was an invaluable resource. The techniques and considerations outlined below are presented in a similar manner to that document.

4.1 Participants

Seven children with ASD were involved with this thesis throughout its course. They were all enrolled in one of two classrooms, referred to in this thesis as Site 1 and Site 2, at the Patricia Avenue School, a school for children with special needs that is affiliated with the University of Waikato. Figure 1 below provides summary information on each of the participants:

	Classroom	
Participant	Site 1	Site 2
A	5 year old male	
B	5 year old male	
C		7 year old male
D		8 year old male
E		5 year old male
F		5 year old female
G	5 year old male	

Figure 1: Age and gender of participants, categorised by participant and site.

Participants A to F participated in the investigation (see Section 5.0). Subsequent investigations (see Sections 6.1, 6.2 and 8.0) used video recording as a means of data gathering, which unfortunately resulted in the withdrawal of Participant F from further involvement in the project due to concerns expressed by her parent/caregiver. Participant G was enrolled at Patricia Avenue School in the second term and thus was only eligible for participation in the latter three of four investigations.

Given the small number of participants involved in this thesis and the widely ranging subset of 'autistic characteristics' possessed by each child (see Section 2.0), it was important and valuable to have continued involvement from each of the children from investigation to investigation. Similar to a short term longitudinal study, this retention of participants allowed the researcher to observe and account for characteristics and behaviours of the children which only became noticeable over the extended period time spent with them.

4.2 Suitable Environment for User Trials

There are advantages and disadvantages to conducting observational user trails in a lab compared to a setting more natural to the participants. However for the participants involved in the user trials undertaken during this thesis, the choice

was clear. Given the anxiety, stress and increase in ‘stimming’ or stereotyped, repetitive behaviour that can occur when children with ASD are introduced to novel surroundings, conducting observational user trials in the lab was inappropriate and would be less effective than conducting user trials in an environment the participants were familiar with.
Given the exploratory aims of this thesis, observing the participants in an environment they were familiar with and had experience being in, allowed more authentic data to be gathered.

4.3 Ethical Considerations

In accordance with the guideline’s set out by the School of Computing and Mathematical Sciences at the University of Waikato, applications were submitted to and received from the SCMS Ethics Committee for each of the four investigations carried out in the course of this project.

A copy of the research consent forms that were signed by the Principal of the Patricia Avenue School can be seen in Appendix 1 and 2. The Bill of Rights that she was provided with can been seen in Appendix 3. Copies of the cover letters and parental consent forms sent home to parents during the investigations of this thesis are displayed in Appendix 4 and 5.

4.3.1 Consent

As part of the ethical submission process for each of the investigations undertaken in this project, written consent was received from both the school that the children attended and the parents of each child involved in the project.

Parents were notified that video material recorded during the investigations undertaken amidst the project would only be viewed the researcher and his supervisor. Any additional use of the material would only take place after further consultation and provided consent was given.

In the user tests performed for this thesis the children were asked if they wanted to participate before every session. This was phrased in an age appropriate manner such as “Would you like to play on the computer this morning?”. In those instances when this request was denied, then the next participant was asked and so on until all the participants at a particular site had been asked. Due to the well documented problems children that are diagnosed with ASD can experience with understanding and using spoken language (see Section 2.3), care had to be taken with inferring both understanding of the request and interpreting the reply given. The children’s teachers and other staff present proved invaluable in this effort, helping to facilitate understanding between the researcher and the children. It was made clear to the staff that if the children didn’t wish to participate or if at any time they wanted to stop the session, then that would be perfectly fine. If at the end of a testing period, time remained, then any children who had responded in the negative to the first request (and thus had not participated in the session) were asked again. If they responded in the negative for a second time, then it was decided that they did not wish to participate in the session for that day.

4.3.2 Deception

As mentioned in 4.3.1, the difficulties that many children with ASD have with understanding and using language, especially spoken language, mean that having a high level of confidence in whether or not they have understood what they have been told in any particular instance can be difficult.

With the help of the staff at each site, the children were informed of what they were being asked to do and why. As with the requests described in 4.3.1, the language used was age appropriate.

An example of this was when the teacher at Site 1 described the purpose of Investigation 1 (see 5.0 for details), to her classroom: “Grant [she touches the researcher’s shoulder] is here to see what we do everyday, so he can get to know you all better.”

At no point in the project were any of the children deliberately deceived.

4.3.3 Debriefing

It was decided that formal debriefing was inappropriate for the children participating in the user trials undertaken during this thesis. In the best case, the cognitive, social and communicative deficits exhibited by the children participating in this thesis would have made determining understanding of the debriefing hard to determine. In the worse case, those same deficits would have made such a formal interaction distressing for the majority of this project's participants, which would have been counter to the ethical basis for the debriefing.

Two of the children, in the investigations that involved them being videotaped, expressed a desire to see a portion of the recorded material. When this was requested, it was fulfilled and in this way an ad-hoc debriefing given.

4.3.4 Withdrawal from the Investigation

Parents were informed of their right to remove their children, at any point, from a particular investigation or the project overall. This right was exercised by the parent of Participant F before the beginning of the Investigation 2, due to concerns with regard to her child being videotaped. As video recording was used as a data gathering method throughout the three investigations that occurred after this decision, Participant F was excluded from further involvement in this thesis.

Likewise, if a teacher wanted a test session to stop or have a child removed from an investigation or the project, then that request would have been enacted immediately. This, however, did not occur during the course of the project.

Similarly, all parents were informed of their right to demand that any of the video material of their children recorded as part of an investigation be destroyed at any point.

As mentioned in 4.3.1, the child in any user test had the right halt the session at any time. If the child seemed agitated or uncomfortable at any point during a user test, they were asked if they wished the session to stop. Again, age appropriate language was used, and staff acted as interpreters, as needed.

4.3.5 Confidentiality

Parents were made aware that all references to the children involved in this project would be anonymous and that any data gathered as part of an investigation that their children were involved in would be kept confidential. This data would only be available to the researcher and his supervisor.

As mentioned in 4.3.1, parents were informed that additional correspondence would occur before any video material or still photographs were included in research-related presentations or documents.

4.3.6 Protection of Participants

Researchers have a primary responsibility to protect participants from physical and mental harm during any investigation. In research involving children, especially children who have difficulties with communication, great caution should be exercised when ensuring that welfare.

4.3.7 Privacy During Observational Research

An attempt was made to make children aware of video recording equipment in those investigations in which it was used. The equipment was shown to them, and they could clearly see where it was positioned. An attempt was made to explain its function.

As mentioned in 4.3.3, two of the children wanted to see some of the material that had been recorded of them during sessions. This, along with any other curiosity about the video equipment, was accommodated by the researcher. The children were permitted to explore the video equipment with the supervision of the researcher and classroom staff.

4.4 Verbalisation Techniques

The ‘think aloud’ protocol, or verbalisation of the thoughts of a user as they work with a product, is one of the principle techniques used by researchers and professionals for finding problems within a design (Nielsen, 1994; Rubin, 1994 in Barendregt, 2006). “This means that the participants are asked to provide a running commentary of their thoughts and feelings while they are performing some given tasks with the tested product.” (Barendregt, 2006, p. 21). In its cleanest form, the researcher should remain silent at all times, only speaking to prompt the user if a certain period of time passes during which they have failed to verbalise their thoughts (Ericsson & Simon, 1984 in Barendregt, 2006). The technique is often cited as used in usability tests, but its application often diverges markedly from that described above (Boren & Ramey, 2000 in Barendregt, 2006).

As discussed in Barendregt’s thesis, children “can have difficulty in verbalising their thoughts” (Boren & Ramey, 2000 in Barendregt, 2006). They find it unnatural to talk to no-one in particular and can often forget to continue thinking aloud (Barendregt, 2006). Prompting frequently to correct this could result in children reporting problems solely in an effort to satisfy the researcher, leading to non-problems being reported (Nisbett & Wilson, 1977 in Barendregt, 2006; Donker & Reitsma, 2004 in Barendregt, 2006).

The acknowledgement of these issues has prompted several solutions within the literature. The first of these is giving an initial instruction to think aloud, then refraining from further prompting, thus helping children feel more comfortable and report fewer non-problems (Donker & Reitsma, 2004 in Barendregt, 2006). This now highly self-initiated thinking aloud is complemented with observations of behaviour in an effort to support the fact that children may forget to mention problems and/or realise that a problem has occurred and/or what the problem may be (Barendregt, 2006). Other suggestions include thinking aloud methods that have no prompting at all, such as co-discovery or constructive interaction (Nielsen, 1993; Miyake, 1986 in Barendregt, 2006) and peer-tutoring (Hoysniemi et al., 2002 in Barendregt, 2006).

All of the thinking aloud techniques described above encounter problems when used with children with ASD. The decision of whether to use prompting or not becomes a lesser concern, with the communication and social deficits experienced by the population (see Section 2.3) far outweighing it in importance.

Given the proportion of children with ASD who are functionally non-verbal, the critical component of the technique, that is, the verbalisation itself, renders the technique unusable unless the prospective population of participants is selected for based on their ability to verbalise. If this notion is to be considered, it needs to be based on the assumption that a researcher has access to a large enough population of children with ASD that sampling for verbal facility doesn't reduce the possible number of participants to an untenable level. In terms of this project and the group of children with ASD that were available, if this form of selection had taken place it would have reduced the number of participants from a possible seven down to two, and therefore this approach was not feasible for the project.

4.5 Direct Inquiry Techniques

A natural parallel to the narrative exploration requested from a user by verbalisation techniques such as the think aloud protocol discussed above (Section 4.4), are direct inquiry methods of sourcing information such as questionnaires, interviews and questioning experts. Instead of the largely user-oriented direction of the information provided from verbalisation techniques, direct inquiry techniques allow the researcher to gain insight into specific areas of interest that have been identified in some way as being pertinent to the investigation.

4.5.1 Questionnaires

As with the verbalisation techniques mentioned in 4.4, the use of questionnaires with children requires that special attention be paid to their developing cognitive, memory, communicative and social faculties. A review of the design and testing of questionnaires for children can be found in Alice Bell's paper, *Designing and testing questionnaires for children* (Bell, 2007), and it is this paper that was used as a primary resource as such for this project.

With regard to the use of questionnaires in this project, the same concern over the respective faculties of the children involved needed to be attended to, along with additional concerns regarding the cognitive, communicative and social abilities of the children being raised given their diagnosis of autism. After these concerns were considered, the use of questionnaires with the children was deemed not viable.

However, during the course of this project a questionnaire regarding the previous computing experience of the participants was prepared and sent home to parents (see Section 6.1.2 for details, or Appendix 5 for a copy of the questionnaire). The questionnaire was filled out by parents/caregivers rather than the children (participants).

4.5.2 Interviews

Similarly to the questionnaires described above (Section 4.4.1), using interviewing with children requires that care be taken that their developing cognitive, memory, communicative and social abilities are not overwhelmed. As a review of research and best practice, chapter 2 of Megan M. Gollop's book, *Children's Voices: Research Policy and Practice* (Gollop, 1999), was extremely useful. Factoring in the concerns mentioned above, while considering the additional challenges faced by the children participating in the project in terms of language, expression and social functioning (see Section 2.3), it was decided that direct interviewing of the children was inappropriate and likely to be ineffectual as a source of useful data.

4.5.3 The Role of Experts

During the course of this thesis, the researcher was able to draw on the expertise of three faculty members from the Department of Psychology at the University of Waikato. All three psychologists have a PhD in psychology and have knowledge of and experience working with children with autism. For specific details on the input they had in the development of the software prototype, see Section 7.0.

Additionally, the staff of both classrooms from the Patricia Avenue School that were involved in the project were an invaluable asset to this project, providing knowledge and expertise well outside of that possessed by the researcher. They served as an interface between the researcher and the participants, smoothing interactions and lessening anxiety and stress for both parties. Without their presence and expertise it would have been impossible to run the user trials undertaken during this thesis.

Given the shortcomings of both using questionnaires with, and interviewing, the participants in this instance, insights contributed by experts were very helpful.

4.6 Giving Help During User Trials

For the user trials performed during the investigations that made up this thesis, deciding when to give help to a participant was a difficult decision. "When setting up an evaluation it should be clear and consistent how the facilitator will respond to questions of the children during the evaluation. Rubin (1994) advises to assist participants only when they are very lost or confused, when they are performing a required task which makes them feel uncomfortable, when they are exceptionally frustrated and may give up, or when a bug occurs or functionality is missing." (Barendregt, 2006, p. 23). Since five out of seven participants involved in this project were functionally non-verbal, relying on questions from a participant before providing help would have been inappropriate. Instead, the researcher attempted to gauge whether or not the children were experiencing problems by monitoring non-verbal behaviour, engagement level and interactions with the software. This was not a straight forward strategy, nor was it error free.

The fact that the majority of the children involved in the project couldn't or wouldn't ask questions during a trial meant two things. The first was that question asking couldn't be used as an indication of problem occurrence and the second was that the content of the question (which hadn't occurred) couldn't be used to help diagnose what the problem might be. In practice this resulted in very cautious acknowledgement of problems during test sessions, veering toward waiting longer to step in than acting as soon as the researcher identified that a problem might have occurred. A possible consequence of this, given the ethical considerations discussed in 4.2.6, may have been that children became discomforted to the point where the session was ended prematurely by the researcher. This is regrettable, but given that the identification of problems experienced by children with ASD was one of the goals of this thesis, providing help too quickly, before a period of time was given for the problem to be observed fully, would been have counterproductive.

4.7 Video Analysis of Observations

> When analysing video material to detect problems there is always the risk of an evaluator effect (Jacobsen et al., 1998), which means that different evaluators identify different sets of problems from the same material. Several suggestions have been made to decrease (though probably not eliminate) this evaluator effect. One suggestion is to add more evaluators (Jacobsen, 1999), another suggestion is to structure the analysis process (Vermeeren et al., 2002; Cockton & Lavery, 1999). Although a combination of these suggestions might seem an ideal solution, with increasing the complexity of the analysis process, the ratio of (session time)/(analysis time) decreases. Ratios usually lie between 1:5 and 1:100 (Sanderson & Fisher, 1994), and for example in Vermeeren et al. (2002) these ratios varied between 1:25 and 1:29. This increase in time to analyse all sessions may make it impossible to use more than one evaluator. (Barendregt, 2006, p. 34).

For investigations undertaken in this thesis, an ethnographic approach to video analysis was the primary technique used. While this may fly in the face of the recommendations given by Vermeeren et al. (2002 in Barendregt, 2006) and Cockton and Lavery (1999 in Barendregt, 2006) above, it was deemed appropriate given the thesis's aims. The quantitative analysis of different problems that would have been provided by rigorous adherence to a coding scheme (such as the one presented in Chapter 3 of Barendregt (2006)) was not necessary or desirable given the exploratory goals of this project. A more qualitative, informal approach had the flexibility necessary to provide the insights that were the purpose of this thesis.

As a compromise with Jacobsen's advice (1998 in Barendregt, 2006) to use more than one evaluator, if at any time the researcher experienced confusion with a section of video that was being analysed, his supervisor reviewed that section and it was discussed.

4.8 Problem Classifications

As discussed in Barendregt's thesis (2006), it is useful to have a classification of the problems that are detected during video analysis. The classification presented in Barendregt's thesis is the only classification specifically tailored for use in evaluating software with children that was found by the researcher, and thus it was this classification that was considered for use in this thesis.

Barendregt's classification is a combination of the classifications proposed by Frese and Zapf (Frese & Zapf, 1991 in Barendregt, 2006 and Zapf et al., 1992 in Barendregt, 2006) and Malone and Lepper (Malone & Lepper, 1980 in Barendregt, 2006 and Malone & Lepper in Barendregt, 1987). Frese and Zapf's classification is briefly outlined below, followed by a brief outline of Malone and Lepper's classification. How Barendregt combines the two classifications is then discussed, followed a discussion of the concerns about the applicability of this conjoint classification in terms of its use with children with ASD.

4.8.1 Frese and Zapf's Classification of Problems

Frese and Zapf's classification was designed to describe problems observed within an office-computing environment. At its top level the classification identifies four main types of problems; functionality problems, usability problems, interaction problems, and inefficiencies. Descriptions of each of these are given below:

- **Functionality problems:** Functionality problems refer to instances where the one of the programmers that created the software made a mistake, i.e. a bug. While bugs were present within the software used during the investigations undertaken during this thesis, the participants had no control of their occurrence or execution. Thus, while their existence was acknowledged as suboptimal and commented upon, individual bugs were not explored further.
- **Interaction problems:** Interaction problems occur when the interactions between two or more users fail in some way. As none of the software used during the investigations undertaken during this thesis had multiuser/multiplayer functionality, there was no opportunity to observe any of these problems.
- **Usability problems:** "Usability problems occur when the functionality of a program is sufficient for its execution, but there are still errors that occur. These problems can be caused by a mismatch between the user and the computer program" (Barendregt, 2006, p. 61). These are explained in more detail below.
- **Inefficiencies:** "Behaviour is described as inefficient when the user is successful in reaching a goal that should have been reached more easily because the system does not make this more efficient way clear to the user" (Barendregt, 2006, p. 61). These are explained in more detail below.

Usability Problems

The classification of Frese and Zapf breaks the range of usability problems down further into eight 'sub problems':

- **Knowledge problems** "occur when the user is unable to carry out a certain task with the program because the design of the program is unclear about the right commands, function keys, or rules. In a computer game these problems may occur when the goal of a sub game is not explained well, or when the actions that have to be taken to reach the goal are not explained clearly" (Barendregt, 2006, p. 62).
- **Thought problems** "occur when the product makes users develop inadequate goals and plans, or take wrong decisions in the assignment of

plans and sub plans, although the user knows all the necessary features of the system. In a computer game these problems may occur when a child wants to go to a certain part of the game but because the navigation-buttons all look alike he or she unintentionally goes somewhere else" (Barendregt, 2006, p. 62).

- **Memory problems** "occur when the user forgets a certain part of the plan and does not complete it, although the goals and plans were originally correctly specified. In testing a computer game for children these problems are difficult to identify because the child's plan should be known in order to detect a memory problem" (Barendregt, 2006, p. 63).
- **Judgement problems** "occur when the user cannot understand or interpret the game feedback after an action. In a computer game these problems occur for example when feedback about the progress in the game is given but the child cannot understand whether the action he or she performed is right or wrong" (Barendregt, 2006, p. 63).
- **Habit problems** "occur when the user performs a correct action in a wrong situation. With adults this may happen for example, when switching from one word-processing program to another. When the user interfaces of the two products are not consistent, the user may try using the same keys to perform an action as in the old program, even though they are not working in the new program. Children playing a computer game could, for example, have habit problems when they play many games that differ in the way the navigation works" (Barendregt, 2006, p. 63).
- **Omission problems** "occur when a person does not complete a well-known sub plan. In a computer game these problems may occur when the child always has to answer a question by clicking a button before being able to go a new part of the game. When such questions are repeated often the child may eventually forget to answer them because he/she is more focused on the next step" (Barendregt, 2006, p. 63).
- **Recognition problems** "occur when well-known feedback is not noticed or confused with other feedback" (Barendregt, 2006, p. 63).
- **Sensorimotor problems** "are related to the required motor-skill in a product, like accidentally clicking the wrong button because it is too small or too close to other buttons" (Barendregt, 2006, p. 63).

Inefficiencies

"According to Zapf et al. (1992), two types of inefficiencies can be differentiated; inefficiencies because of lack of knowledge and inefficiencies because of *habit*. The first type of inefficiency occurs when the user follows an inefficient path because he or she does not know a better way. The latter implies that the user uses routines although he or she knows that there are more efficient ways." (Barendregt, 2006, p. 63).

4.8.2 Malone and Lepper's Classification of Fun Problems

The classification Barendregt borrows from Malone and Lepper describes fun problems. In her thesis, Barendregt defines a "fun problem" to be:

> Fun problems occur when there are aspects in the game that make the game less motivating to use, even though they are not usability problems. For example, the music may be too scary, the characters can be too childish, or the challenge level is either too low or too high. (Barendregt, 2006, p. 64)

Malone and Lepper provide four main heuristics by which 'fun' can be identified and measured for an activity:

- **Challenge:** "The activity should provide a continuously optimal level of difficulty for the user." (Barendregt, 2006, p. 41)
- **Fantasy:** "The activity may promote intrinsic motivation by using fantasy involvement." (Barendregt, 2006, p. 41)
- **Curiosity:** "The activity should provide an optimal level of informational complexity or discrepancy from the user's current state of knowledge and information." (Barendregt, 2006, p. 41)
- **Control:** "The activity should promote feelings of self-determination and control on the part of the user." (Barendregt, 2006, p. 41)

From each of these four heuristics, Barendregt derives an associated subtype of fun problem, defining each such sub-problem as an instance where the corresponding heuristic is not upheld within the software. For example, when a suboptimal level of difficulty for a user is detected, a challenge subtype of fun problem has been identified.

4.8.3 Barendregt's Classification

Barendregt's classification contains five major types of problem at its top level, four derived from Frese and Zapf's classification (functionality problems, interaction problems, usability problems and inefficiencies) and one from the classification of Malone and Lepper (the fun problem). As mentioned in Section 4.8.1 above, two of the four main problems derived from Frese and Zapf's classification (functionality problems and interaction problems) do not apply to the investigations undertaken during this thesis, thus we are left with three main types of problems within the classification; usability problems, fun problems and inefficiencies. These in turn can be broken down further into a list of 16 sub-problems; knowledge problems, thought problems, memory problems, judgement problems, habit problems, omission problems, recognition problems, sensorimotor problems, challenge problems, fantasy problems, curiosity problems, control problems, knowledge inefficiencies and habit inefficiencies, all of which are described above in their respective sections.

4.8.4 Concerns with Barendregt's Classification Regarding Children with ASD

As discussed at the beginning of Section 4.8, the fact that Barendregt's classification has been formulated specifically for use in evaluating software with children suggests that it could be useful in a similar role within the investigations undertaken during this thesis (see Sections 6.1, 6.2 and 8.0 for more information on investigations that explored interactions with software) - after all, the participants involved are children. However, is their status as children sufficient to guarantee the applicability of the classification scheme, or do the assumptions that underlie the classification described above fail to adequately describe what the executive dysfunction hypothesis of autism depicts as a distinctly different, but analogous process within an autistic population? (Section 2.5) While a definitive answer to that question is outside the scope of this thesis, it is considered below in order to determine if and how Barendregt's classification should be used when analysing the video data gained during the investigations undertaken during this thesis. After the applicability of Barendregt's classification for use with children with ASD is discussed, difficulties experienced while using it to classify the problems observed during the investigations undertaken during this thesis are discussed.

As can be seen in Figure 2, Frese and Zapf's classification of usability problems is based on a model that has two dimensions: steps in the action process and levels of action regulation. "The first dimension is based on the assumption that actions are goal oriented (Norman & Draper, 1986), and that there are three different steps in the action process to reach these goals. First, goals and plans have to be developed, then plans have to be monitored and executed, and finally the outcomes have to be evaluated on the basis of feedback whether the goals have been reached." (Barendregt, 2006, p. 61).

Knowledge base for regulation	Knowledge problems		
Levels of action regulation	**Steps in the action process**		
	Goals/planning	**Monitoring**	**Feedback**
Intellectual level of regulation	Thought problems	Memory problems	Judgement problems
Level of flexible actions patterns	Habit problems	Omission problems	Recognition problems
Sensorimotor level of regulation	Sensorimotor problems		

Figure 2: A classification of usability problems (Zapf et al., 1992 in Barendregt, 2006) with two dimensions; steps in the action process and levels of action regulation. Taken from (Barendregt, 2006).

Given the *executive dysfunction* hypothesis of autism (see Section 2.5), which specifically identifies these areas of goal production, self monitoring and outcome appraisal as qualitatively different to that of neurotypical individuals, the question arises as to whether individuals with ASD experience usability problems in the same way as neurotypical individuals. If the executive dysfunction hypothesis is accepted, then some, if not all, of the definitions of the various usability problems outlined in Section 4.8.1 seem to fall short of adequately describing or comprehensively qualifying what is or 'could be' occurring when a usability problem occurs for a child with ASD. For example, if we consider that thought problems as defined in Section 4.8.1, "occur when the product makes users develop inadequate goals and plans, or take wrong decisions in the assignment of plans and sub-plans" (Barendregt, 2006, p. 62), then we need to recognise that for a child with ASD it may not be entirely from aspects of the software that the 'inadequate goals and plans' arise, and that it is likely that a more fundamental deficit or difference associated with their diagnosis of ASD is playing a significant part in the identified problem.

In summary then, the main problem with the use of Frese and Zapf's classification as a descriptive device, is that it assumes the child is neurotypical - with action and goal production as Frese and Zapf describe. With children with ASD, research suggests this is not the case.

As well as the question of *applicability* discussed above, the functionally non-verbal status of five out of the seven children with ASD that participated in user trials during this thesis (see Section 4.1 for details on the participants), made using Barendregt's classification to *differentiate between* and classify observed problems difficult. As discussed in Section 4.6, the fact that the majority of the children involved did not ask questions during trials or give any other verbal indication as to what their goals and motivations were, meant that identifying and classifying problems was difficult. Furthermore, even if all of the children involved within this project had been 'verbal', it is quite possible that the aforementioned issues with goal production and self-monitoring would have meant that the content of any utterances recorded during user trials would have been insufficient to provide the insight necessary to make problem classification easier. While lack of evaluator knowledge about the motivations and goals of users is an acknowledged difficulty when running user trials with children, the further lack of that knowledge that is experienced when working with children with ASD increases the difficulty experienced dramatically.

Unlike the usability problems derived from Frese and Zapf's classification, no underlying theory is provided upon the fun problems of Malone and Lepper are based; instead four highly subjective heuristics are presented. Without the ability to compare the underlying theory behind the construction of the fun problems to corresponding research with individuals with ASD, it is very difficult to determine if the fun problems *apply*. More so than with the usability problems, the non-verbal status of the majority of the children that participated in this thesis reduced the available evidence that a fun problem was or could be occurring to a worrisome level. As a result of this, the researcher was reluctant to use this portion of Barendregt's classification at all.

Given the issues of *applicability* and *problem differentiation* outlined above, Barendregt's classification was used cautiously when analysing video from the user trials undertaken during this thesis. Many of the observed problems and insights didn't fit neatly into any of the categories defined by Barendregt's classification, nor was it the case that the mutual exclusivity implied by the classification existed. Some problems and insights were identified that seemed to belong to more than one category of problem. Given these problems with using the classification as it was intended, an alternative approach was found that preserved its role as a frame of reference, but also provided more flexibility. As can been seen in Sections 5.3, 6.1.3, 6.2.3 and 8.3, reference to one of the problem types from Barendregt's classification was suggested when the researcher decided that the problem was 'similar' to one defined therein.

In the end it was decided that, qualified by the misgivings described above, both portions of Barendregt's classification would be used as a framework for suggesting when problems experienced by the children involved in this thesis were similar to those experienced by neurotypical children. It is clear, however, that much more research is required into developing a classification of problems for evaluating software with children with ASD.

5.0 Investigation 1: Observing the Children and Staff within the Classroom Environment

Once someone has decided they want to design a piece of software for children diagnosed with ASD, what is the next step? What is the stage after the current research (see sections 2 to 4) has been perused and assimilated? In this section an exploratory ethnographic investigation is described where the researcher spent three weeks observing the day-to-day activities of a group of children diagnosed with ASD. In the process a rough model was built up about the routines of the children and the highly individualised characteristics that typify people diagnosed with ASD. The findings of this investigation were used to inform the initial stages of prototype development for a piece of software that is being developed as part of this thesis (see section 6), as well as determine the next steps within the project.

5.1 Investigation Aims

Given the acknowledged deficits in various forms of play experienced by children with ASD (see Section 2.4) and the promise that computers and virtual environments (like games) show in helping to elevate some of those deficits (see Section 3.0), one of the principal aims of this investigation was to find an activity or form of play that the majority of the children enjoy. This activity would then be used as the basis for the software being developed as part of this thesis.

Similarly, given the benefits of 'untethered environments' in allowing children to interact in a more natural and developmentally appropriate manner (see Section 3.0), it was decided that the Smartboard interactive whiteboards that were installed in many of the classrooms at the Patricia Avenue School would be the hardware that the software being developed as part of this thesis would be deployed on. Thus, interactions associated with its use were of marked importance during this investigation.

In addition to the primary aim mentioned above, the following research questions and supplementary aims were established before the investigation began:

- How much experience do the children have with computer use? Do they use computers at home or just at the school?
- Examine day to day activities of the children, especially looking out for periods of unconstrained play.
- Observe how the children and staff interact with classroom artefacts, and consider if this interaction has any bearing on software interaction.
- Observe how much intervention is required from staff with respect the children and their activities (again paying special attention to periods of unconstrained play).

As well as these aims and questions, the opportunity for unforeseen observations was noted and is indeed one of the reasons the observation was undertaken. The fact that not all relevant aspects of how users interact with their environment can be predicted or modelled accurately is one of the key principles that make observational studies so crucial at this stage of software development. In this case the users are from such a widely diverse group (both as children and as individuals diagnosed with ASD) it is important to gain as accurate a model of their daily activity as possible.

5.2 Method

The investigation was undertaken at two sites, called Site 1 and Site 2 within this thesis, both associated with the Patricia Avenue School (a school for children with special needs that is affiliated with the university). Of note, is that at Site 1 there was a Smartboard interactive whiteboard, while at Site 2 there was not (although one is to be installed soon). This piece of equipment is the desired platform for the final iteration of the prototype to be produced in this project, so interactions associated with its use were of marked importance during this investigation.

The observation was performed over 3 weeks following the timetable presented below:

Day	Time	Location
Tuesday	09:00 – 10:30	Site 1
Wednesday	09:00 – 12:30	Site 1
Thursday	09:00 – 15:00	Site 2
Friday	09:00 – 15:00	Site 2

Figure 3: Investigation 1 timetable.

During a given session the children and staff present at a site were observed while they went about the normal activities of the day, with emphasis given to those children the researcher had been informed were diagnosed with autistic spectrum disorders (two at Site 1 and four at Site 2). Manual notes were taken by the researcher for later analysis.

The children ranged in age from five to eight, with five males and one female. Their positions on the autistic spectrum ranged from mid to high functioning, with four of the six functionally non-verbal (see Section 2.3).

Behaviour was observed and inferences regarding intent and motivation were noted when those behaviours were recorded. This was an exploratory investigation designed to discover and/or help model how the children went about their daily activities.

At the beginning of the study the researcher's role was purely observational. However, once it had been established by the staff that the children had become accustomed to the researcher's presence, the researcher was occasionally asked to help with an activity. This involvement resulted in an increase in child and staff rapport. The importance of building rapport with staff and children is discussed in more depth in section 5.3.7.

Several informal gatherings were held with staff members to discuss the project with them. These gatherings were held at times convenient for the different members of staff, which normally meant that they occurred during morning tea or lunchtime. Not every member of staff was present at every gathering and it is worth noting that separate meetings were held for the different classrooms. This meant that the all the staff members for the different classrooms were never present at the same meeting. While this was not optimal, it was a trade off that catered to the busy schedules of the staff members involved.

5.3 Findings and Discussion

The following observations are listed, under headings, in order of the aims presented earlier in this report.

5.3.1 Computing Experience

Neither classroom had records of whether the children had access to computer equipment at home or if the children used computers outside of the classroom, thus a questionnaire was sent home to parents prior to the start of the Investigation 2 (see Appendix 5 for a copy of the questionnaire and Section 6.1.3 for details of what was discovered from the questionnaires).

5.3.2 Play

At both sites, the children received approximately four to six periods (of about 10 minutes) a day where they could select an activity to occupy themselves with. The activities available to the children were constrained only in that they needed to fulfil the following criteria:

- Quiet. They could be louder if they were outside, but the noise level was still monitored.
- If the weather was poor, they needed to be inside.
- They had to be non-injurious to the child and other children nearby.
- They could not involve damage to property or materials not deemed appropriate; i.e. it was fine to cut sheets of paper with scissors, but not the child's clothes.

- They had to be of a scope that they could be accomplished within the approximate 10 minutes normally allotted to each period.
- The child needed to participate in an activity. Non-active behaviour, e.g. sitting quietly, was not an acceptable use of these periods.

If any of the above criteria were not fulfilled, it resulted in intervention by a staff member. The staff member would suggest an activity and get the child started on that activity, if necessary. Other than this, staff intervention was minimal, unless expressly requested by the children (in which case it was almost always given).

Staff members would suggest activities to the children only as a last resort; the children were encouraged to select an activity for themselves. In the three weeks during the observation, by far the most popular activities were (in no particular order): 'playing on' or using the PC, 'building' with blocks of one sort another, or 'drawing' with a 'marker' or 'pen' of some description. These activities are discussed further below, in the 'Drawing' subsection of Section 5.3.4

When asked about how important they thought play was, all the staff said that they thought it was important. However, several members of staff also suggested that the more unconstrained the play became, and thus the less input was required by them, the less that they felt the activity 'belonged' to them as staff members and the more it belonged to the children who had initiated it. Another staff member suggested that "For that type of play [unconstrained], it's our job to set the scene, but after that it's all about what the child wants". The undercurrent during this conversation suggested that at least a few of the staff thought that unconstrained play was more suitable outside of class time or should, at the very least, be constrained to choosing time.

The children could play together or by themselves, however it was often observed that only one child was permitted in the PC area at Site 2 at a time (there was two PC sat Site 1 and one PC at Site 2). This was possibly to prevent the altercations that often arose when more than one child was present around the PC at a time.

The above observations made about play within the two classrooms provided a useful list of criteria that the software prototype developed as part of this thesis (see Section 6.0) needed to adhere to in order to have the best chance of fitting seamlessly into the classroom timetable. The biggest decision that needed to be made was whether the prototype would actively attempt to maintain each criterion or if instead it would support each criterion but leave its enforcement to the staff. As the latter option created more flexibility as to how the prototype could function, it was selected.

Many of the criteria on the list above were already supported by virtue of the nature of what the prototype is, i.e. software that operates on computer equipment. Those that weren't implicitly supported in this fashion are listed below, with a suggested feature that could have been included in the prototype to offer the support mentioned above.

- The need for relative quiet. This is likely to be already supported by audio hardware, however software controls should exist, to offer that option to users (both children and teachers).
- The prohibition against inactivity. An indicator could be implemented that would alert staff if a period of inactivity was detected. Care would have to be taken however as this indicator might become part of the 'play' the child was involved in. For example, if a tone sounded when the software had not detected input for a proscribed amount of time, then causing this tone to sound could become part of the game as far as the child was concerned. While this form of serendipitous game creation wouldn't necessarily be 'bad', the tone could easily become a distraction that drew the child's attention away from the main activity.
- A limited timeframe of approximately 10 minutes. As an unconstrained model of play is being assumed at this stage, this criterion will be implicitly supported by the prototype in that it will be up to the child to manage the how long he or she plays for. A more active form of support could be the inclusion of a timer that would indicate to staff when a defined period of time had passed. For example, if this timer was set for 10 minutes, then after that period of time had elapsed the game could pause itself and display a menu or similar notifying staff that the requested time had expired.

5.3.3 Multiplayer Games

In course of this investigation none of the participants were seen 'playing' together in unconstrained play during 'choosing time'. There were instances at Site 2 where the staff supervised the children in activities where they had to cooperate and take turns, but these were curriculum based activities formulated and managed by the staff, not the children.

While a multiplayer component could have been included within the software prototype, it was not. As described above, all 'multiplayer' activity occurred only with the supervision of staff. This requirement of supervision would likely mean that the multiplayer feature would see little or no use.

5.3.4 Classroom Artefacts

Below is listed a series of observations made about significant artefacts within the classroom environment.

The Smartboard Interactive Whiteboard

The Smartboard is a rear projection interactive whiteboard that allows users to interact directly with software by contact with its surface, typically with their outstretched finger. The following observation is a sample of the interactions seen with the children and the Smartboard interactive whiteboard:

Participant A has been asked to 'write' his name on the Smartboard. He is encouraged by the staff to get up from his chair and move around the tables to stand in front of the Smartboard. Upon the Smartboard his name is positioned off to the lower right upon its surface. This is Participant A's first day using the Smartboard and he seems very tentative and anxious. The teacher within the classroom appears to have expected this and stands close to Participant A, ready to help if required. Participant A continues to be unsure and has yet to touch the Smartboard. Very slowly, the teacher encompasses Participant A's hand with hers and guides his hand onto the Smartboard's surface. This done, the teacher pushes down with Participant A's hand on the area where the Participant A's name is *'resting' and, still pushing down, drags the name into a rectangular box positioned on the upper left hand side of the Smartboard in one long continuous motion. This operation complete, Participant A is congratulated by all the staff in the classroom, with the other children being encouraged to join in. The sound this display generates seems to make Participant A uncomfortable and with a sudden discordant shriek, he rushes back to his chair and sits down. He has his hands over his ears and is rocking back and forth slowly. This reaction to the applause of the staff and other children seems to have been expected by the teacher and staff, and while in no way is Participant A being ignored, none of the staff show undue concern at this reaction. Another child is selected by the teacher to write his name upon the Smartboard...*

A well as being located in a centralised position within the classroom, the Smartboard was also the main medium used by the teachers for presenting information to the children (replacing the traditional blackboard or whiteboard within the classroom). The following observations were made:

- The children had trouble with the size of the Smartboard. Most weren't tall enough to reach the upper area of its surface. This was exacerbated by the height at which it was positioned on the wall, which seemed more appropriate for use by the teachers than the children.
- The children sometimes (or often, in the case of new users) used a supporting hand when using the Smartboard. This created problems as its surface is only designed for one point of contact. When multiple points of contact occurred, the point of focus (i.e. the 'mouse pointer' or 'cursor') became the average of the contact positions. The use of a supporting hand was more likely the higher up on the surface of the Smartboard the child was trying to reach.

The fact that the use of a supporting hand was more likely the higher up on the surface of the Smartboard the child was trying to reach, suggests that both the size and wall position of the Smartboard were contributing factors. In terms of prototype development, this suggested that it might not always be appropriate to assume that the child could use the complete surface of the Smartboard.

- Controls, such as buttons, displayed within software designed specifically for use on the Smartboard were very large, even given the size of the equipment's surface.

These disproportionally large controls might be an effort to counteract the problem of the upper surfaces being harder to reach for short users or it might be that the controls are larger to accommodate the reduced levels of fine motor control or precision within a younger user group. It also could be that given the difficulty a lot of users experience with 'switching scale' with respect to user controls, that it is accepted practice for designers to favour the 'larger' scale as opposed to the 'smaller'.

This convention accommodates the acknowledged difficulties many children with ASD have with fine motor control, difficulties that go beyond those experienced by neurotypical children (see Section 2.2). As such, it was a convention that was upheld within the software prototype.

- Because the Smartboard uses a front projection system, the silhouette cast by the user blocks a portion of the viewing surface and thus hides a proportion of the information displayed. Practice seemed to result in accommodation to this fact, as the more experienced children stood in profile (at least partially), extending the body part they were using as an interface point away from their body as a way of distancing the 'area of focus' from the 'area of shadow'.

The silhouette caused by the front projection nature of the Smartboard suggests that care be taken in determining how big the user's 'point of focus' indicator or 'mouse cursor' is. If it is too small, the silhouette of the child's fingertip or hand may prevent the child from seeing it.

- Due to the use of projection technology, for the image displayed upon the Smartboard to be as clear as possible, the lights in the classroom had to be off. This had an impact on what others in the class could do at the same time as the Smartboard was used.

To help keep the prototype as clear as possible while being displayed on the Smartboard (while the classroom lights are on) a high contrast of colours should be used. This accommodation would have to be accordance with other factors, such as user preferences, but if they didn't conflict, it would be a useful feature.

- In comparison to the PCs (which were connected to CRT monitors) present at both sites, solitary use of the Smartboard was infrequent. In the one instance when it was observed, the children were using PECS cards to select various Priory Woods music clips to be played before class began. Even this instance wasn't solitary use in the form usually implied by the term, as the children were only permitted to choose one song at a time and were supervised to make sure that turn taking took place.

This suggested that unconstrained play with the software prototype, using the Smartboard, was unlikely to be commonplace at either site. It is possible that the reason for the lack of unconstrained play on the Smartboard is as a result of a lack of software that is suitable for such play, but given how managed all of the children's activities seem with it, it is more likely to be a conscious choice by the staff. This finding didn't directly affect the development of the software prototype, but it does suggest a deviation from how the researcher expected it would be used.

- 'Rubbing stuff out' or erasing work on the Smartboard seemed to be an activity the children found enjoyable, sometimes to the extent that they would rather have done that than the prescribed task.

This suggests that 'erasing' should be investigated as an activity that could be supported within the software prototype. While, due to time constraints, this was not done to the degree the researcher initially envisaged, it is supported within the software prototype (see Section 8.0).

Personal Computers

PCs were present in both classrooms. There were two available to the children at Site 1 and one at Site 2. These PCs were connected to CRT monitors and used keyboard and mouse as input devices. The following was observed:

- Access to the PCs was available to the children during "choosing time" (scheduled free play).
- One punishment for classroom misbehaviour is to disallow use of the PCs for a given time period. In addition to the punishment itself, the threat of the punishment was occasionally used to gain co-operation from the child when they were refusing to comply with instructions.

The fact that this was an effective punishment shows how much some of the children enjoy using the computers. This supports the notion that the computer is an environment that is attractive and captures the interest of these children (see Section 3.0).

- Of the children who use the PCs regularly, it was noted that on several occasions they had 'navigated' to the configuration or 'setup space' of the software they were using. While it's possible the children intended to navigate to this space, the uncertain and sometimes distressed behaviour that was observed when this happened suggested otherwise. In one case, where a child was interacting with the setup space of the SwitchIt! Jigsaw Maker 2 software, this negative experience was exacerbated by the child's difficulty in leaving the space or conceptually 'undoing' what he had done to get there in the first place.

Given this last point, an idea that may help to prevent it from occurring within the prototype was to keep the 'play space' functionally separate from the 'configuration space'. An execution model could be used whereby configuration took place before 'play' and was unreachable from within the 'game' itself or where the two activities were separated into two applications, with the children interacting only with the application associated with play.

The children's experience with using PCs within the classroom was further explored in Investigation 2 (see the 'Classroom computing experience' subsection in Section 6.1.3).

Building Blocks

The third artefact that warranted greater attention was actually a collection of artefacts, roughly described as blocks, including Lego™, Duplo™, Magnetix™ and coloured wooden blocks. The following was observed:

- The multicoloured, multi-sized aspect of the blocks suggested sorting as an activity. This activity was very popular and was observed often.
- The building of larger objects with the blocks was also frequently observed
- The complexity of what was constructed from the blocks differed dramatically from child to child, from Participant A's roads to Participant C's 'bridges' (see below).

The following observation is a sample of the interactions seen with the children and building blocks:

It is choosing time and Participant C has decided to play with some coloured blocks. They are quite large and are made of wood. He is sitting in a space by himself, but there is another child within two meters of him (also playing with blocks, in this case Duplo™). He has arrayed a lot of the blocks about the floor and seems to be slowly constructing two wall-like structures that are parallel to one another. Different coloured blocks in different sizes are being used for either wall, so this seems quite different from some of the other 'sorting activities' I have seen the children engage in. Although the two children are playing with similar materials and are quite close to each other spatially, there is no attempt from either child to interact with the other or with what they are each building.

Even though 'building' with blocks was a popular activity with the children, it was not selected as the form of play to be supported by the software prototype developed during this thesis. There were two reasons for this. The first was the inherent complexity that supporting a 3D activity (building with blocks) through a 2D interface (the Smartboard) would have created within the software. Considering the acknowledged cognitive deficits that many children with ASD possess (see Section 2.5), this complexity would have been very difficult for them to manage. The second reason for the above decision was the fact that the 'physicality' of blocks, which was observed to be one of the most compelling factors of their use by the children, would have been difficult to preserve within a virtual environment.

Drawing Tools and Mediums

With respect to the 'markers', 'pens', chalk or other drawing tools or mediums that the children were seen using to draw, the following was observed:

- Different children seem to prefer different 'types' of these drawing implements. That said, chalk seemed to be very popular amongst all the children.
- The children were observed closely by the teachers when using anything to draw with other than chalk. This observation seemed to be fuelled by the staff's concern that the children would deface the classroom with more permanent media.

The following observation is a sample of the children and drawing with various tools and mediums:

It is about 8:45am in the morning, and so about 15 minutes before the school day will officially start. All of the children that have already arrived at the classroom are engaged in an activity of their choosing (within certain criteria). Participant A has chosen to draw on an area just to the left of the door outside of the classroom door upon the paving stones. The area is fenced to prevent escape. He is drawing with white chalk. If I had to guess, I would say he is drawing a series of interconnected roads, but of course, that is only a guess. The pattern of parallel and perpendicular lines is quite elaborate and vast, taking up an area of at least two metres square. Participant A doesn't make much noise while drawing, apart from the odd muttered phrase that I can't quite hear. It seems apparent that he is *not talking to me. He continues to draw, stopping only to replace his piece of chalk with another from a container. The new piece is also white, which is interesting since there is quite a rainbow of colours available. As it approaches 9:00am, one of the staff comes out of the classroom and tells Participant A in a voice that both loud and clear, that it's "time to go and sit down [Participants Name]". After a few repetitions of this instruction, participant A puts his chalk piece into the container and caries it inside.*

This activity was selected as the form of play that would be supported by the software prototype developed during this thesis. Unlike building with blocks described above, supporting a 2D activity (such as drawing) through a 2D interface (the Smartboard) resulted in a straightforward, natural control interface that was easy to understand (see Sections 7.0 and 8.3).

As discussed in Section 2.4, drawing is an activity that traverses two stages of Piaget's framework for the development of play: both sensorimotor and symbolic. As such, the support of drawing as a form of play provides the opportunity to augment a child's cognitive development within a greater range of stages and for a greater number of children.

A further reason for focusing on drawing is that drawing is an activity that all the children were observed participating in, and enjoying, during this investigation.

5.3.5 Evidence of Work

An unforeseen facet of the classroom work flow was the importance placed upon evidence of work by the staff. For the majority of task oriented activities within the school day, it was expected, if not required, that there be some concrete artefact that resulted from it. These artefacts were then placed within the individual child's workbook, hung upon the classroom walls or placed within the child's bag to be taken home and given to their parents. During the duration of this investigation, on two occasions at Site 1 and one occasion at Site 2, displays were constructed from a collection of these artefacts and photographs were taken. Evidence of play, that is the unconstrained periodic play that occurred during choosing time, was never created. If it was created by virtue of the activity chosen by the child (for example drawing on paper with a crayon), it was never put into the child's workbook.

Participants C and D also liked to create material from the computer game 'Blue's ABC Time Activities', where they would print out line pictures at the end of the computer game and then colour them in as a separate activity. While not necessarily 'evidence of work', this desire for associated material supported the inclusion of a similar facility with the software prototype.

5.3.6 Opinion of the Project

The only indicator of how the children feel about the project was gained when the teacher of each classroom introduced the researcher to the classroom. In the process each teacher explained that the researcher was going to "create some software for them to use on the computer". This resulted in clapping by some of the children (in both classrooms) and also one child said "that's nice of him to help us like that". Of the six children diagnosed with ASD involved in this investigation, none spoke directly with or to the researcher, thus it is assumed they were at least ambivalent to the project.

When the opinion of the staff was gauged, the following was noted:

- The staff were pleased that the project was oriented toward designing software for "children with special needs". Some concern was expressed when they realised the project was directed specifically toward children diagnosed with ASD, but then receded when it was explained that the resultant software would still be usable by all the children in the class.
- There was confusion expressed by certain staff members about what the software would be used for. Indeed, a scenario of use described by one of the staff members detailed a highly structured, curriculum based piece of software that contrasted sharply with the initial project description given by the researcher. This confusion resulted in several more meetings with staff members, in an effort to merge aspects of what they all wanted out of the project with the initial aims of the project overall. At the end of this process, the feeling of staff with respect to the project is positive, with

many members expressing eagerness to see the prototype that will be developed.

Despite some initial confusion amongst the staff, support for this project was high. All members of staff were eager to see the prototype software and how the children would interact with it.

5.3.7 Building Rapport with the Staff and Children

Earlier in this report it was mentioned that building a rapport with staff and children was important. Even if no other benefit had been gleaned from the 3 weeks spent with the staff and children at the 2 sites, the building of relationships and familiarity would have still made the investigation worthwhile. The reasons for this are outlined below.

As mentioned earlier in this report, the children diagnosed with ASD that the project was focused on, can find interacting with new people stressful (see Section 2.3). By slowing familiarizing himself with the children, the majority of the signs of observable stress caused by the researcher's presence ceased. As the researcher became a part of their routine, the children stopped reacting to his presence in an excitable, unpredictable way, allowing him to observe them go about their daily activities without disruption. Roughly one week into this investigation, the researcher was either ignored or, more commonly, periodically sought out for brief interactions. This allowed the researcher to observe their activities in a closer, more engaged setting. While it is always important to maintain objectivity with regard to the analysis of observations, the ability to interact with and observe the children in a natural, relaxed setting is invaluable.

Building a rapport with the children also helped the researcher gain support with the staff. As the staff witnessed the researcher's interactions with the children and his interest in their activities, they in turn became more interested in the project. It was one thing for them to have the project explained to them initially, it was quite another for them to become personally interested and invested in its success. As a resource, the staff at each Site were invaluable. They have experience with each of the children that the researcher will never have the time to replicate, even if had the training and opportunity. This granted them insights into each of the children that the researcher would never be able to gain access to without their support.

5.4 Conclusions

The investigation described in this section explored the daily activities of two classrooms of children with special needs over three weeks, focusing on a group of six children with ASD that were split over the two classrooms. Areas of interest within the activities observed included those activities the children engaged in during periods of unconstrained play, where the content of their interactions weren't governed by school curriculum, as well as which artefacts within the classroom the children preferred or enjoyed interacting with and how.

The insights gained during this observation served to inform the development of a software prototype being developed during this thesis. Specifically, as a result of the investigation described in this section, drawing was selected as the form of play the software would support. Key factors in how the children interact with the Smartboard interactive whiteboard were identified and will also serve to inform the software development process. Some insight was gained into issues dealing with how the children interact with software on PCs, but more time and greater focus was required in this area and as such it was the focus of the next two investigations: Investigation 2 (see Section 6.1) and Investigation 3 (see Section 6.2).

Finally, a level of rapport and support was garnered with the staff and (to a lesser extent) the children involved in this investigation and the project over all. The initial boundaries with social interaction presented by the difficulties many of the children have with communication, anxiety and disruption of routine were begun to be overcome. This decreased the negative impact the researcher's presence had on the classroom environment and even allowed some minimal interaction with the children.

6.0 Observing the Children Using Software within the Classroom

How children with ASD interact with software is an area of crucial importance for identifying how software should be designed to suit the widely varied characteristics that are symptomatic of the disorder. Unfortunately, it is also an area where only a small amount of research has taken place (see Section 3.0). In the findings of Investigation 1, how the children interacted with software was identified as needing to be explored further (see section 5.1.4). This exploration was undertaken in two parts.

Investigation 2 sought to explore how the children interacted with game software that they were familiar with and enjoyed (see Section 6.1), while Investigation 3 sought to explore how the children interacted with the more ‘application-style’ drawing/art package Kid Pix Studio 4 (see Section 6.2). Investigation 3 resulted from the decision to support drawing as a form of play within the software prototype that was developed as part of this thesis. Given the differences in gameplay and interface between games designed for children and art packages designed for children, it was decided that Investigation 3 was warranted.

6.1 Investigation 2: Observing the Children Using Children’s Computer Game Software within the Classroom

In this section an investigation is described where the researcher spent two weeks observing a group of children diagnosed with ASD use computer game software within the classroom environment. Problems observed during that period are identified and discussed, both in general design terms and with emphasis on how they effected and informed the development of the software being developed as part of this thesis (see Section 8.0).

6.1.1 Investigation Aims

The aim of this investigation was to determine how the children involved in this project interact with computer game software they are familiar with and enjoy. The behaviour exhibited by the children during the course of this investigation was then used to inform the design of the software prototype that was developed as part of this thesis (see Section 8.0).

6.1.2 Method

The investigation was undertaken at two sites, called Site 1 and Site 2 within this thesis, both associated with the Patricia Avenue School (a school for children with special needs that is affiliated with the University of Waikato).

Three children with ASD from each site participated in the investigation. The children ranged in age from five to eight, were all male and four of the six were functionally non-verbal (see Section 4.1 for more information on the participants or Section 2.3 for more information on language and communication deficits amongst children with ASD).

Before the investigation took place parental consent forms were sent home with the children, along with a short questionnaire requesting information concerning the availability of computer equipment at home and also about any software preferences the children might have (see Appendix 5 for a copy of the questionnaire). Both of these documents were intended for the parents/caregivers to fill out. One of the consent forms was returned in the negative due to concerns the parent had about their child being videotaped and therefore that child was not included in the study. The information gathered from the questionnaire is summarised below (see the 'Computing experience' subsection in Section 6.1.3).

The observation was performed in the morning before class began, over a two week period. Each child was asked to participate in three trials over the course of the investigation; each trial lasted up to 15 minutes. As described in section 4.3.1

and 4.3.4, the children could halt the trial at any time. Each child was limited to one trial per day. This lessened the impact of ‘having a bad day’ on the data collected, captured as great a range of behaviours as possible by spreading the trials out over a greater number of days and reduced the impact of the investigation on the children involved (see section 4.3.6 for more information on the protection of participants during this thesis).

Before any trials, the researcher checked to see if any of the staff present within the classroom wished to handle interaction with the child during the trial or if direct interaction from the researcher was appropriate. For reasons similar to those discussed with reference to direct inquiry methods of investigation (see section 4.5), the anxiety engendered within some individuals with ASD during social interactions with unfamiliar people meant that this check was necessary to prevent undue distress to the children involved. If direct interaction from the researcher was deemed appropriate, the child was asked if they wished to participate that morning, using age appropriate language such as “Would you like to play on the computer?” If the child answered in the affirmative, the trial proceeded; if not, then the next child was asked and so on.

The software used for each trial was selected by the children from the software available within the classroom. For some children this wasn’t possible, in that they weren’t capable of making the choice of which software to use. If a child could not or would not select their own software, then software was selected for them by the staff of that classroom. As a result of this policy, the following software was selected by or for the children, as indicated in the table below:

	Software selected by	
Participant	Participant	Staff
A		Alphabet Express
B		Alphabet Express
C	Blue's ABC Time Activities	
D	Blue's ABC Time Activities	
E		Priory Woods Interactive Music Video
G		Alphabet Express

Figure 4: Software used by participants in Investigation 2, as selected by staff or participant.

Originally, those children who played games on the computer at home were going to be given the option of bringing in their own games to play. However, it was discovered that, of the three children who played games on the computer at home, all played online games that were attached to websites. Internet access was not available on the machine that was used for trials at Site 1; thus, for consistency, it was decided that only software available within the classrooms would be used. For more information on home computer use amongst the children, see the 'Home computing experience' subsection within Section 6.1.3 below.

Each trial was recorded on video, with the video camera positioned to get the best view of the keyboard, mouse and profile of the child involved. At the same time screen capture software was used to record video of the software on screen, as it was used.

As outlined in Sections 4.7 and 4.8, an ethnographic approach to video analysis was taken, whereby the issues and problems that were observed were categorized principally by their content. Where possible a guess at the type of problem, as defined in Barendregt's classification, was also hazarded.

6.1.3 Findings and Discussion

Home Computing Experience

As mentioned in Section 6.1.2 above, before the investigation took place, short questionnaires were sent home to the parents/caregivers of the children invited to be participants in the investigation. The parents/caregivers filled these questionnaires out for their children. Six out of the seven questionnaires sent home to parents/caregivers were filled out and returned. From these questionnaires, the following information was revealed:

- Participants B, C and D play games on the computer at home.
- Participant E and G have computers available to them at home, but do not use them.
- Participant A does not have a computer at home that he is allowed to use.

Thus, most of the children who have access to computers at home use them in their play. Given the number of children that the questionnaire provided information about, this number shouldn't be overstated, but it does show that the computer is attractive to some of the children as an environment for play (see Section 3.0).

This information also suggested that Participants B, C and D would be more practised at playing games on a computer. This experience was taken into account when analysing video of their trials.

- Participant G, who does not use a computer at home, likes to watch his older brother playing games on the computer.

This showed that while he may not have been at a stage where he wished to directly play games on the computer, that the computer, as an environment for play, showed some appeal for Participant G. This further supports the idea of the computer as an attractive environment for play for the children involved in this thesis.

- None of the children who play games on the computer at home use specialised input hardware. They all use a keyboard and a mouse.

This suggested that using a similar setup, with a PC, keyboard and mouse, would be suitable. Since the aim of this investigation was to explore how the children interacted with software they were familiar with and enjoyed, making sure that the input hardware was what they were used to was important.

Classroom Computing Experience

As well as gathering information on home computer use amongst the children involved in the investigation (see 'Home computing experience' above), the staff of both classrooms were asked to identify which of the children had experience with using the PCs that were available to them within the classrooms.

Participants B, C, D and G were identified as having used a PC regularly.

As established as a result of the Investigation 1 (see Section 5.0), for the children to have experience with using the PCs within the classrooms they would have expressed a desire to use them during 'choosing time', one of the free play periods that occur four to six times a day.

Figure 5 combines the information regarding home computer use with information concerned with classroom computer use for each of the participants, providing an overall impression of their experience with computers. An * denotes indirect interaction with the computer, i.e. watching someone else play on the computer.

Participant	Home use	Classroom use
A	No	No*
B	Yes	Yes
C	Yes	Yes
D	Yes	Yes
E	No	No
G	No*	Yes

Figure 5: Home and classroom computer use by participant.

We can see from the above table that only one participant, Participant E, has no interaction of any form with computers either at home or within the classroom. This reinforces the notion that the computer is an environment that is attractive and captures the interest of these children.
Participant A refused to participate with any of the trials during this thesis and his relative lack of experience with computers may offer an insight as to why.

Staff Presence During User Trials

A staff member was closely involved with the first trial with Participant E, who was described as "not having used the PC much and I'm not sure if he'll want to". He spent the time during the trial either being shown a behaviour/interaction or sitting with his hands close to his sides. This contrasted sharply with the two trials when a staff member wasn't closely involved. In these trials, Participant E, while still seeking some prompting before he touched the mouse each time, appeared more prepared to initiate interaction by himself. It is important that we recognise that there could be a number of factors in play, such as Participant E's reported lack of experience with PCs, mice and keyboards or that it could be that Participant E is always tentative when first trying a new activity.
However, given that it is often the role of the staff to stop these children from engaging in inappropriate or 'autistic' behaviours, their presence could also inhibit the display of novel behaviour. Acknowledging the effect that the presence staff members may have on the behaviour of the children during trials is important, both in the positive and the negative.

Clear Requirement for Input

There needed to be a clear requirement from software for the majority of the children to understand that it was necessary (see example below), and furthermore, what kind of input was required. Out of the five children that took an active part in trials, only Participant C and D were able to navigate through all three of their user trials without any problems caused by confusion as to whether input was required at certain points, or what kind of input was required. These problems of identifying when input was required and what input was being requested seem to fall into the category of 'Judgement' or 'Recognition' problems under Barendregt's classification (see Section 4.8).

Both Blue's ABC Time Activities and Alphabet Express had a 'login phase' where the software requested name information from the children that was then used to personalise the game for them, using their names in textual prompts and in any hardcopy that could be printed at the end of the game. These login phases typified instances where an input requirement was non-obvious to the children, and even for those children that understood that input was required, the type of input that was being requested seemed unclear. The result of this confusion was that a participant had to wait for a built in time period within the software to pass before they could continue with the game. An interaction is described below which illustrates the most striking observed occurrence of this:

Participant G is playing Alphabet Express. It is the start if the game and upon the screen an Alligator (or Crocodile) dressed in a train conductor's outfit is explaining to Participant G that he needs to enter his name or his three favourite letters of the alphabet onto a 'ticket'. The Alligator then produces this ticket and an animation occurs of it being pulled from the Alligator's pocket and flying into the middle of the screen. The ticket has a space, in which the word CONDUCTOR is written then disappears, and then the letters ABC are written and they too disappear. The cursor remains, blinking within the centre of the ticket. During this time the Alligator tells Participant G that once he has written his name or favourite letters on the ticket that he should press a certain button. The button in question is highlighted with a glow effect that surrounds the button briefly and is *accompanied by a "toot toot" train sound. There are two buttons present on the ticket, the one that has just been highlighted and another that is adjacent to it. Participant G does not enter his name or any letters onto the ticket, nor does he click the button referred to by the Alligator. Approximately 15 seconds pass and then the Alligator begins talking again, telling Participant G that "the train will be here soon, click the button and we'll be on our way". Participant G seems to be enjoying watching the Alligator and has spent this period of instruction slowly bouncing upon his chair and waving his arms. He does not click on the button. This cycle of 15 seconds of waiting followed by the Alligator's prompt of "the train will be here soon, click the button and we'll be on our way" occurs twice more, with neither additional instruction resulting in the prompted for activity from Participant G. Approximately 5 seconds after the last such prompt from the Alligator, the ticket disappears and the train arrives, accompanied by 'dinging' and 'chuffing' sounds as the train rolls into the station. The train's arrival is greeted by an apparently happy response from Participant G, whose slow bouncing and hand flapping increases in tempo as the train arrives.*

An interaction very similar to the one described above occurred again during Participant G's second trial. In his third trial, it was decided that all that could be observed from watching him fail to navigate through or passively 'wait out' this initial 'ticket phase' interaction had been observed, and therefore it was appropriate to help him navigate through it more quickly in order to have more time to watch his interaction with the rest of the software. During the two trials in which Participant G interacted during the ticket phase as depicted or similar to what is described above, it seemed as though he failed to understand or manage the inputs required of him during the interaction and thus could not continue with the game until a relatively long amount of time had passed (approximately 1.5 minutes for each trial). Furthermore, Participant G seemed to find these requests for input pleasurable or rewarding, instead of instructive. This is further discussed below, in the subsections 'Audio instructions' and 'Continual reward'.

Participant C and D had far less of a problem with determining when input was required during user trials, and what kind of input was required. This may have been a byproduct of their experience with computers (see subsections 'Home computing experience' and 'Classroom computing experience' above) or it could have been that they were very familiar with the software they were using (Blue's ABC Time Activities) and thus had learnt how to navigate through the sections of the game by rote. Alternatively, both children might simply have had a greater facility to indentify when input was necessary and determine what form of input was required. As mentioned in Section 2.1, research exists that demonstrates the ability of children with ASD to learn and execute sometimes quite elaborate series of actions, quickly turning them into rote routines that are in engaged repeatedly. The similarity in the order of activities played that existed within the trials of Participants C and D, from trial to trial, certainly supports this idea.

Implications for design of software prototype: Displaying the need for input to the children in a way that is clear and obvious was apparent from the results of this investigation. With respect to how to accomplish this within the design of the software prototype, a two-fold method was devised. Firstly, simple and minimalist input requests were used where possible; gimmicks such as a talking alligator or a train ticket as a login dialogue were avoided. The idea behind these cluttered, thematic input requests seems similar to Malone and Lepper's suggestion that fantasy elements be used to motivate and engage the child (see Section 4.8.2). However, given the confusion that this incorporation of fantasy seems to generate, its inclusion within 'best practice' seemed unwarranted. Secondly, if and when a change in input type was required, for example from clicking buttons to clicking and dragging, the screen was made as clear of unrelated graphical content as possible. The idea was to the remove the 'clutter', and thus increase the children's chances of detecting a change within the structure of the software.

With specific reference to login phases within software, the control that such a phase has on the flow or continuation of the game needs to be carefully weighed against the utility that being able to 'log in' brings to the game. As is seen in the interaction described above, log in phases can delay progression into other activities within the software, so unless 'logging in' pays significant dividends in terms of additional functionality provided to the child playing the game, should the feature exist? For the software prototype being developed as part of this thesis, it was determined that the user profiling functionality (see Section 7.0), that required logging in, justified its use.

Audio Instructions

The majority of audio instructions given to the children within the software used during trials seemed to be ignored by the children, or, alternatively, interpreted as pleasurable or rewarding instead of instructional. This was seen in the interaction between Participant G and the Alligator Conductor from Alphabet Express described above. He didn't show any signs of understanding the audio instructions given, but he did seem to find the stimulus of the Alligator talking enjoyable.

Even Participants C and D, children who seemed to have the least trouble interacting with the software during trials, gave evidence of ignoring audio instructions. Both children would skip past them when they were presented within Blue's ABC Time Activities. With respect to Participant C, this behaviour seemed a straightforward acknowledgement that he understood the activity and thus saw the audio instructions as an unnecessary delay. Child C however, would often ask out loud, after he had skipped past the instructions, why something was behaving as it was, when that behaviour had been indicated within the instructions. This suggests that he had either never listened to the instructions, thus rendering them irrelevant, or that they had not been effective in their role of conveying understanding about the activity, suggesting that they were ineffective.

Studies that show a bias toward processing the phonological characteristics of words in preference to the semantic within individuals with ASD ((Boucher & Warrington, 1976 in Whitehouse, 2006; Mottron, Morasse & Belleville, 2001 in Whitehouse, 2006; Toichi & Kamio, 2003, 2005 in Whitehouse, 2006), would certainly predict the failure of audio instructions within software. It has been shown in these studies that individuals with autism focus their cognitive resources on processing the *sound* of spoken utterances rather than on trying to assign *meaning* to the words. Given this insight into how Participant G could have processed the audio instructions of the Alligator Conductor, it is easy to see how he could have found them quite engaging and enjoyable, while at the same time, utterly meaningless. Viewing the actions of Participants C and D in a similar way, their skipping past the audio instructions provided by Blue's ABC Time Activities could be explained as lack of interest in the phonological characteristics of the instruction, with no consideration given to the subsequent lack of semantic content.

The problems of understanding and acting upon audio instructions, within the software used during trials, seem to fall under the category of ‘Recognition’ problems within Barendregt’s classification. As is suggested above, however, the definition provided by Barendregt’s classification seems to fall short of adequately explaining the probable cause(s) of such problems.

Implications for design of software prototype: As a result of observing both the ineffectiveness of audio instructions in communicating what was required of the children during the trials and the possible distraction it could cause, audio instructions were not used within the software prototype developed as part of this thesis.

Sound and Animation

Elements containing sound and animation seem to be very effective in capturing the children's attention. The majority of children seem to enjoy them and displayed behaviours such as giggling, smiling and animated movement when they were presented. Out of the five children that took an active part in trials, two covered their ears initially when loud sounds were played, but this was only for a very short time in each instance.

Implications for design of software prototype: Within the software prototype, sound and animation are both used as positive feedback whenever input focused on the main task is provided by the user (see Section 8.0 for details). Care has been taken not to over-use this feedback, however, as during the trials all of the children were easily distracted from the main focus of an activity. Even though none of the participants had an extreme reaction to any of the sounds played by the software during trials, sound can be disabled within the software prototype. Given the extreme reactions that some of the children have had with sound emitted from software in the past (as reported to the researcher by Patricia Avenue School staff), such a precaution was deemed prudent.

Periods of Inactivity

Long periods of time between input opportunities often resulted in the children becoming disinterested during trials. Out of the five children that took an active part in trials, Participants B, E and G all became disinterested (again Participant C and D were exceptions) when input was not required for periods of five seconds or more. The disinterested behaviour displayed included the child's gaze shifting away from the screen and roaming about the classroom or becoming fixed upon an activity that was not the software interaction, the child rotating their sitting position on their chair or the child getting out of their chair and walking away from the physical space near the PC (this nearly always resulted in the session ending, with the children being reluctant to return and continue, even after the passing of the period where input was not accepted).

As a result of analysing periods of inactivity during trials, it became clear that the 'input/output model' of the software used by the children had a profound effect on its success in capturing their attention and maintaining it. The term 'input/output model' is used here to describe the frequency of the input requirement, whether the input requirement is continuous or discrete and also the ratio of response to this input from the software, e.g. output. Activities that had smaller periods of time between instances where input was required maintained the children's attention better. Conversely, long periods of delay between input opportunities increased the likelihood that participants become disinterested in the software interaction and quit prematurely.

In terms of Barendregt's classification, problems associated with lack of motivation to play, caused by not enough interaction, would probably be classified as 'Control' problems.

Implications for design of software prototype: The continuous input requirement of the drawing activity being modelled within the software prototype means that delays between input opportunities should occur infrequently or not at all. Continuous input activities are more suited to this group of children than activities that require less frequent input, and this supports the choice of drawing as the activity the software should support.

Continual Reward

When any of the software used during trials provided a reward (in terms of sound and motion) the children were less inclined to provide further input, unless it was required for the reward to continue or be repeated. Thus, during periods of continual reward (where further input was not required for the reward to continue) the children often ceased to provide additional input. This was best demonstrated during trials at Site 1, when the Alphabet Express software was used. The main selection screen or 'selection loop' that occurs within the game displays a train circling a track inside of which are the letters of the alphabet, each of which is a button that transitions the game to a new area or screen. A series of train sounds and an "All Aboard" song are played while the animation of the train circling the track occurs. This continues without the child needing to provide any further input. For one of the children, Participant B, for whom this particular animation and sounds seemed quite appealing, this meant that he didn't seem inclined to provide further input and progress the game. Although game progression may be of limited impact, and Participant B might still be described as having enjoyed himself, the resultant lack of activity or 'active engagement' was not ideal.

In terms of Barendregt's classification (see Section 4.8), problems associated with lack of motivation to play, caused by the continual reward described above, would be classified as 'Challenge' problems.

Implications for design of software prototype: The above observation suggested that any reward of sound and motion provided within the software prototype be highly correlated to the presence of input from the child. Therefore, during periods of no input from the child, sound and motion should be nonexistent or extremely minimal. Fortunately, this corresponded well with the continuous input requirement of the drawing activity being modelled within the software prototype.

Idiosyncratic Input

Often the software used by the children during the trials failed to accommodate for their individual input quirks or practices. An example of this was Participant D, who, during trials, would click the mouse button repeatedly while the cursor was over a button, in an effort to gain a faster response from the software. This desire was assumed from statements Participant D gave, such as "I'm clicking it lots, but it won't hurry up" or "I'm clicking it lots, it needs to be faster". This behaviour rarely had the effect he desired, and often resulted in activity from the software he hadn't predicted, such as the software reacting to his repeated clicking by storing the clicks and the mouse position and applying them to future screens, resulting in a series of screen transitions that Participant D had not intended. The question then becomes, where possible, should software, especially software designed for users such as children with ASD, cater to the input idiosyncrasies of its users or should it hold to the accepted input conventions developed by experts in the field?

In terms of Barendregt's classification, problems that effect motivation to play, caused by a misunderstanding of how the controls work within a game, would probably be classified as 'Control' problems.

Implications for design of software prototype: Where possible, the design of the software prototype held to accepted input and interface conventions. While this meant that individual behaviours and input idiosyncrasies were not catered for, it also meant that the children had the opportunity to learn input conventions that could be generalised to other software.

Hardware Interaction

Problems with Participants E and G using interface hardware, such as the mouse and screen, were observed during trials. These problems are described below:

Both Participants E and G had trouble using the ball mice that were connected to the computers used during trials. The ball mouse needed to be used within the confines of the mouse pad, and therefore the available space in which it could be used by the children was restricted. At times this also limited how much they could move the cursor along a vector, until they picked the mouse up, relocated it on the mouse pad and continued. The correct execution of this series of steps was extremely infrequent form both Participant E and G. The ability to perform this kind of complex fine motor action, not to mention the underlying symbolic understanding necessary to identify when it is required, are both recognised deficiencies for many individuals diagnosed on the autistic spectrum (Section 2.0).

On several occasions during trials with Participant E, he touched the screen in an attempt to interact with the software, instead of using the mouse or keyboard. Note that Participant E was participating in trials at Site 2, which, at the time of this investigation, did not have a Smartboard installed. Nor, to the knowledge of the researcher, did Participant E have any prior experience with using touch screen technologies. This supports the ideas espoused by Wendy E. Keay-Bright and others (see Section 3.0), that 'untethered' interface technologies, such as a touch screen, are a more natural and age appropriate form of interaction hardware than traditional peripherals, such as a keyboard and mouse.

Comparing the level of complexity in the fine motor movements required between a touch screen and a mouse/keyboard there is a large discrepancy in favour of the touch screen. Likewise, if one compares the level of abstract or symbolic understanding required to use a touch screen compared to the mouse/keyboard, a similar level of difference is discovered, also favouring the touch screen.

Strictly speaking, Barendregt's classification doesn't cover problems derived from interactions with hardware. However, if it did, the two problems outlined above would probably be classified as 'Control' problems.

Implications for design of software prototype: Both of the difficulties discussed above supported the decision to deploy the software prototyped on Smartboard interactive whiteboard hardware.

Environmental Distractions

Distractions caused by the classroom environment, such as high noise levels and other children interrupting user trials, were observed during this investigation. That they had a negative effect on a participant's attention and focus was acknowledged, but given the choice made to run user trials with the classroom as opposed to a lab (see Section 4.2), they were unavoidable. The occurrence of these distractions was also acknowledged as authentic in reference to the actual day to day routine of the children involved and this was considered a positive aspect of the choice of environment.

Implications for design of software prototype: It was an implication involved in the *deployment* of the software prototype that was a deciding factor in the choice of user trial environment. Given that the software prototype was going to be deployed within a classroom environment, observing children with ASD interact with software within a similar environment was more valuable than those same observations would have been if conducted in a lab, an environment quite dissimilar from the classroom.

6.1.4 Conclusions

The investigation described in this section explored how five children with ASD interacted with computer game software that they were reported to be familiar with and enjoy. The insights gained during trials covered many issues to do with that interaction, but in summary included the following:

- When input was required from the children, the requirement needed to be clear.
- Audio instructions were ineffective and were sometimes distracting to the children.
- Sound and motion were effective at capturing and maintaining the attention of the children.
- Periods of inactivity, where the children did not need to provide any input, resulted in them becoming distracted and losing focus.
- Continual reward, without a corresponding requirement of input from the children, quickly resulted in the children failing to progress further into the game they were playing.
- Idiosyncratic input from the children was not dealt with well by the software and resulted in output from the software that the children did not expect.

- Hardware interface issues experienced by two of the children suggested that the choice of a touch screen technology, such as the Smartboard interactive whiteboard, had merit.

All of these insights informed the design and development of the software prototype produced as part of this thesis.

6.2 Investigation 3: Observing the Children Using Children's Drawing/Art Software within the Classroom

In this section an investigation is described where the researcher spent two weeks observing a group of children diagnosed with ASD use drawing/art software within the classroom environment. This investigation was undertaken as result of the decision to support drawing as a form of play within the software prototype developed as part of this thesis (see Section 6.0). Given this decision, exploring how the children involved in this thesis would interact with an existing, and acclaimed, art package was warranted. The results of such an investigation would either reveal that drawing, as a form of play for children with ASD, could be supported by existing software, or it would offer insight into what changes to such software were required for that goal to be met.

The software used in this investigation was Kid Pix Studio 4. This software was selected as it is a top selling creativity product for children all over the world and is very popular within NZ Schools.

6.2.1 Investigation Aims

The aim of this investigation was to determine how the children involved in this project interact with art and drawing software. This aim was motivated by the selection of drawing as the form of play that the software developed as part of this thesis would support. The behaviour exhibited by the children during the course of this investigation was used to inform the design of this software (see Section 8.0).

6.2.2 Method

The investigation was undertaken at two sites, called Site 1 and Site 2 within this thesis, both associated with the Patricia Avenue School (a school for children with special needs that is affiliated with the University of Waikato).

Three children with ASD from each site participated in the investigation. The children ranged in age from five to eight, were all male and four of the six were functionally non-verbal (see Section 4.1 for more information on the participants or Section 2.3 for more information on language and communication deficits amongst children with ASD).

The parental consent form sent home to parents before the beginning of Investigation 2 (see Section 6.1) included this investigation in its coverage.

Kid Pix Studio 4 software was installed at Site 1 and 2 on the same day, one day before user trials began at Site 1 and one week before trials began at Site 2. An unforeseen consequence of this was that Participant C and D noticed the installation of Kid Pix Studio 4 at Site 2 one week before user trials began there. Thus, when user trials began at Site 2, Participants C and D already had one week of experience using Kid Pix Studio 4.

The observation was performed in the morning before class began, over a two week period. The trial protocol used was the same as that used in Investigation 2 (see Section 6.1.2).

Each trial was recorded on video, with the video camera positioned to get the best view of the keyboard, mouse and profile of the child involved. At the same time a second camera captured video of what the monitor displayed. This additional camera was used in rather than the screen capture software employed in Investigation 2, due to the adverse effect that software had on the performance of the PC hardware available for use at Site 1 and 2.

The same process used in Investigation 2 (see Section 6.1.2) was used to analyse the video data collected during this investigation.

6.2.3 Findings and discussion

Hardware Interaction

In terms of Barendregt's classification (see Section 4.8), two 'Control' problems were identified:

As in Investigation 2 (see Section 6.1), Participants E and G had trouble using the ball mice that were connected to the computers used during trials. Participant A had similar difficulties with delicate and continuous movements with the mouse. As the user trials run during this investigation were the first occasion that Participant A was observed using a PC, it is fair to say that his experience with using mice was very limited.

As in trials run during Investigation 2 (see Section 6.1), Participant E tried to use the CRT monitor connected to the PC used during trials as a touch screen. At the time this investigation was undertaken, a Smartboard interactive whiteboard had yet to be installed at Site 2. Participant A also evidenced this behaviour during his user trials, attempting to 'push' the buttons on the left toolbar that were displayed on screen with his index finger. This is slightly different situation than Participant E, as Site 1 has had a Smartboard installed during the entire time Participant A has been enrolled, and thus he has experience with using touch technologies. As discussed in Section 6.1.3, this behaviour supports the use of and deployment to untethered interface technologies, such as the Smartboard interactive whiteboard.

Implications for design of software prototype: The difficulties experienced by Participants A, E and G with using the mouse during user trials, and Participant A and E's subsequent attempts to use the CRT monitor as a touch screen, supported similar observations collected during Investigation 2 (see Section 6.1.3, 'Hardware interaction' subsection). As detailed in the results of Investigation 2 (see Section 6.1.3, 'Hardware interaction' subsection), these observations support the decision to deploy the software prototype on Smartboard interactive whiteboard hardware.

Software Interface

Figure 6 presents the main screen that is displayed within Kid Pix Studio 4. This is the screen where all the ‘drawing’ and creative interaction are accomplished by users, and the screen in which the participants spent the majority of their time during trials (for four of the six participants, it was the only interface apart from the ‘log in’ interface that they dealt with).

As can be seen in Figure 6, the ‘left’ and ‘bottom’ toolbars occupy a large portion of the screen space (or ‘screen real estate’). One of the effects this had during some of the user trials was to increase the number of instances where one of the buttons or objects on either toolbar was clicked unintentionally. Participants A, E and G were observed to click on buttons within both of the toolbars in just this fashion during trials. The main contributing factor in this occurrence was likely to be their lack of control with the mouse as a ‘pointing device’ (likely a combination of the poor fine motor control that is symptomatic of children with ASD and a lack of experience with mice). However, the large amount of screen space that both toolbars occupied also seemed to contribute.

The left and bottom toolbars occupy such a large proportion of the available screen space in order to contain the large number of tools on the left toolbar and the large number of configurable options for each tool on the bottom toolbar. The large amount of space required for buttons for each of these tools is then exacerbated by the large size of the buttons/objects. These two factors, button size and number of tools, are discussed below.

The large size of buttons/objects upon both toolbars seemed to be a design accommodation to the reduced levels of fine motor control or precision within a younger user group. As discussed in Section 5.3.4 (within the ‘Smartboard interactive whiteboard’ subsection), this convention accommodates the acknowledged difficulties many children with ASD have with fine motor control and as such, it was a convention that was upheld within the software prototype.

Figure 6: Main screen view from Kid Pix Studio 4, with the 'draw' tool selected.

Looking at Figure 6, there are 17 tools provided on the left toolbar within Kid Pix Studio 4, labelled from A to Q:

A. idea machine
B. help
C. draw
D. ABC
E. paint
F. fill bucket
G. stickers
H. rubber stamps
I. mixer
J. backgrounds
K. sounds
L. animations
M. grab
N. eraser
O. start over
P. undo
Q. colour selector

When one of these tools is selected, the bottom toolbar or 'configuration' toolbar alters to suit the new tool. For example, as can be seen in Figure 6, when the 'Drawing' tool is selected upon the left toolbar, the bottom toolbar alters to display a total of 18 buttons: 1 to 4 select the drawing medium (pencil, chalk, crayon and marker), 5 to 7 select the 'size' of the drawing medium, 8 to 16 select the 'drawing mode' (free drawing, straight line, curved line, empty quadrilateral, filled quadrilateral, empty ellipse, filled ellipse, empty polygon and filled polygon), 17 plays media such as sound files (disabled for this tool), and 18 go to the slideshow view.

Although the number of combinations and art activities that this range of tools provides seems impressive, are they all appropriate for a drawing package designed for children with ASD? The following observations made during user trials suggest not:

- During trials with Participants A, B, E and G, the tool used by the participant was never *intentionally* changed.

As discussed above, Participants A, E and G sometimes selected other tools when they pushed buttons upon the left toolbar, but this always appeared to be accidental rather than deliberate. Participant B appeared satisfied with the default ‘draw’ tool, and did not select a different tool during trials.

- When Participants A, E or G selected a new or different tool, it rarely resulted in them *using* the new tool.

This further supported the working hypothesis that the change in selection was accidental.

- When Participants A, E or G selected a new or different tool, i.e. clicked upon a button on the left toolbar, this often became a *distracting* activity, causing them to stop drawing and instead focus on pushing more buttons upon the toolbar.

While this ‘playing with the buttons’ behaviour was not necessarily bad, it did redirect attention of Participants A, E and G away from their previous task of drawing. Also, while Participants A, E and G were *interacting* with the buttons on the left toolbar, they were not using them for their *original purpose*, as a means of selecting or changing a tool. The tension between designing software to support user enjoyment (here, ‘playing with buttons’) and designing to support a task (here, drawing) is revisited in Section 8.0.

The interface use displayed in trials with Participants C and D was markedly different from that displayed by the other participants in their trials. Recall that both of these participants had one week of experience familiarising themselves and experimenting with Kid Pix Studio 4 (see Section 6.2.2), a period of experience and familiarisation that did not occur for the other participants. The difference between the interface use of the two ‘groups’ of participants is illustrated in a trial with Participant C, described below:

Kid Pix Studio 4 has been started. Participant C skips past the initial animated ‘splash screen’ with a click of the mouse. The login interface is displayed. Participant C says, “I want to go to my name”. He says “My name” as he selects his name and then “Go!” as he pushes the go button to the left of his name. Participant C goes straight to the ‘ABC’ tool on the left toolbar and then inserts a textbox into his picture. He fills this textbox with a very large string of ‘t’ characters, with no spaces between them. Participant C pushes the play button off to the right on the bottom toolbar. Nothing happens. Participant C turns the sound on for himself by turning on the PC speakers. He pushes the play button again. When this fails to produce sound, he turns the volume on the speakers up. This still doesn’t work, and he says, “I can’t hear, I cannot hear”. When I reply that I can’t hear either, he responds with, “I wonder what is going on with the sound”. As I attempt to troubleshoot the sound issue, Participant C repeats the “Tee Tee Tee Tee Tee” mantra to himself. While I am attempting to solve the sound issue, Kid Pix Studio 4 crashes. As this happens, Participant C says, “Oh it doesn’t want to work either”.

Kid Pix Studio 4 has been restarted. Participant C logs in again. The textbox experiment as described above is retried; again it fails to work (the desired ‘Tee Tee Tee Tee Tee’ sound is not produced when the play button is pushed). Participant C says, “Lets get this one to work later, because he’s not letting me say ‘Tee Tee Tee Tee Tee!’”. As this explanation is given, Participant C inserts a background image of a photo of a jungle into his image. Participant C insists there is no sound, even thought the buttons on the left toolbar are all making sounds when he pushes them. When I inform him that there is sound, he replies by saying, “No, because he doesn’t want to talk”, and then, “Because the camera *was on first". I inform him that the camera is not having any affect on the computer or Kid Pix Studio 4. He responds by saying "It was the camera's fault", followed up by "Because he put it on first" and then "He was first" and finally "I can't hear Tee Tee Tee Tee Tee!".*

I try to divert Participant C by asking him what else he wanted to do within Kid Pix Studio 4. He doesn't respond straight away and instead starts placing 'stickers' (small existing images that are inserted into an image via the 'stickers' tool within Kid Pix) onto the jungle scene. After the first sticker is placed, he says, "It's me hooping on the grass". Another sticker is placed. "This is [child's name from Site 2 not involved in study]. He sits up the top." This sticker is positioned at the top of the screen. "He likes to sit on the top". Another sticker and another classroom member are added ("We stay away from [child's name from Site 2 not involved in study – different from previous]"); this sticker is placed to the left, away from the other two.

Participant C inserts a sound into his picture. He clicks on the play button on the bottom toolbar. A suspenseful piece of music is played. Upon hearing this music, Participant C says "It's just the music, not the Tee Tee Tee Tee Tee sound!" Participant C then completes a series of actions so quickly I can't see the exact actions. The end result is that Kid Pix Studio 4 is playing a slideshow of all the 'images' Participant C has created. All of the animation and sounds within each image play and then the slideshow transitions to the next image. Participant C says during this slide show, "I want to start again and make it make its Tee and Tees". He then closes the slide show and starts a new image, saying, " I'll make it Tee all over again."

A new image is opened. Participant C inserts a textbox into the image and quickly fills it with a string of t characters. He repeats the "Tee Tee Tee Tee Tee" mantra repetitively as he does so. This time, when he pushes the play button on the bottom toolbar, the vocalisation works. Participant C is elated: "Ha ha!" "I can hear the Tee Tee Tee now!"

From the trial described above, and the others undertaken with Participants C and D, the following observations were made:

- During trials with Participants C and D, the tool used by the participant was changed often.

A large array of tools within Kid Pix Studio 4 were being used and thus that the number and variety of tools available was a valuable and useful design feature with Kid Pix Studio 4 for these two participants. However, the next observation qualifies this somewhat:

- During trials with Participants C and D, the draw and paint tools were never used.

While Participants C and D did and created a lot during trials, none of their activity could have been considered drawing (or painting, which is similar enough to drawing for the purposes of this thesis).

In terms of Barendregt's classification, problems associated with accidental interaction with interfaces seem to be classified as 'Sensorimotor' problems, however, this definition seems to inadequately describe the distraction problem that also occurred.

Implications for design of software prototype: Based on the observations listed within this section, it was decided that the software prototype would only support one drawing tool (see Section 8.0 for details). In this way, the two concerns associated with the large amount of screen space required by the large number of tools supported within Kid Pix Studio 4, accidental tool selection and the subsequent likelihood of distraction, would be averted. This decision was supported by the observation that 4 out of the 6 children participating in this investigation did not intentionally select a new tool, and were satisfied with the default 'draw' tool. There was some evidence from the user trials undertaken with Participants C and D that they did use a large proportion of the great variety of tools supported within Kid Pix Studio 4, however, upon examination it was revealed that none of these 'other' tools were being used to draw. As the software prototype had the previously asserted goal of supporting drawing as a form of play, these extra activities and the tools that supported them, distract attention from the primary focus (drawing).

Interaction Design

One of the hypotheses postulated as a result of the findings of Investigation 2 (see Section 6.1.3), was that an interaction design or input model that required a user to continually provide input in order to received a corresponding reward or output was likely to be more successful in maintaining focus and engagement with these children (see Section 6.1.3, 'Continual input requirement' subsection). Such an interaction design, due to its higher input requirement, could also result in a higher level of activity from the children. As Kid Pix Studio 4 utilised the interaction model outlined above, an opportunity existed to informally test this hypothesis through analysis of the user trials undertaken during this investigation (Investigation 3). The following was observed:

- Participants B, C and D displayed high levels of activity and engagement for the entire period of their user trials.
- Participants B, C and D participated in their user trials for a very high proportion of the allowed time limit, which was 15 minutes.

This supports the hypothesis that the interaction design outlined above, as implemented within Kid Pix Studio 4,contributed to maintaining high levels of activity and engagement for extended periods for these three participants.

- Participants A, E and G seemed to lose focus after approximately 5 minutes and were often easily distracted before that time.

This observation seems counter to one previously made, and suggested that the 'continual input' interaction model was not as successful as had been predicted. However, the following observation revealed the possibility of a confounding factor:

- Participants A, E and G had far lower activity levels than Participants B, C and D.

Given the results of the previous ‘Hardware interaction’ subsection and the above observation, we see that the three participants that displayed a shorter period of engagement and focus, characterised by less activity than the other three participants, were also the three participants who were least accomplished with the use of the mouse (which was the primary interaction hardware used in the user trials during Investigation 2).Thus, the suggestion becomes that the ‘continual input’ interaction model was successful in promoting a high level of engagement and activity for some of the participants within this investigation, but that these benefits were *contingent* on a level of mastery of the required input (and thus also the necessary input hardware).

As discussed in the results of Investigation 2 (see Section 6.1.3), problems associated with the interaction design of software can also to be classified as ‘Control’ problems within Barendregt’s classification.

Implications for design of software prototype: As is suggested within the final paragraph of this subsection, for the hypothesised benefits of a ‘continual input’ interaction design to be realised, the required inputs had be easily accomplished. The low level of mastery with a mouse evidenced by half of the children involved in this investigation supported the deployment of the software prototype to Smartboard interactive whiteboard hardware, a device with the children were expected to be proficient in using (see Section 6.1.3, ‘Hardware interaction’ subsection).

Sound and Animation

As was observed during Investigation 2, elements within Kid Pix Studio 4 that contained sound and motion were very effective in capturing and maintaining the children’s attention during user trials.
However, not all instances where sound and motion captured the children attention were optimal or desirable. For example, within Kid Pix Studio 4, when a user ‘mouses over’ any one of the buttons upon the left toolbar (items A to Q in Figure 6), a sound is played constantly until the mouse is moved. In many of the user trials with Participants A, E, and G this resulted in the child abandoning the

activity that was his earlier focus (i.e. drawing) in favour of listening to the sounds and watching the animations provided by the buttons as the mouse cursor was placed over them. As discussed in the 'Software Interface' subsection above, while the participant engaging in this alternate activity was not necessarily 'bad', the distraction it caused runs contrary to the original goal of the software (drawing).

Given that children with ASD can become preoccupied by stimuli that they enjoy (see Section 2.2), care needs to applied as to when and where such stimuli, e.g. sound and motion, are used. If the goal of a piece of software is to support a specific activity, then it is reasonable to suggest that the use of stimuli effective at capturing and maintaining a users attention be contingent on active participation in that activity.

In terms of Barendregt's classification, problems associated with lack of motivation to play, caused by not enough interaction, would be classified as 'Control' problems.

Implications for design of software prototype: As described in the results of Investigation 2 (see Section 6.1.3, 'Sound and animation' subsection), the use of sound and animation within the software prototype was limited to activity associated with the supported activity of drawing.

Bugs

Bugs, while accepted as suboptimal within all software, can result in much more significant effects when encountered by users with ASD. During user trials with Kid Pix Studio 4, a number of bugs were discovered and in some instances these caused significant confusion and distress for the participants involved. The trial with Participant C described earlier is a good example of this. During that trial Participant C had, as one of his goals, the desire to hear a succession of "tee" sounds vocalised within Kid Pix Studio 4. When this goal couldn't be accomplished, even though Participant C had completed all of the actions required for it to be accomplished (i.e. a bug was encountered), Participant C became increasingly agitated. In one part of the trial, the researcher became concerned enough with Participant C's level of agitation that he attempted to divert him from his goal. If that diversion had not worked, the researcher considered it likely that the user trial would have had to have been halted in an effort to reduce Participant C's level of agitation observed within Participant C. That this halting of the user trial would have been unlikely to reduce Participant C's level of agitation was also deemed likely, further illustrates how detrimental the occurrence of bugs can for children with ASD.

Given the strongly negative reactions caused by bugs observed during the user trials of this investigation, it is likely that staff responsible for classrooms with children with ASD avoid software with a large number of bugs. Conversations with Patricia Avenue School staff on this topic support this conclusion.

As described in Section 4.8, bugs are classified as 'Functionality' problems within Barendregt's classification.

Implications for design of software prototype: Ensuring that the least possible number of bugs existed within the software prototype was always a goal of this thesis. However, after observing, for the children involved in this thesis, that bugs caused not just nuisance, but distress, it became a priority.

Help

Kid Pix Studio 4 offers an extensive help facility as a way of assisting users with the complexity caused by the number of tools that exist. Unfortunately the help facility is similarly complex. Users gain access to help within Kid Pix Studio 4 by selecting the help tool. Once selected, this tool transforms the mouse cursor into a question mark, which is then applied to another button/object upon the interface. Not all elements within Kid Pix Studio 4 have associated help. Once the 'help cursor' has been applied to another button/object, a dialog box appears (see Figure 7) and the text within that dialog is immediately 'read aloud' to the user as an audio instruction. As can be seen in Figure 7, three buttons are displayed along the bottom of the dialog box. If the user wishes the audio instruction to be replayed, they can press the 'Replay' button (button A in Figure 7). Alternatively, if the user pushes the ‘Movie’ button (button B in Figure 7), they are shown a movie that shows them how to use the tool they requested help for.

The complex chain of interactions described above, that is required to use the help facility within Kid Pix Studio 4, places a high expectation of understanding upon users, especially since those users are expected to be children. Given the cognitive and learning deficits experienced by many children with ASD (see Section 2.0), this expectation is even more untenable.

During trials, the help tool was only selected by Participants C and D, and their selection seemed accidental rather than deliberate. The audio instructions that immediately started playing once they had applied the help tool to another tool caused confusion and frustration, eliciting comments such as “What is it talking for?” and “Why is it talking? I don’t want that”. At these points assistance was provided by the researcher, and the help dialog was closed.

While the help support within Kid Pix Studio 4 is more sophisticated than within the software observed in Investigation 2 (see Section 6.1), its use of sound as an instructional medium was as unsuccessful as similar attempts within the software observed in Investigation 2. As none of the participants viewed help movies during trials, no evidence as to their effectiveness was obtained.

The problems associated with the help facility within Kid Pix Studio 4, experienced by Participants C and D, seem to be a mixture of ‘Control’ and ‘Recognition’ problems in term of Barendregt’s classification.

Implications for design of software prototype: As discussed in the results of Investigation 2 (Section 6.1.3, ‘Audio instructions’ subsection), audio instructions were not used within the software prototype.

Given the observations made above concerning the effectiveness of the help facility within Kid Pix Studio 4, the creation of a help facility which would enable children with ASD to administer their own self-help effectively through its use was judged a considerable undertaking, and outside the scope of this thesis.

Another insight that resulted from the above observations was that children with ASD did not cope well with tools that required a complex chain of actions to use. Therefore, all tools and functionality within the software prototype were designed to be as simple and easy to use as possible.

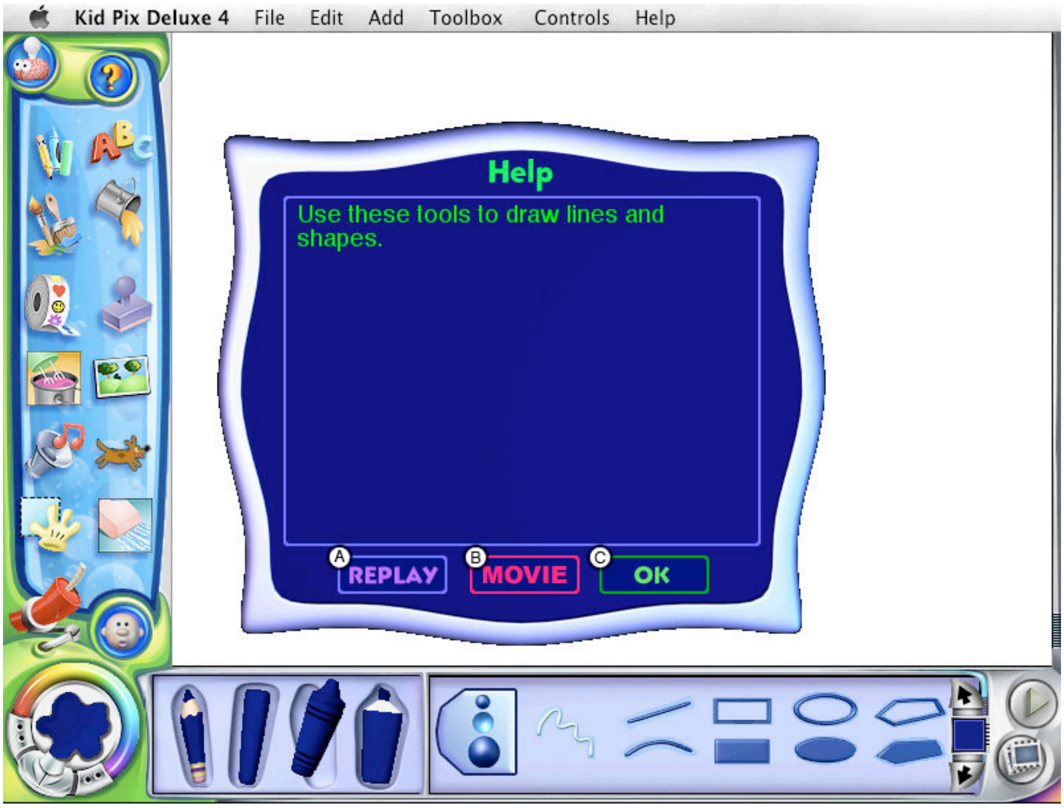

Figure 7: Main screen view from Kid Pix Studio 4, with the 'help' tool selected and applied to the 'draw' tool.

What Was Drawn?

The images that were created by participants within Kid Pix Studio 4 during this investigation differed from participant to participant. The most significant point of difference between the images created by the participants was that, as discussed earlier in the ‘Software interface’ subsection, Participants C and D did not use the ‘draw’ or ‘painting’ tools during user trials, and thus they did not actually draw any of the images they created. Considering this difference in the images produced by Participants C and D, their images are discussed after those created by the other participants.

The similarities between the images created by Participants A, B, E and G are described below:

- Participants A, B, E and G, all created drawings that were composed of ‘dots’ and long straight and curved lines. There were few instances of detailed drawing.
- Participants A, B, E and G used only the ‘draw’ tool to create their images.
- Participants A, B, E and G did not alter the line thickness of the drawing tool they used within Kid Pix Studio 4.
- Participants A, B, E and G used only the ‘free drawing’ configuration (item 8 in Figure 6) of the drawing tool they used within Kid Pix Studio 4.

These observations suggest that a single drawing tool with a ‘free drawing’ mode is the only tool that is required within the software prototype for these participants to accomplish their drawing goals.

- For Participants A and B, filling all of the available ‘white space’ displayed upon the main screen of Kid Pix Studio 4 seemed to be one of the goals of their drawing activity.

This suggests that this goal, of filling the available drawing space within the software prototype, be possible.

Observations the consider the similarities between the images created by Participants C and D are described below:

- Participants C and D created complex images composed of a variety of clearly distinct graphical elements.
- Participants C and D used a large number of tools to create their images.
- Participants C and D altered the configuration of the tools they used to create their images.

Initially, these observations suggest that for Participant C and D to accomplish the ‘graphical goals’ they had during user trials, that the same number of tools (with similar functionality and configuration options) that exist within Kid Pix Studio 4 would need to exist within the software prototype. However, after examination, it is revealed that all of the graphical elements within the images created by

Participants C and D could have been drawn, it was simply the case that the tools used by Participant C and D within Kid Pix Studio 4 made the creation of these graphical elements easier.

Considering that the software prototype developed as part of this thesis was supporting drawing as a form of play, enabling users to draw was its primary focus. Even though drawing the individual graphical elements within Participants C and D's images of would be harder than within Kid Pix Studio 4, it was still possible and furthermore, would result in Participant C and D actually drawing.

6.2.4 Conclusions

The investigation described in this section explored how six children with ASD interacted with the Kid Pix Studio 4 software package. At the beginning of this section it was stated that the results of Investigation 3 would either reveal that drawing, as a form of play for children with ASD, could be supported by existing software, or that those results would offer insight into what changes to such software were required for that goal to be met.

The Kid Pix Studio 4 software, as the most recognised and highly regarded drawing/art package for children within New Zealand schools, was selected to represent the 'state of play' for existing software. After the results of this investigation were considered, it was judged that the Kid Pix Studio 4 software was not suitable for use for children with ASD. Acknowledging this, the following insights informed the design and development of the software prototype produced as part of this thesis:

- Hardware interface issues experienced by three of the children suggested that the choice of a touch screen technology, such as the Smartboard interactive whiteboard, had merit, especially given the demands of the interaction design inherent in a drawing activity.
- The large proportion of 'screen real estate' occupied by the interface within Kid Pix Studio 4 seemed to increase the number of accidental button pushes amongst participants who had trouble using a mouse.

- The number of tools within Kid Pix Studio 4 seemed more than was [strictly] required to support drawing as an activity, and in two cases distracted the participants from drawing.
- Interaction designs that supply reward or output that is highly contingent on level of input seem to encourage high levels of engagement and activity. However, for this to occur, the input required by the interaction design must be at a level that can be mastered by users.
- Sound and animation were effective at capturing and maintaining the attention of the children. However, if they were used inappropriately they often distracted participants from the main activity - drawing.
- The bugs encountered within Kid Pix Studio 4 were observed to cause a high level of stress within two Participants involved in this investigation. Due to this observation, the elimination of bugs within the software prototype developed as part of this thesis became a priority.

7.0 The Neon Chalk Software Prototype

The software prototype developed for this thesis is named "Neon Chalk" from the mixture of soft tones and 'glow points' it is possible to create whilst drawing with it. It was designed to support drawing as a form of play for children with ASD through deployment to a Smartboard interactive whiteboard. Its design was informed by observations of a group of children with ASD (see Section 4.1), made while watching their daily routine (see Section 5.0) and their interactions with existing technologies (see Section 6.0).

During design, emphasis was placed on creating an environment that was straightforward and easy to use. Compelling visuals and rich contrast would capture the children's attention, and the deliberate removal of distracting elements would help to maintain it. To this end, there would be only one drawing tool, other 'in game' controls were kept to an absolute minimum and stimulus was made contingent on the child's act of drawing (i.e. the visual and aural components only change when the child is actively drawing). To allow this streamlined interface, all configuration was moved from 'in game' to a customised profile for each child that was configured before they started drawing.

Within this section the Neon Chalk prototype developed during this thesis is discussed. Firstly, three walkthroughs of the software prototype are provided (see Section 7.1), each describing a version of the prototype's use: the child's play, the staff member helping the child during play, and the staff member setting up the game for the child. Neon Chalk was designed to support both children with ASD and the staff/care providers that work with them, and each walkthrough illustrates the differences in how they were expected to interact with it.

Following the walkthroughs mentioned above, the key features of the Neon Chalk prototype are examined in more depth and the technical details of their development are discussed (see Section 7.2).

7.1 Walkthroughs

As mentioned above, The Neon Chalk prototype was designed to be used by two different types of users: children with ASD and the staff/care providers that work with them. Three walkthroughs are presented below, each describing how the two different types of users were expected to interact with the Neon Chalk prototype. The first two walkthroughs describe activity expected to occur during a game or 'drawing session', while the third describes behaviour during game setup.

7.1.1 Playing the Game

Gameplay

Figure 8 presents the Gameplay screen within the Neon Chalk prototype, as it would be seen by a child user beginning their 'drawing session'. As soon as they touch the drawing surface, the chalk begins to appear. If they move their hand quickly, subtle 'motes' of chalk are scattered along the arch the movement of their hand describes. As their hand slows, the line of chalk becomes continous and the colour grows brighter. If their hand rests for long, the colour will approach white. They can draw anywhere upon the Smartboard that is not already occupied by one of the controls (items 1 to 6 in Figure 8).

As they draw, a silhouette of a piece of chalk in the lower right hand corner grows shorter and shorter, representing the amount of the chalk that they have used. As they draw even more, the chalk silhouette finally disappears. At this point when the child draws, the oldest parts of their drawing will vanish as they continue to draw. They can play with this effect, if that is what they wish to do, or if they touch the button where the silhouette used to be, their drawing will disappear and the chalk will be renewed.

The timer (item 6 in Figure 8) keeps track of the length of time that the child draws. The child can play for as long as their 'drawing session' has been configured to last for; the Neon Chalk prototype will pause when the allotted time has passed. Once the ‘drawing session’ has ended, the child, with help from a staff member, can pick one of the screen shots of their picture taken during their ‘drawing session’. This screen shot can be printed, perhaps to provide an additional activity or as a record of the ‘drawing session’.

Interface

As described above, Figure 8 presents the Gameplay screen within the Neon Chalk prototype as it would be seen by a child user when they begin their ‘drawing session’. The three interface components present within the Gameplay screen that a child user is intended to interact with are described below:

Drawing Surface

The drawing surface within the Gameplay screen was designed to occupy the largest possible amount of space, while still accommodating the other interface components that exist. As described above (see ‘Gameplay’ subsection), a child user can draw anywhere upon this surface not already occupied by an interface component (items 1 to 6 in Figure 8).

Chalk

The chalk that is created at the beginning of a child user’s ‘drawing session’ is configured based on the values recorded within their profile (see Section 7.1.3). Depending on those values, the colour, width and even the sound played while the chalk is used can vary. Figure 9 provides an example of a drawing with *large multicoloured rainbow* chalk.

‘Running out of chalk’ is a byproduct of the underlying architecture of how the chalk works (see Section 7.2), and thus given continued drawing by the child user, is inevitable. An indication that this event is about to occur is provided by the silhouette image of a piece of chalk that is depicted upon the ‘chalk refresh’ button (see subsection ‘Chalk refresh button’ below). This silhouette image gets shorter as the chalk is ‘used up’. Once the child user has ‘run out of chalk’, the oldest portion of their drawing will slowly disappear as they continue to draw.

Figure 8: Gameplay screen within the Neon Chalk prototype.

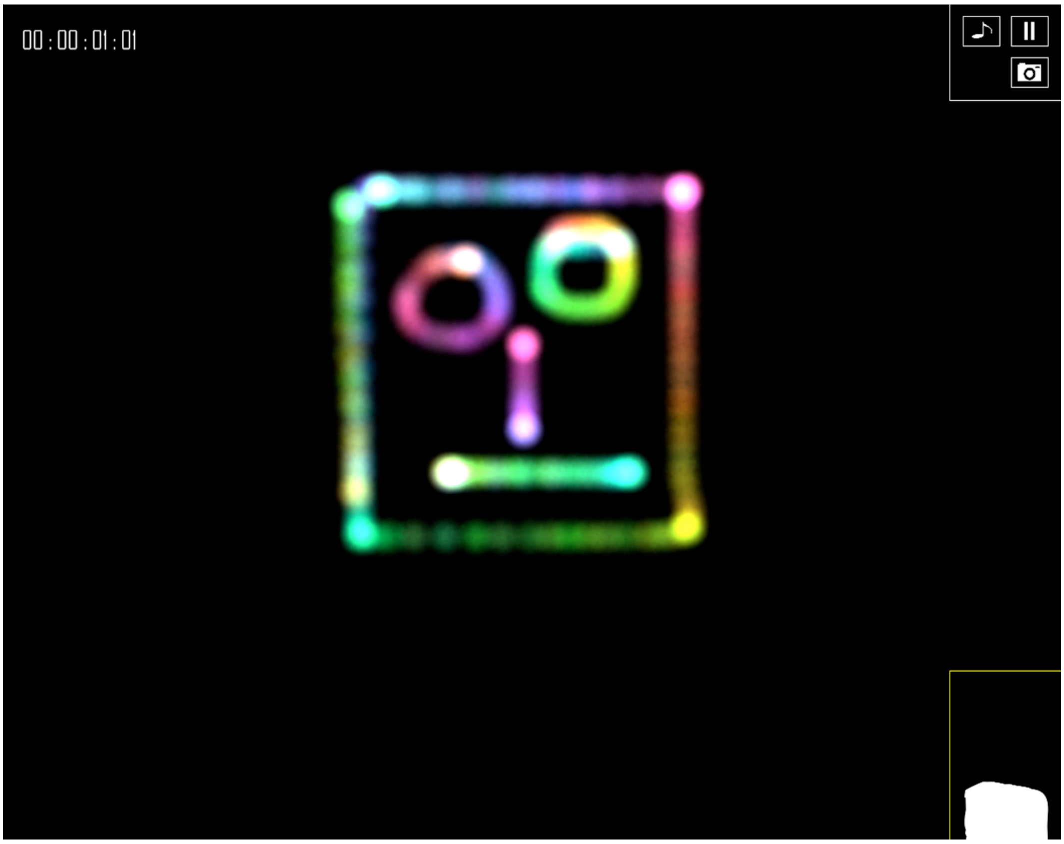

Figure 9: Gameplay screen within the Neon Chalk prototype with an example image that has been drawn using *large multicoloured rainbow* chalk.

The possibility that child users could have a negative reaction to this effect was recognised during the development of the Neon Chalk prototype. Children with ASD are acknowledged as preferring predictable environments with predictable outcomes (see Section 2.1), and thus the creation of an environment that had a transparent cause-and-effect model was a principal design goal during development. The fear existed that, especially when the effect was first encountered, that a child user would not be able to understand *why* it was occurring, and *what* action they had initiated that had *caused* it to occur.

It was this uncertainty about whether a child user would understand *what* was occurring when they 'ran out of chalk', and *why*, that was the justification for the graphical representation of the current 'chalk quantity' that is displayed upon the 'chalk refresh' button (see subsection 'Chalk refresh button' below). This display shows the child the proportion of the chalk that they have left, and reduces constantly as they draw.

Chalk Refresh Button

The 'chalk refresh' button (item 5 in Figure 8) is the only interface component, apart from the background, that is for use by a child user. As the child draws, the silhouette image of a piece of chalk, depicted upon the 'chalk refresh' button, grows progressively shorter, simulating that the child is 'using up the chalk'. Once the child has 'used up' all of the chalk, the 'chalk refresh' button will be completely black, simulating that they have 'run out of chalk'.

When the 'chalk refresh' button is pushed, the child user's drawing disappears (i.e. is deleted) and the silhouette image depicted upon the 'chalk refresh' button returns to its initial length, simulating that the chalk has been 'renewed' or 'refreshed'.

7.1.2 Helping with the Game

During a game or 'drawing session' within the Neon Chalk prototype, a situation may occur in which a staff member/care provider wishes to intervene or become involved. Perhaps the child user has become agitated with the sound that plays as he draws, or the child user has drawn a particularly impressive image that the staff member wishes to record. The Gameplay screen within the Neon Chalk prototype has a ‘control panel’ with three controls designed to allow a staff member to intervene in situations like this, with as little disruption to the child user’s activity as possible.

The control panel and its controls are described below:

Control Panel

The control panel (item 1 in Figure 8) is positioned high in the right hand corner of the screen so the child users will not be able to reach it. As described above, the controls upon the control panel are designed to allow a staff member to quickly interact with the Neon Chalk prototype during a ‘drawing session’, with as little impact on the child user as possible. The control panel contains three controls: sound (item 2 in Figure 8), pause (item 3 in Figure 8) and screen shot (item 4 in Figure 8).

Sound Control

The sound control enables and disables the playing of the ‘chalk sound’ that may have been configured to play within the profile of a child user (see Section 7.1.3, ‘Profile Options’ subsection). During a ‘drawing session’, a staff member may notice that the child user has become agitated due to the ‘chalk sound’ configured to play when they are drawing. When this occurs, the staff member can quickly ‘push’ the sound control upon the control panel and this will disable the ‘chalk sound’. If later, after the child has calmed down, they think it is appropriate, the ‘chalk sound’ can be enabled by another quick ‘push’ of the sound control. This control’s default setting is ‘enabled’.

Pause Control

The pause control pauses the game and shifts focus to the Pause screen that is displayed when the control is ‘pushed’. This control is not designed to deal with any specific situation during a ‘drawing session’, but rather is a ‘catch all’ that allows a staff member to halt play within the Neon Chalk prototype, deal with a situation, and then resume play (or exit the ‘drawing session’, if they prefer) for the child user. Maybe the staff member requires the child user’s attention, or maybe events outside of the game mean that the child user’s ‘drawing session’ must be halted early. Unless the ‘play timer’ has been enabled within the child user’s profile (see Section 7.1.3, ‘Profile options screen’ subsection), pausing the game with this control is the only way to gain access to the Pause screen, which, in turn provides the only way to end a ‘drawing session’.

Screen Shot Control

The screen shot control takes a screen shot of the background or ‘drawing surface’ within the Neon Chalk prototype, without the other interface elements (items 1 to 6 in Figure 8) being included. This control is provided so that if a staff member notices that the child user has drawn a particularly impressive image, they can take a screen shot of it (and maybe print it later, through use of the Screen Shot Gallery) with a quick ‘push’ of this control. Unless automatic screen shots have been enabled within the child user’s profile, this control is the only way to take a screen shot within the Neon Chalk prototype.

The screen shot taken is added to the collection of screen shots that have been recorded through a given ‘drawing session’. These screen shots can be viewed in the Screen Shot Gallery, which is accessed through the Pause screen. The Pause screen and Screen Shot Gallery are discussed later in this section.

Timer

The timer positioned in the upper left hand corner of the Gameplay screen (item 6 in Figure 8) displays the amount of time that has elapsed since the child user’s ‘drawing session’ began.

Pause Screen

Figure 10 presents the Pause screen within the Neon Chalk prototype. This screen can be accessed manually through the control within the Gameplay screen (item 3 in Figure 10), or automatically once a specified period of time was passed during a ‘drawing session’, through use of the ‘play timer’ feature that can be configured within a child user’s profile (see Section 7.1.3, ‘Profile Options’ subsection).

The Pause screen is not intended to be interacted with by an unsupervised child user; this screen is accessed either by the pause control on the control panel (see above ‘Pause control’ subsection), or automatically when the ‘play timer’ has detected that a predefined period of time has passed, as configured within the child user’s profile (see Section 7.1.3, ‘Profile Options’ subsection).

Three options are presented within the menu displayed on the Pause Screen: resume game (item 1 in Figure 10), view screen shots (item 2 in Figure 10) and end game (item 3 in Figure 10). The ‘resume game’ and ‘end game’ options are straightforward, with the ‘resume game’ option transitioning from the Pause screen back to the Gameplay screen (see above ‘Gameplay and interface’ subsection), while the ‘end game’ option transitions from the Pause screen to the Main Menu screen (see Section 7.3.2, ‘Main menu’ subsection). The ‘view screen shots’ option transitions to the Screen Shot Gallery, which is described below.

Screen Shot Gallery

Figure 11 presents the Screen Shot Gallery within the Neon Chalk prototype. This screen is accessed through the Pause screen described above. Within the gallery all of the screen shots taken during the current ‘drawing session’ are displayed as thumbnail images (items 1 to 8 in Figure 11). If more screen shots have been taken during the current ‘drawing session’ than be accommodated within the confines of one Screen Shot Gallery ‘screen’, then multiple such screens are created and can be navigated through by use of the ‘Previous’ and ‘Next’ buttons (items 9 and 11 in Figure 11).

Note that both buttons are ‘greyed out’ in Figure 11, as the eight example screen shots did not require multiple Screen Shot Gallery ‘screens’ to be created. If the ‘Done’ button upon the Screen Shot Gallery is ‘pushed’, a transition back to the Pause screen (see above ‘Pause screen’ subsection) occurs.

If a thumbnail image within the Screen Shot Gallery is 'pushed', it enlarges to occupy a majority of the available screen space (see Figure 12). In this zoomed mode, the image can be printed by using the 'Print' button (item 2 in Figure 12), while use of the 'Cancel' button (item 1 in Figure 12) will return focus to the Screen Shot Gallery. The Screen Shot Gallery is intended to be used by a staff member with possible input from the child user who has just been drawing within the Gameplay screen. Together they can decide if one of the screen shots taken during the 'drawing session' should be printed.

7.1.3 Setting Up the Game

As discussed at the beginning of this section, one of the design goals of the Neon Chalk prototype was to create a simple, straightforward interface for the child user that only contained the *essential* elements necessary to support the activity of drawing. One of the ways this was accomplished within the Neon Chalk prototype was to shift the configuration of the drawing tool, the chalk, from *within* the game to *before* the game began.

This change meant the controls required to configure the chalk during the 'drawing session' were no longer required within the 'in game' interface. Findings from Investigation 3 (see Section 6.2.3), where the participants involved in this thesis were observed using the drawing/art package Kid Pix Studio 4, showed that tool configuration controls were either ignored by the participants, their function unused or not understood, or they became a distraction, a kind of 'button game' unrelated to their function of configuring a drawing tool. The removal of these unused or distracting elements of the 'in game' interface was done to encourage the child user to keep their focus on drawing.

Configuration of the chalk is done before the game via a *profile* for each of the child users of the Neon Chalk prototype. For each child user, it is intended that a profile be created and then a configuration of the chalk be *customised* within that profile to suit the needs of that child, as determined by the relevant staff member that works with them (i.e. the classroom Teacher). A given child user could be involved in the configuration process, if that was deemed appropriate by the staff member, but it was assumed that the staff member would be directing it.

Figure 10: Pause screen within the Neon Chalk Prototype.

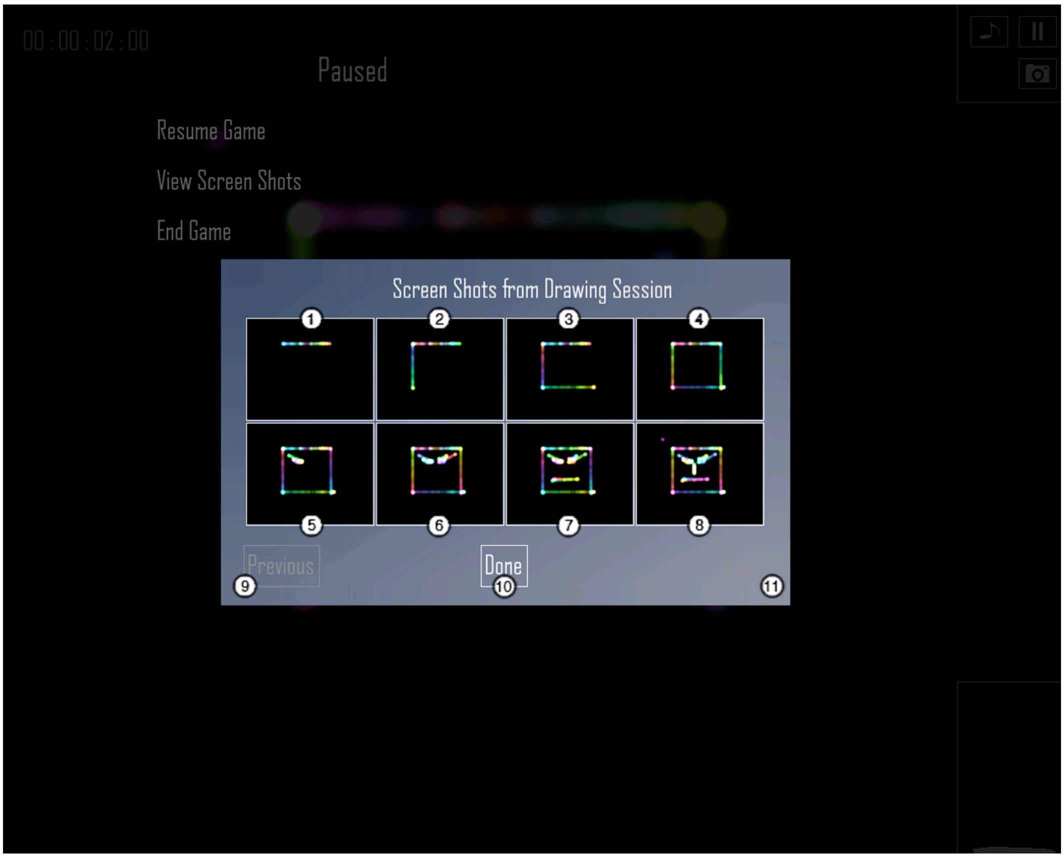

Figure 11: Screen Shot Gallery within the Neon Chalk.

Figure 12: A 'zoomed in' view of a screen shot from the Screen Shot Gallery within the Neon Chalk prototype.

The walkthrough that follows describes how a staff member would use the interface provided within the Neon Chalk prototype's 'profile management screens' to create a profile for a child user. After the profile is created, the chalk is configured within the profile and then the profile is saved. Once it is saved, the profile can be used to launch a game or 'drawing session' within the Neon Chalk prototype where the chalk created is configured by the profile.

Main Menu

Figure 13 presents the Neon Chalk prototype's Main Menu screen, the first screen displayed when the Neon Chalk prototype is opened. To create a new profile from here the staff member needs to select the 'Create New Profile' option (item 2 in Figure 13) described below.

Create New Profile

Upon selection of the ‘Create New Profile’ menu element from the Main Menu screen, an on screen keyboard is displayed (see Figure 14). The staff member enters a name for the new profile by pushing the alphabet buttons and then presses the ‘OK’ button when they are finished.

Once a staff member has inputted a name for the new profile, the Main Menu screen transitions to the Profile Options screen described below.

Profile Options Screen

When this screen is first displayed (see Figure 15), all the profile options are set to default values. Each option that is not greyed out can be altered by pushing the option label on the left hand side of the screen (items 1 to 9 in Figure 15). Every time an option label on the left is ‘pushed’, the corresponding option value on the right hand side cycles through one of its possible settings. All of the options presented in Figure 15 are described below:

Single/Multicoloured Chalk

Configurable values: Single coloured or multicoloured.
This option switches the colour mode of the chalk from single coloured to multicoloured and back again. Looking at the sample of eight of the possible ‘chalk colours’ presented in Figure 16, we can see that multicoloured chalk colours create a gradient of hue when they are drawn with, while the single coloured chalk colours create a single colour.

Chalk Colour

Configurable values (multicoloured): blue, cyan, green, yellow, cyclic, tiedyed, rainbow, red or magenta.

Figure 13: Main Menu screen within the Neon Chalk prototype.

Figure 14: On-screen Keyboard within the Neon Chalk prototype.

Figure 15: Profile Options screen within the Neon Chalk prototype with options set to default.

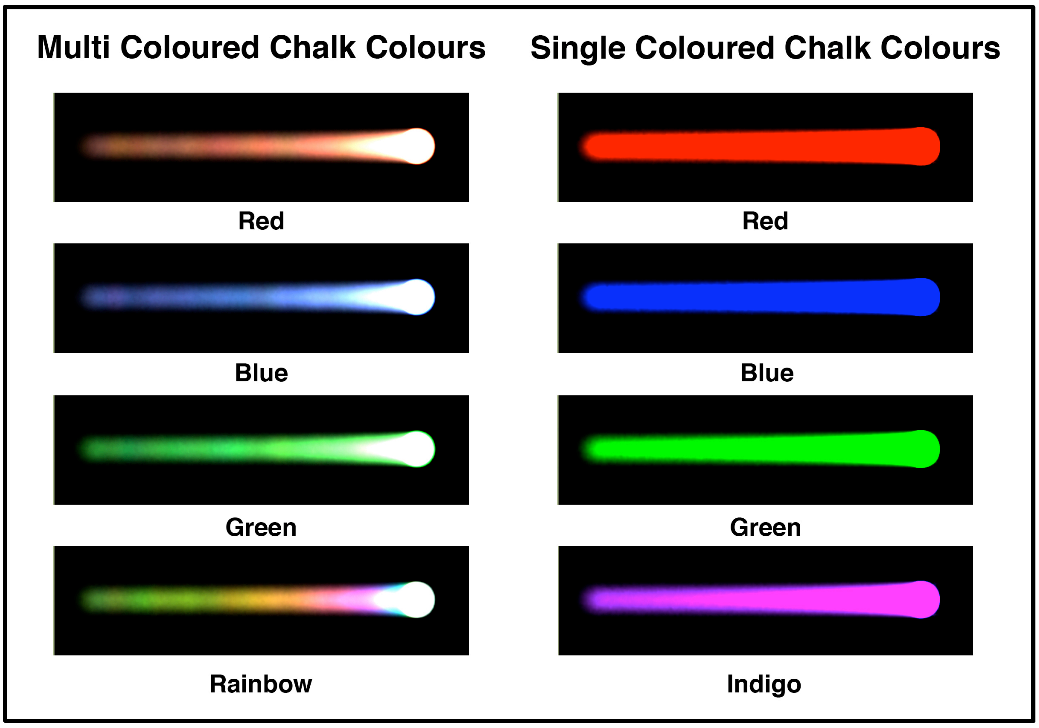

Figure 16: Colour comparison between 'multicoloured chalk colours' and 'single coloured chalk colours'.

Figure 17: Profile Saved dialog within the Neon Chalk prototype.

This option changes the colour of the chalk. To demonstrate what the selected chalk colour looks like, as this option is cycled through, the image below the colour value changes to match the selected colour.

Chalk Size

Configurable values: Small, medium, large, huge.
This option changes the size of the chalk in terms of the radius of its 'tip'.

Suggested Improvements for further development of software prototype: As a user cycles through the four size values that the chalk can be set to, those values are very loosely defined for the user. In the future, this option could alter the size of the chalk displayed within the image positioned below the chalk colour value (item 12 in Figure 15), and thus describe the relative size difference between the values.

Enable Play Timer

Configurable values: yes or no.
This option enables or disables the play timer within the Gameplay screen of the Neon Chalk prototype (see Section 7.1.1, 'Gameplay and interface' subsection). As discussed in the findings of Investigation 1 (see Section 5.3.2), an automated timer facility would enable the staff at both sites to start a child playing with the Neon Chalk prototype and then apply their attention elsewhere, confident that the prototype would halt play after a specified period of time. It was also hoped that by transferring the role of play cessation from the staff to an impersonal artefact (i.e. the Neon Chalk prototype) that some of the disagreements that had been observed to occur when children were told they were to stop playing on the computer would not occur or would be lessened in magnitude.

Play Time

Configurable values: 1:00, 2:00, 3:00, 4:00, 5:00, 10:00, 15:00, 20:00, 25:00 or 30:00.
This option sets the period of time within the Gameplay screen that the Neon Chalk prototype will allow to pass before it pauses the game. See Figure 10 to see what the Pause screen looks like, and Section 7.1.2, 'Pause screen' subsection, for more information on the Pause screen.

Enable Automatic Screen Shots

Configurable values: yes or no.
This option enables or disables the automatic recording of screenshots within the gamespace of the Neon Chalk prototype. When this option is enabled, a screenshot will be taken after every increment of time specified in the option positioned just below this one (item 7 in Figure 11). If this option is disabled, screen shots can still be taken manually from within the Gameplay sceen (see Section 7.1.1, 'Gameplay and interface' subsection).

Time Between Screen Shots (in Minutes)

Configurable values: 0:15, 0:30, 0:45, 1:00, 1:15, 1:30, 1:45, 2:00, 2:15; 2:30; 2:45, 3:00, 3:15, 3:30, 3:45, 4:00, 4:15, 4:30, 4:45 or 5:00.
This option sets the time period between when automatic screen shots are taken.

Suggested Improvements for further development of software prototype: As can be seen from the large set of configurable values described above, what an appropriate 'level of granularity' between
the configurable time periods is at this is stage is indeterminate. More testing with, and feedback from, children and staff is required.

Enable Sound

Configurable values: yes or no.
This option enables or disables the 'chalk sound' within the Gameplay screen of the Neon Chalk prototype.

Sound Scheme

Configurable values: chalk, motorcycle and horse.
This option sets the 'chalk sound' that plays within the gamespace of the Neon Chalk Prototype. The 'chalk' sound is that of squeaky chalk on a blackboard, the 'motorcycle' sound is that of a revving motorcycle changing up through its gears, and the 'horse' sound is that of a horse trotting on cobblestones. The sound selected is only played while the child user is drawing. The creation of these sounds is described in Section 7.2.3.

Save Profile

This option saves the currently configured options within a profile with the name supplied by the user at beginning of the profile creation process. When this menu element is selected, and once the profile has been saved, the Profile Option screen transitions to the Main Menu screen and a Profile Saved dialog is displayed to the user confirming that the profile has been saved (see Figure 17).

Edit Profile Screen

Figure 18 presents the Edit Profile screen, which is available from the Main Menu screen (see Figure 13). It is comprised of a list of the existing profiles (items 1 to 3 in Figure 18) which, when selected, are displayed within a Profile Options screen with the options appropriately configured (see Figure 19).

Delete Profile Screen

Figure 20 presents the Delete Profile screen, which is comprised of a list of the existing profiles (items 1 to 3 in Figure 20). When a staff member selects one of profiles, a Confirm Profile Delete dialog is displayed (see Figure 21) that has two options. If the staff member selects 'Delete' (item 1 in Figure 21), the profile is deleted, and a Profile Deleted dialog (Figure 22) is displayed as the Delete Profile screen transitions to the Main Menu screen. If the user selects 'Cancel' (item 2 in Figure 21), the dialog disappears and the Delete Profile screen comes back into focus.

Suggested Improvements for further development of software prototype: There are several improvements that could be made to the three 'profile management' screens that would reduce the number of steps in the chain of actions required to use them. As can be seen in the 'mock up' of the prospective Profile Management screen shown in Figure 23, in a future iteration of the Neon Chalk prototype, the Edit Profile Screen (Figure 18) and the Delete Profile screen (Figure 20) could be combined into one.

This screen would display a list of existing profiles, with 'edit' and 'delete' buttons provided for each profile (items 2 to 9 in Figure 23). Additionally, a 'Create New Profile' option would be positioned at the top left of the screen (item 1 in Figure 23). With these changes, the functionally of all three existing screens (the Edit Profile screen, the Delete Profile screen and the Profile Options screen) would be offered by two (the new Profile Management screen and the Profile Option screen), and with a lot less transitioning between screens.

Figure 18: Edit Profile screen within the Neon Chalk prototype.

Figure 19: Profile Options screen with options configured as per the 'Walkthrough Example' profile.

Figure 20: Delete Profile screen within Neon Chalk prototype.

Figure 21: Confirm Profile Delete dialog within the Neon Chalk prototype.

Figure 22: Profile Deleted dialog within the Neon Chalk prototype.

Figure 23: 'Mock up' of a Profile Management screen within a future iteration of the Neon Chalk prototype.

Figure 24: Pick Profile and Play screen within the Neon Chalk prototype.

Pick Profile and Play Screen

Figure 24 presents the Pick Profile and Play screen, which is comprised of a list of the existing profiles (items 1 to 3 in Figure 24). When a staff member selects one of the profiles, the screen transitions to the Gameplay screen, with that screen being configured as per the specifications of the selected profile. This is the screen used to launch a game or 'drawing session' for a child user within the Neon Chalk prototype.

7.2 Key Features and Their Development

The key features of the Neon Chalk prototype are discussed below. These key features include the development framework used in the development of the prototype, the 'chalk' that is used to draw within the Gamesplay screen of the Neon Chalk prototype, the 'chalk sounds' that play when the chalk is drawn with, the screen management system that supports the creation of profiles within the prototype and finally, the specialised components that needed to be customised to the 'mouse only' interface of the Smartboard interactive whiteboard. The functionality of these features is examined in more depth and the technical details of their development are described.

7.2.1 Development Framework

The Neon Chalk prototype was developed using Microsoft's XNA framework.

Microsoft XNA is a set of tools, with a managed runtime environment provided by Microsoft, that promotes computer game development and management. XNA includes an extensive set of class libraries, specific to game development, that promote code reuse across Windows XP, Windows Vista and Xbox 360. The framework runs on a version of the Common Language Runtime that is available for all three of the platforms previously mentioned (XNA Frequently Asked Questions, http://msdn.microsoft.com/en-us/directx/aa937793.aspx). Since XNA games are written for the runtime, and not a specific platform, they can run on any platform that supports the XNA Framework with minimal or no alterations. While games can be written in any .NET-compliant language, only C# and XNA Game Studio Express IDE and all versions of Visual Studio 2005 are officially supported by Microsoft (XNA Frequently Asked Questions, http://msdn.microsoft.com/en-us/directx/aa937793.aspx).

Practically speaking, there were four reasons XNA was selected as the development framework for the software prototype developed during this thesis. The first was that the computer equipment at Patricia Avenue School all used Windows XP, thus a Common Language Runtime was available that would enable a prototype built within XNA to run. The second reason XNA was selected as a development framework was that, although the software prototype might not be considered a computer game in the traditional sense, the conceptual architecture that it used was very similar, and so XNA's tailored development environment suited its creation well. The third reason XNA was selected as a development framework was the extensive library of code samples, tutorials, code 'starter kits', and the help forum that were available from the XNA Creators Club Website (http://creators.xna.com/en-US), a website set up by Microsoft to offer support to children, hobbyists, and independent game developers. The final reason

XNA was selected as a development framework was that the researcher involved in this thesis had used it before, and was comfortable using it again. Given the time constraints that existed during this thesis, and the prior experience the researcher had with XNA, learning to use another development environment, when XNA was so suitable, would have been an unnecessary expenditure of time.

For all of the reasons outlined above, XNA proved to be an excellent choice as a development environment, with the advice available from the XNA creator's club forums proving to be especially helpful.

7.2.2 The Chalk

Development

After the results of Investigation 1 (see Section 5.0), in which drawing was established as the form of play which would be supported within the software that was being developed as part of this thesis, a brainstorming phase began to search for ideas that would make the drawing environment within the software prototype compelling. One of the ideas fielded during this brainstorming phase of development was the idea of exploring the 'Flurry' screen saver, a popular screen saver released with Mac OS (since 'Jaguar', version 10.2).

After locating the homepage of the screen saver's creator, Calum Robinson (http://homepage.mac.com/calumr/flurry.html), and discovering that he had made the screen saver's source code available, exploration began into unravelling the techniques used to create the visual effects displayed within it. To this end, the first step was to get a version of the screen saver working within XNA.

The screen saver was written in C and utilised OpenGL graphics libraries. XNA, as discussed above, only officially supports C# and uses Microsoft's DirectX graphics libraries, thus the source code had to converted into C# and the OpenGL function calls had to be substituted for corresponding function calls within the DirectX libraries. At the same time, the underlying architecture of the screen saver was discarded and replaced by the 'game' model within XNA.

In the process of translating the Flurry screen saver into the XNA environment, a lot was discovered about the graphical techniques used, practically speaking 'how it did what it did' and 'looked how it looked'. The 'flurry' is a particle system that uses the additive blending of its constituent particles, coupled with the randomisation of the colour of those particles (within given parameters) to create the range of colours seen within the screen saver. At the same time, the movement of the particles within the system is managed to give the display a 'multi-tentacled', organic appearance (see Figure 25).

For the purposes of supporting drawing, the 'flurry', while visually interesting, was unsatisfactory. Instead, another particle system was built and dubbed 'chalk'. Like the 'flurry', it is comprised of a multitude of constituent particles. Each particle has a colour and a position. As with the 'flurry', additive blending in conjunction with the overlaying of multiple 'chalk particles' creates a compelling visual effect. The major difference between the two systems, is that while the 'flurry' used all of its particles at the same time to create the animation of a multi-limbed organic creature built of light, the chalk has the position of its particles sequentially assigned by user input, e.g. through a mouse. This critical difference meant that while the 'flurry' 'dances', the 'chalk' can be used to draw.

Running Out of Chalk

However, there is one major drawback to using a particle system like the newly created 'chalk' as a drawing medium. As a particle system, it contains a large, but finite, number of constituent particles. When the last 'chalk particle' has had its position assigned by user input, i.e. it had been drawn with, either the drawing had to stop, more 'chalk particles' have to be created, or existing 'chalk particles' hav to taken from their current positions and reassigned.

The first option, that drawing should stop once all the original 'chalk particles' were assigned, would have meant that the flow of play within the software prototype was stilted. Drawing could occur up until the last 'chalk particle' was used and then the child user would have to realise that they could not draw anymore and act upon that realisation to continue drawing. Understanding this complex chain of actions is well outside the abilities of the majority of the participants involved in this thesis, and as such this option was untenable.

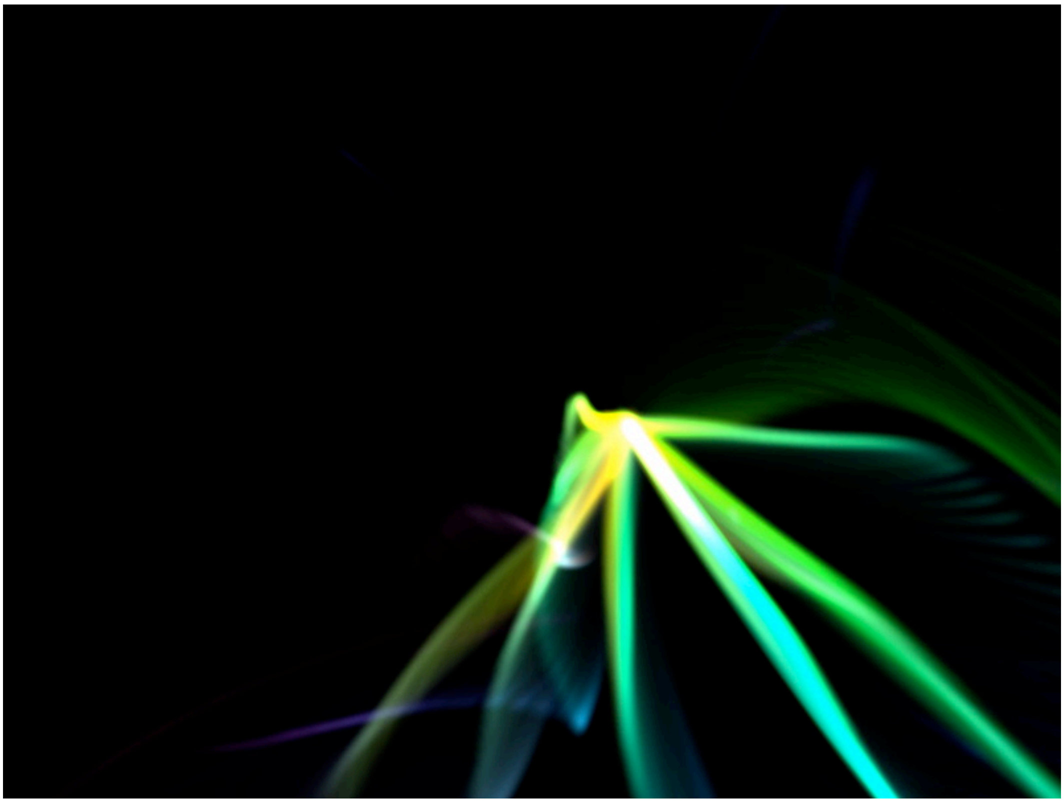

Figure 25: Flurry screen saver.

The second option, that more 'chalk particles' be created as they are required, was tempting from the interaction design perspective in that it would allow drawing to continue. However, from the point of view of implementation, it had a serious flaw. The more 'chalk particles' that exist within the 'chalk', and thus the more 'chalk particles' that need to be rendered on every drawing pass, the worse the performance of the prototype becomes. A point would be reached where the delay between the user's input and the prototype drawing the 'chalk particles' would become so large that the prototype became unusable.

That left the third option, of reassigning existing 'chalk particles' once each of the 'chalk particles' had been assigned a position once. It was decided that the least important 'chalk particles' within a particular drawing were those chalk particles that had been assigned first, i.e. the 'oldest chalk particles'. Thus the user would never *have* to stop drawing, as with the first option above, but if they continued to draw for long enough, they would inevitably reach a point where the oldest parts of their drawing would ‘unravel’ as they continued to draw - this occurrence was dubbed ‘running out of chalk’ within the Neon Chalk prototype.

While the implementation of the third option described above meant that drawing within the Neon Chalk prototype didn’t *have* to stop, the scope or size of the images that was possible within the prototype was still limited by the number of ‘chalk particles’ within the ‘chalk’. As hinted at within the reason the second option described above was not implemented, the prototype’s level of performance, or ‘responsiveness’ in terms of the act of drawing, is inversely proportional to the number of ‘chalk particles’ that exist within the ‘chalk’. Thus a trade off between the number of ‘chalk particles’ and the level of responsiveness while drawing had to be found. It was decided that that an acceptable number of chalk particles would be deemed to exist within the ‘chalk’ when the entire drawing surface of the Gameplay screen within the Neon Chalk prototype could be covered with ‘medium sized chalk particles’. This rough guide was shown to be overly conservative during Investigation 4 (see Section 8.0), when the size of the majority of the images drawn by the participants was observed to be far smaller than the entire drawing surface of the Gameplay screen within the Neon Chalk prototype.

Expert Opinion

Once the ‘chalk’ had been developed to the point where it could be used to draw within the Neon Chalk prototype, a demonstration was given to three faculty members from the Department of Psychology at the University of Waikato (see Section 4.5.3). Considering the sensory sensitivity discussed in Section 2.2, the psychologists’ opinion on the suitability of the visual stimulus provided by the ‘chalk’ was sought. After reviewing the possible output that could be accomplished with the ‘chalk’, all three psychologists agreed that the ‘chalk’ would be suitable for the majority of children with ASD, but that provision should be made to make it customisable to the specific sensitivities of individual children. They also pointed out that a further step was necessary: that another mode within the chalk was required that would reduce the complexity of the visual stimulus it provided, to accommodate those children for whom the additive blending and mixture of colours would be over stimulating. This additional mode was implemented as ‘single coloured chalk’ (see subsection ‘Customising the chalk’ below).

Customising the Chalk

There are a number of variables that define how the ‘chalk’ appears and behaves that can be configured within the Profile Options screen (see ‘Profile options screen’ subsection of Section 7.1.3). These variables, and how they affect the chalk, are discussed below.

Single/Multicoloured Chalk

This option switches the colour mode of the chalk from single coloured to multicoloured and back again.

When the chalk is set to single coloured mode, its constituent ‘chalk particles’ are all set to one colour when they are created and this never changes. Also, when its constituent ‘chalk particles’ overlay each other as they are drawn with, additive blending does not occur. No mater how many ‘single coloured chalk particles’ reside in one position, the colour that is displayed upon the drawing surface within the Neon Chalk prototype will always equal the colour value that the chalk is configured to. This is the colour mode implemented as per the recommendation of the three psychologists whose consultation is described above (see Section 7.2.2, ‘Expert opinion’ subsection). It was developed to reduce the visual complexity of the chalk compared to the ‘multicoloured’ colour mode described below, for those children with ASD for whom the multicoloured chalk would be over stimulating.

When the colour mode is set to multicoloured, the colour of the ‘chalk’s’ constituent ‘chalk particles’ is set to black when they are created. However, the colour of these ‘chalk particles’ is altered to one of a range of colours defined by the ‘chalk’s’ ‘multicoloured chalk colour’ when they are first drawn. If the chalk has been set to the ‘cyclic’ ‘multicoloured chalk colour’, it’s constituent ‘chalk particles’ will alter periodically throughout their lifespan, i.e. the colour of a picture drawn with ‘cyclic’ chalk will shift over time. Additionally, additive blending occurs when one or more of these ‘chalk particles’ overlay each other as they are drawn with. The more ‘chalk particles’ that overlay a particular area of the drawing surface within the Neon Chalk prototype, the closer the colour of that area will get to white. The combination of these two factors is what provides the ‘chalk’ the range of colours that create its compelling mix of subtle shades and ‘glowing’ white points.

Chalk Colour

Configurable values (single colour): White, red, orange, yellow, green, blue, indigo or violet.
Configurable values (multicoloured): blue, cyan, green, yellow, cyclic, tiedyed, rainbow, red or magenta.
When the ‘chalk’ is set to ‘single coloured’ the chalk colour value defines the colour the ‘chalk particles’ will have when they are drawn, however, when the ‘chalk’ is set to ‘multicoloured’ the chalk colour value defines the range of colours that the ‘chalk particles’ will have their colour selected from when they are drawn. Figure 13 displays eight samples of the possible colours the ‘chalk’ can set to. Note the difference that the ‘colour range’ and additive blending gives the ‘multicoloured chalk’ in comparison to the ‘single coloured chalk’, even when they are set to the same colour.

Chalk Size

Configurable values: Small, medium, large, huge.
This option changes the radial size that the ‘chalk’s’ constituent ‘chalk particles’ are drawn with. Thus, when this value is set to ‘huge’ the constituent ‘chalk particles’ are drawn with a greater radius than if the chalk size were set to ‘medium’.

7.2.3 The Chalk Sounds

Based on the working hypothesis that sound that was contingent on the child user drawing within the Neon Chalk prototype would increase the focus and engagement level of the child users, three sample 'chalk sounds' were developed for the Neon Chalk prototype.

These sample sounds were assembled from free content available from the Internet. Given the sensory sensitivity than many children with ASD experience (see Section 2.2) with regard to auditory stimuli, the sample sounds needed to satisfy certain criteria. The sounds needed to begin with a low level of volume and pitch, so they didn't startle the child user when he/she touched the Smartboard and began drawing, and they also needed a second 'segment' that could be played after the quieter first segment and looped to play again and again as the child user continued to draw.

The three sample sound schemes or 'chalk sounds' that were created for the Neon Chalk prototype are described within the Profile Options screen as: chalk, motorcycle and horse. The 'chalk' sound is that of squeaky chalk on a blackboard, the 'motorcycle' sound is that of a revving motorcycle changing up through its gears, and the 'horse' sound is that of a horse trotting on cobblestones.

The sample 'chalk sounds' were prepared for use within the Neon Chalk Prototype through the use of Microsoft's XACT tool, which is an audio programming library and engine released by Microsoft as part of the DirectX SDK.

7.2.4 Customising the Screen Management System

The screen management system within the Neon Chalk prototype is based off the 'Game State Management' sample that is available for download from the XNA creator's club website (http://creators.xna.com/en-US/samples/gamestatemanagement). The sample included "a simple game flow with a main menu, an options screen, some actual gameplay, and a pause menu. It displays a loading screen in between the menus and gameplay, and uses a popup message box to confirm whether the user really wants to quit" (http://creators.xna.com/en-US/samples/gamestatemanagement). This sample code was an extremely valuable time saver, providing a suggested architecture for how similar screens could be implemented and managed for the Neon Chalk prototype.

All of the screens within the Neon Chalk prototype were created based on those provided within the sample, however substantial work was still required to customise them to the specific requirements of this thesis. The sample code provided within the 'Game State Management' sample was designed to be used with a keyboard or Xbox 360 controller, not a mouse. As the Smartboard interactive whiteboard treats all input on its surface as though it were provided by a one-button mouse, this was unsuitable. The base functionality provided within the code was altered to support interaction from a one button mouse, and additional functionality that enabled 'buttons' to be added to screens was also added.

After this was accomplished, an On-screen keyboard component was built that would allow textual input upon the Smartboard interactive whiteboard (see Figure 14). Once this was done, the individual screens required by the Neon Chalk prototype were built. In the process of this screen construction, various topics such as Printing, and File I/O within the XNA environment were researched to overcome challenges and provide the functionality necessary within the Neon Chalk prototype.

As suggested by the mock up of a new 'Profile Management' screen presented earlier in this section (see Figure 22; Section 7.1.3, 'Delete profile screen' subsection), the interface designed and built at the end of this development phase was far from the state required from finished product ready for release. However, this was prototype software, and the interface was at a stage that would support the Neon Chalk prototype to the degree necessary to begin testing.

7.3 Conclusion

This section provided an overview of the Neon Chalk software prototype developed during this thesis. Within the first part, a series of walkthroughs presented the prototype as it would be used by the two types of users it was designed for: children with ASD and the staff/care providers that work with them.

The second part of this section explored the key features of the prototype. The development of these features was described and the challenges and decisions that needed to be made during this period were discussed.

8.0 Investigation 4: Observing the Children Using the Neon Chalk Software Prototype within the Classroom

In this section an investigation is described where the researcher spent two days observing a group of children diagnosed with ASD use the Neon Chalk Software prototype developed during this thesis (see Section 7.0) within the classroom environment. The design of the Neon Chalk prototype had factored in the results of three previous investigations undertaken during this thesis (see Sections 5.0, 6.1 and 6.2), and this investigation was an opportunity to evaluate the design features implemented.

8.1 Investigation Aims

The aim of this investigation was to determine how the children involved in this project interacted with the Neon Chalk prototype through use on a Smartboard interactive whiteboard. This interaction would then serve as a review of the features implemented within the prototype during its design, as well as providing design direction for future prototype development (see Section 9.0).

8.2 Method

The investigation was undertaken at two sites, called Site 1 and Site 2 within this thesis, both associated with the Patricia Avenue School (a school for children with special needs that is affiliated with the University of Waikato).

Three children with ASD from each site participated in the investigation. The children ranged in age from five to eight, were all male and four of the six were functionally non-verbal (see Section 4.1 for more information on the participants or Section 2.3 for more information on language and communication deficits amongst children with ASD).

The parental consent form sent home to parents before the beginning of Investigation 2 (see Section 6.1) included this investigation in its coverage.

Because the Neon Chalk prototype was run on the Smartboard at both Site 1 and Site 2 during this investigation, special considerations had to be made with this investigation that had not been necessary previously (see Sections 6.1.2 and 6.2.2). At both Site 1 and 2, the Smartboard within each classroom had a central position, and, like a traditional whiteboard or blackboard, was a primary teaching tool. These two factors meant that, in the context of this environment, that the one-on-one user trials used in previous investigations were inappropriate for this investigation. Upon consultation with the staff at both sites, it was also decided that only including those children previously involved with this thesis would cause undue distress to the other children within the classroom, who might feel bad at being ‘left out’. This requirement, that all of the children at both sites ‘have a turn’ during a single school period, meant that the amount of time each child could interact with the Neon Chalk prototype was limited to 5 minutes.

As a result of these considerations, the following experimental procedure was used: at each site, the first period of one school day was provided for the researcher to conduct the investigation. At the beginning of this period the staff at each site assembled the children (as per a normal day). The researcher was then introduced, and it was explained to the children what they would be doing that morning. The researcher gave the class a short two minute demonstration of how to use the Neon Chalk prototype and each child was given a 5 minute ‘turn’ at using the Neon Chalk prototype to draw. Those children who were participating in this thesis had their user trials, or ‘turns’, videotaped, as outlined below. Those children who were not participating in this thesis did not have their ‘turns’ videotaped or otherwise recorded, and their actions were not used in any way within this thesis.

Participant G’s user trial only lasted approximately 20 seconds before he ended it, by returning to his seat and displaying no further indication that he wished to continue. Unfortunately, 20 seconds is very little time to discern anything about how he interacted with the Neon Chalk prototype, thus his user trial is not discussed in the next section.

Each user trial involving a participant involved in this thesis was recorded on video, with the video camera positioned to get the best view of the Smartboard and the child involved. Because of the size of the Smartboards installed at Sites 1 and 2, separate video of what was occurring onscreen was not necessary.

The user trial run with Participant B during this investigation differed from the procedure outlined above. The researcher had been informed by the staff at Site 1 that Participant B was leaving the school shortly, and therefore provision was made to undertake the investigation at Site 1 at a date before this occurred so that Participant B could be included. However, on the day the investigation at Site 1 was originally planned, the Smartboard within the classroom was inoperative. As it was unlikely the Smartboard would be repaired before Participant B had left the school, his user trial was undertaken with the Neon Chalk prototype running on the researcher's laptop computer.

The same process used in Investigation 2 (see Section 6.1.2) was used to analyse the video data collected during this investigation.

8.3 Findings and Discussion

8.3.1 Hardware Interaction

Participants A and E, who had trouble using the mouse to during user trials in Investigation 3, experienced no problems using the Smartboard during their user trials during this investigation.

None of the other participants involved in the Smartboard user trials undertaken during this investigation showed any problems with using the Smartboard to draw. As mentioned in the Method Section above (see Section 8.2), due to unforeseen circumstances, Participant B had to do his user trial with the Neon Chalk Prototype running on a laptop computer, not a Smartboard - so no data regarding his ability to draw using the Smartboard could be gathered.

Implications for further development of software prototype: The findings above support both the decision to deploy the Neon Chalk prototype to Smartboard interactive whiteboard hardware and the rationale behind that design decision (see Section 7.0).

8.3.2 Sound

Participants B, C and D all displayed behaviour during their user trials that suggested they enjoyed the 'chalk sound' component within the Neon Chalk prototype (see Section 8.0). These behaviours included smiling, laughing and an increase in focus when they realised the sound continued for as long as they were drawing.

During his user trial, there was one point where Participant B covered his ears with his hands and 'scrunched' up his face, suggesting he was distressed by the sound. At this point the sound was muted within the Neon Chalk prototype, but the ambient sound level in the classroom was so high that this seemed to make little difference. It could have been that there was something specific about the 'chalk' chalk sound (see Section 7.0) that Participant B didn't like, or it might have been that the overall noise level within the classroom had become too high.

Participant A seemed to dislike when the 'motorcycle' chalk sound (see Section 7.0) reached a certain pitch level, but showed no behaviour that suggested he was uncomfortable with the sound before it reached this level. It would have been interesting to have seen Participant A's reaction to the 'chalk' chalk sound, which has a lower pitch, but due to the circumstances outlined in the Method Section above (see Section 8.2), only one trial was possible with each child.

Implications for further development of software prototype: As mentioned above, more testing with participants would be useful in determining how suitable the current 'chalk sounds' are, but based on the above observations, the use of sound within the Neon Chalk prototype (see Section 7.0) seems promising.

8.3.3 Colour

All of the participants appeared to enjoy the high contrast of the colour of the chalk upon the black background within the Neon Chalk prototype, although more testing is necessary to see if particular colours were less or more successful than others.

The variable speed of the drawing done by Participants A and B (described below, within the 'Drawing activity' subsection), provided some evidence to suggest that they were exploring how the additive blending used with the Neon Chalk prototype works, and that they 'enjoyed' or were engaged in this exploration.

Implications for further development of software prototype: As mentioned above, more testing with participants would be useful in determining if certain 'colour modes' were more or less successful than others, but based but on the feedback from user trials, the use of colour within the Neon Chalk prototype (see Section 7.0) was well received.

8.3.4 Drawing Activity

During certain periods within their user trials, both Participant A and Participant B seemed to be experimenting with the effect that drawing faster or slower had on how the chalk appeared upon the black background within the Neon Chalk prototype. While caution needs to be exercised when analysing the small quantity of data collected during this investigation, this evidence of explorative activity is promising.

Participants A, B and D all 'ran out of chalk' (see Section 7.0) at some point during their user trials.
During the design of the Neon Chalk prototype, the possibility of a negative reaction to this event by some or all of the participants had been identified (see Section 7.0). Fortunately, none of the three participants who 'ran out of chalk' expressed distress at this occurrence. Instead, they displayed a variety of different behaviours. Participant A seemed to enjoy 'chasing' the point at which his image

was disappearing, following it upon the Smartboard with his finger tip. Participant B appeared to ignore it, and during his user trial drew for 4 minutes without seeming to notice that he was 'out of chalk' and thus, that the older portions of his drawing were slowly disappearing as he continued to draw. During his user trial, Participant D showed signs of noticing the effect that drawing while 'out of chalk' had, but instead of it distressing him, he seemed to incorporate the phenomenon into his drawing activity. He did this by first drawing a large sprawling image upon the bulk of the Smartboard and then by focusing his attention upon a much smaller area. The resultant act of drawing while 'out of chalk' caused the previous image to slowly 'unravel'. As this process finished, Participant D said "Yeah! Look, its gone!"

While the 'out of chalk' effect does seem to have the potential to distract a user from *drawing a particular thing* (e.g. Participant D's reaction), it does not appear to distract users from *drawing*. In none of the three user trials where it occurred, did the participants involved stop drawing. Given these observations, it suggests that trying to maximise the 'amount of chalk' (see Section 7.0) available to a user might not be as important as was assumed during the prototype design.

Participants B and D appeared to be attempting to 'colour in', i.e. fill sections of the background of the Smartboard with colour. Given that with certain 'chalk sizes' (see Section 7.0), it was impossible to fill in the entire background of the Smartboard with colour before the participant 'ran out of chalk', it was difficult to be sure if that was something these two participants were trying to accomplish.

All of the participants (except Participant G) used the 'chalk refresh' button (see Section 7.0) during their user trials. From the context of its use, it seemed as though the participants used primarily as a way of 'erasing the chalk' from the background within the Neon Chalk prototype, as opposed to a way of preventing the effect that occurred when they 'ran out of chalk' (see Section 7.0). During his user trial Participant C initially tried to use the whiteboard eraser that comes with the Smartboard to erase portions of his picture. When it was explained to him that that wouldn't work and that he had to use the 'chalk refresh button' instead, he acquiesced without rancour, saying after he had used the 'chalk refresh' button, "Oh, all of it must go". This statement revealed that he was looking for a way of deleting only a portion of his picture, a feature that presently does not exist with the Neon Chalk prototype.

During user trials there was a noticeable delay between when the participants provided input to the Smartboard and when the Neon Chalk prototype would draw the 'chalk particles' (see Section 7.0) on screen. Participant C actually appeared to alter his input technique to cater for this delay, switching from the long sweeping motions that he tried initially, into a 'patting' or 'dabbing' style that provided him with the bold lines he wanted, despite the delay. This delay was not large, but the fact that it was noticeable and that it caused one of the participants to alter his style of drawing meant that the delay was too large. Given that promoting a 'sense of agency' within users was a priority during prototype design (see Section 7.0), this period of delay was disappointing.

During a large portion of his user trial, Participant E seemed to play a game with the 'mouse pointer'. He would tap an area of the Smartboard with his finger, and then tap an area further away from the first point he had tapped, showing delight at the fact that the mouse pointer appeared wherever he tapped his finger. This game, while providing obvious enjoyment to Participant E, seemed to distract him from any drawing activity he may have participated in otherwise. It is interesting to note that the only reason a 'mouse pointer' exists with the Neon Chalk prototype is because it was developed within a PC environment, with all of the testing also done on a PC. As users use their own finger as a pointing device when using a Smartboard interactive whiteboard, the mouse pointer is unnecessary and should be removed in future versions of the prototype.

Implications for further development of software prototype: While the overall response of the children to the 'chalk' and how it behaved within the Neon Chalk prototype was positive, there were areas that, after review of the observations outlined above, need to be altered within any further iteration of the prototype.

The delay between user input and 'chalk particles' being drawn could be rectified by reducing the number of 'chalk particles' within the particle system that models the 'chalk' (see Section 7.0). This reduction in particle number would improve the frame rate, and as a byproduct of that, reduce the latency between user input and the ‘chalk particles’ being drawn. This reduction in ‘chalk particles’ would mean that users would ‘run out of chalk’ faster, but given the observation made during this investigation, that none of the participants had a negative reaction to ‘running out of chalk’, this isn’t expected have a negative side effect.

During his user trial, Participant C sought a method by which he could delete only a portion of his image and not all of it (the ‘chalk refresh’ feature currently implemented deletes the entire image). If this feature were to be implemented in the future, it would have a huge impact on the current design of the Neon Chalk prototype. One of the key design principals within the current prototype is that users only have one tool with which they can use while drawing. This means that they can ignore tool selection and focus on the drawing activity. As soon as another tool is added, tool selection becomes a task that attracts focus and requires monitoring from the user – and so the primary design principal would be compromised.

The game of ‘hopping mouse pointer’, played by Participant E during his user trial, highlighted the vestigial presence of the ‘mouse pointer’ within the Neon Chalk prototype. While the mouse pointer is useful for testing the prototype on a PC environment with a mouse, it will be toggled off within future iterations of the prototype that are intended to be deployed to a Smartboard interactive whiteboard.

8.3.5 Engagement and Activity Levels

All of the participants, save Participant G, showed high levels of activity and engagement throughout the duration of their user trials. Participant A did have periods of lower activity, but his focus remained on the Smartboard during these periods. His behaviour during these periods seemed more contemplative than distracted.

The time limitation of 5 minutes that was placed upon the user trials undertaken during this investigation made it hard to determine how long the participants involved would choose to draw with the Neon Chalk Prototype in an unconstrained setting. However, the user trial with Participant B, that took place on the researcher’s laptop rather than a Smartboard, had no such time limitation.

During that trial, Participant B drew for a period of 27 minutes before a low power warning from the researcher's laptop called a halt to the trial. The trial was going to be halted by the researcher at 15 minutes, but after consultation with the staff at Site 1, it was decided that Participant B did not appear to be tired and was obviously engaged and 'enjoying himself', and thus the user trial was allowed to continue. While only a 'one off' case, this reception the Neon Chalk prototype got from Participant B and indeed all of the children that participated in this investigation was promising.

During a discussion with staff after the user trials were completed, a comment was made by one teacher that the most astonishing thing from her point of view had been the willingness of the children observing to sit and watch another child use the software without the disruptive behaviour that would normally have accompanied such an event. This statement was quickly backed up by the other staff present. Each series of user trials took approximately 50 minutes at each site, a period in which the children who had had their turns or were waiting for their turns had to sit and watch. The fact that they did so, with little or no disruptive, is an indication of how engaging they found the Neon Chalk prototype to be.

Unlike neurotypical children, whose enjoyment and excitement at the prospect of interacting with a new artefact or game has coined such phrases as "he's like a child playing with a new toy", children with ASD are acknowledged as often wary of novel artefacts, games or procedures (see Section 2.1). Given this aversion to objects and activities that are not an established part of their routine, the participants' engagement with and apparent enjoyment of the Neon Chalk prototype during this investigation was surprising. While the period each participant had with the prototype was short, the level of engagement that the participants showed while using and observing the Neon Chalk prototype was reassuring.

Implications for further development of software prototype: The observed engagement levels of participants during user trials, as well as the feedback received from staff about 'audience engagement levels', was very positive. The biggest implication this has for the further development of the Neon Chalk prototype is as a baseline for engagement and activity during future user testing.

If alterations were made to existing features of, or new features were added to, the Neon Chalk prototype, and future testing indicated that users were not as engaged as was evidenced during this investigation – that would suggest the alterations or additional features were negatively received.
An alternate hypothesis is that the high levels of engagement and activity observed during this investigation were the result of a 'novelty effect'. This outcome is unlikely, however, given the acknowledged aversion many children with ASD have to novel artefacts or procedures that are not a part of their established routine (see Section 2.1).

8.3.6 The Role of the Smartboard within Each Classroom

The Smartboards installed at Site 1 and 2 are both positioned at the front of each classroom, and dominate a person's view upon entering. This means that any activity that uses the Smartboard, at either site, also dominates the available space of the classroom. At both sites they are positioned at a height on the wall more suited to the teacher than the children. Both sites have a wooden step that the children use to offset the effect this wall position has on their use of the Smartboards.

The Smartboards at both sites are used as the primary teaching tool within each classroom, and as such, are part of the classroom routine of both sites throughout the day. Also, as an unspoken rule that exists at both Site 1 and Site 2, the Smartboards are used exclusively for curriculum based activities that involve the whole class – they are not available to the children during the free play periods that occur throughout the day.

Each of the features outlined above, with regard to the role that the Smartboard has at each site, affected how it could be used for user trials during this investigation. While the effect on the amount of time that was available for user trials (limiting participants to 5 minutes each) was unfortunate, it was interesting to see the other effects that this role had. These effects are described below.

Participant E displayed behaviours at the beginning of his user trial that was consistent with behaviour observed from children using the Smartboard at Site 1 during Investigation 1. At the beginning of his user trial Participant A ran up to the Smartboard, and tapped its surface and then moved to sit down again. This was very similar to the behaviour witnessed at Site 1 during Investigation 1, where children were asked to approach the Smartboard, push the correct button on screen and then go and sit down again.

During his user trial, Participant C seemed initially unsure of himself, and before touching the Smartboard asked, “What am allowed to draw?” The implication here seemed to be that the Smartboard was for work, and thus that what was accomplished upon it was likely to be judged right or wrong. There is a need to be cautious with this sort of attribution of thought, but given the Smartboards at both Site 1 and Site 2 are used almost exclusively for curriculum based activities, this interpretation seems likely.

Implications for further development of software prototype: While the observations made above do not suggest directions for future development of the Neon Chalk prototype, they, and similar observations made during time spent at Site 1 and 2, do provide insight into the likely context of use for game software in these classrooms. It seems unlikely that the Smartboards at either site will become available for unconstrained or free play in the near future. Within the classroom environment the Smartboard has replaced the whiteboard, which in the past replaced the blackboard, and as such it has inherited that artefact’s legacy of *belonging* to the teacher.

8.3.7 Automatic Timer

All of the user trials undertaken during this investigation, save that of Participant B, used the Neon Chalk prototype’s automatic timer feature (see Section 7.0). All of the participants responded well to it, accepting that their ‘turn’ was over when, after 5 minutes, the game automatically paused itself and displayed the words “Paused – Game Time Expired”. Even Participant D, who is well known at the Patricia Avenue School for his love of computer games and recalcitrance when it comes time to stop playing, accepted that his turn had finished after being told “Look, the computer says your time is up”.

Implications for further development of software prototype: The observed success of this feature in user trials suggests that it should be retained in future versions of the Neon Chalk prototype. The participants seemed to more readily accept the termination of their drawing activity from an impersonal source (the Neon Chalk prototype) than they would from a staff member; perhaps experience has taught them the futility of arguing with software?

8.3.8 Screen Shot Gallery

Given the very short period of time available for each user trial, there was little opportunity to try to explain or demonstrate the Neon Chalk prototype's 'automatic screen shot' or 'screen shot gallery' features (see Section 7.0) during this investigation. From what was observed, the participants found the screen shot gallery, and especially the thumbnail zoom effects, interesting, but it was not evident that they understood what its purpose was. An additional obstacle faced in trying to demonstrate the screen shot gallery to the staff and participants was that there was no printer connected at either site. Because of these issues, no conclusions could be drawn about the effectiveness of either feature.

8.4 Conclusions

This investigation provided a short evaluation of the Neon Chalk prototype. The following features received favourable feedback from participants:

- The Neon Chalk prototype's deployment to Smartboard interactive whiteboard hardware enabled all the participants to use it with proficiency.
- The use of sound and colour with the Neon Chalk prototype seemed to promote engagement and 'enjoyment'. However, more testing was identified was required to evaluate the success of particular 'chalk sounds' and 'colour modes'.
- The effect that 'running out of chalk' had on the three participants that experienced it was in one case indifferent, but no cases negative.
- The 'chalk refresh' button was used successfully by all participants to erase their images.

- The Neon Chalk prototype engaged the attention of both the child using it, and also those children who were watching.
- The automatic timer feature available within the Neon Chalk prototype helped facilitate the ending of each child's 'turn'.

The following features received negative feedback from participants:

- There was a noticeable delay between the input provided by participants and the subsequent drawing of 'chalk particles'.
- Participant C expressed a desire to erase only part of his image, a feature than is unavailable in the current Neon Chalk prototype.
- The vestigial presence of the 'mouse pointer' within the Neon Chalk prototype was revealed by a game Participant E played with it during his user trial.
- The role of the Smartboards at both sites as 'curriculum oriented hardware' seemed to affect the behaviour of Participant C and E during user trials. Both participants sought permission to interact with the Neon Chalk prototype, and Participant C was concerned with drawing the 'wrong' picture.

9.0 Conclusions

There were two general aims of this thesis:

3. The first aim was to develop a piece of prototype software that would support a play activity for children with ASD. This first goal was engineered as a way of both providing a means of answering the question posed below, and as a way of applying the answers discovered in a practical fashion that would in turn be subject to evaluation.
4. The second aim was to explore user-centred data gathering techniques as a means of involving children with autism spectrum disorders in the design and development of software tailored for their use.

These two aims were investigated through a series of four investigations conducted through the development of the Neon Chalk software prototype. The same core group of children with ASD participated throughout the four investigations.

In this section, the main findings of this thesis are reviewed, followed by a brief overview of the contributions of this thesis.

9.1 Adaptations to User Centred Data Gathering Techniques for use with Children with ASD

During the investigations undertaken during this thesis, a number of factors related to the age and autistic status of the participants involved resulted in the re-evaluation, and subsequent adaptation, of the user-centred data gathering techniques implemented. An outline of the most significant adjustments to these procedures and the justification behind those changes is given below:

- Due to the non-verbal status of five out the seven children with ASD that participated in this thesis, the use of the ‘think-aloud protocol’ during user trials was unfeasible as a technique for gathering data. For the same reason, interviewing the children as a means of gathering data was also infeasible.

The 'think-aloud protocol' is a difficult data gathering technique to use with neurotypical children, but with even more so with children with ASD. The individually varied subset of the characteristics symptomatic of the ASD diagnosis render this technique unusable.

It is worth noting, that even if a greater proportion of the participants involved in this thesis had been verbal, that the idiosyncratic social behaviours that they exhibited during social interactions observed during this thesis would have likely meant that the 'think-aloud' protocol would produce far less useful data than is normally expected.

- A questionnaire was used a method of gathering data during this thesis, however the questionnaire was not created for, or intended to be completed by, the children with ASD that participated in this thesis.

When questionnaires are used with any population of child participants, special attention needs to be paid to their developing cognitive, memory, communicative, and social faculties. With participants who are *children* and who possess an individually varied subset of the characteristics symptomatic of being diagnosed with ASD, the design and use of questionnaires with those participants becomes a daunting proposition worthy of research in and of itself. Considering this fact, the use of a questionnaire designed for, and intended to be completed by, the *parents or caregivers* of the participants involved in this thesis was the most practical and effective recourse.

- Given the difficulties encountered with direct inquiry and user-centred narrative data collection techniques, observation was the primary data gathering technique used.

This use of observation as the primary method for gathering data during an investigation is long established in fields such as ethnography, but is not often used without supplementary techniques within user-centred design. While its use in such a fashion requires that caution be applied to any causal relationships ventured, the qualitative and content rich data the technique can provide is the best suited to investigations with user populations such as children with ASD, where alternative data gathering techniques are unfeasible or require an untenable expenditure of time.

- During this thesis, the researcher had access to three psychologists with knowledge of and experience working with children with autism. Additionally, the school staff at both sites had knowledge and experience that was not possessed by the researcher, and were extremely forthcoming in their desire to share that information.

Given the shortcomings encountered with direct inquiry and user-centred narrative methods of data gathering during this thesis, the ability to engage in discourse regarding observations made during investigations was invaluable. When working with such a challenging user population, in terms of the researcher's ability to source data directly from the target users – the insights contributed by experts are especially valuable.

The value of such interdisciplinary collaboration was seen during the design and development of the Neon Chalk prototype when, after consultation with the three psychologists mentioned above, an entirely new colour mode for the chalk was identified as necessary to fully accommodate the sensory sensitivity of the target population.

The nature of the insights provided by staff members within the classroom was less removed and objective, but their ability to interpret the nature of the behaviour exhibited by the participants was useful. Given that the staff members insights were less removed and objective, then that suggested that they are too close to the children to interpret the events occurring in a participant observation.

An example of where their ability to interpret the participant's behaviour was useful can be seen in an example taken from one of the user trials undertaken during this thesis. One of the problem's encountered during user trials with

Participant B, was in interpreting whether his (rather aggressive) grunting noises were a display of frustration or anger, or if they indicted something else entirely. After consulting with staff members, I was informed that "[Participant B] tends to do that when he has become over stimulated". As the concept of 'over stimulation' was not one I had encountered before, and thus even considered, this insight was valuable.

- The problem classification scheme developed by Wolmet Barendregt (Barendregt, 2006) was designed to aid in the evaluation of computer games for children. While this classification scheme seemed likely to be useful initially, it proved to be unsuitable for the classification of problems during this thesis. This lack of suitably stemmed from a lack of grounding within current cognitive theory of autism.

The foundation that Barendregt's classification had in the action theory of Norman and Draper (1986 in Barendregt, 2006) presented a possible conflict with current research associated with the executive dysfunction hypothesis of autism. The executive dysfunction of autism suggests that children with ASD possess deficits in the executive processes associated with all three of the 'action stages' described in that theory. A comprehensive evaluation of the applicability of Barendregt's classification for children with ASD was outside of the scope of this thesis, but further consideration is clearly warranted.

9.2 Staff as Users with the Classroom

Discovering that the staff at both sites had a pivotal role as users within the classroom (at both sites) was a key insight made during this thesis.

- The children within the classrooms at each site are not the only users of software. In fact children and staff members often use the same software at the same time, through a 'child as primary user', 'staff member as support user' relationship.

After considering the observations made in Investigation 1 (see Section 5.0), it quickly became apparent that it was erroneous to assume that the children with

ASD within a classroom would be the sole users of software developed to support their play. The staff within each classroom already assisted the children in their play activities, both those that utilised computing hardware and those that did not. Accommodating and embracing this role the staff have within the classroom appears to have been successful within the design and implementation of the Neon Chalk prototype. Without the acknowledgement that staff could also be users, the complexity required by the profile management functionality (see Section 7.1.3) within the Neon Chalk prototype would have been unfeasible to implement (i.e. it would have unreasonable to assume the children could accomplish it).

9.2.1 The Role of the Smartboard within the Classroom

The specific role that the Smartboard interactive whiteboard has within both classrooms (at both sites) dictates how it used currently, but also how it is likely that it will be used in the future. The following insights describe its current role within the classroom:

- The Smartboards installed at Site 1 and 2 are both positioned at the front of each classroom, and dominate a person's view upon entering. This means that any activity that uses the Smartboard, at either site, also dominates the available space of the classroom.

In practice, this means that for the Smartboard to be used, the entire class needs to be involved. This means that the children will most likely have to take turns and that the activity the class will be engaged in will be an activity that focuses on curriculum content and not play.

- At both sites the Smartboard is positioned at a height on the wall more suited to the teacher than the children. Both sites have a wooden step that the children use to offset the effect this wall position has on their use of the Smartboards.
- It seems unlikely that the Smartboards at either site will become available for unconstrained or free play in the near future. Within the classroom environment the Smartboard has replaced the whiteboard, which in the

past replaced the blackboard, and as such it has inherited that artefact's legacy of *belonging* to the teacher.

The ownership of the Smartboard by teachers, that was observed during this thesis, appears to restrict its use by the children within the classroom, even though its installation was motivated by a desire to empower the children and offer new aspects to their learning. This has significant ramifications for any software deployed to the Smartboard within the classroom, as no matter how it is percieved by the children or its intended mode of use (i.e. unconstrained play), strictures upon its use that stem from this ownership seem likely to override other concerns.

9.3 Suitable Interfaces for Children with ASD within Neon Chalk

The Neon Chalk software prototype developed during this thesis was subject to a short evaluation by the participants in Investigation 4. The results of this evaluation, along with relevant insights from the other investigations undertaken throughout this thesis, are summarised below:

- The minimalist interface implemented within the Gameplay screen of the Neon Chalk prototype (see Figure 8) appeared to be successful in reducing distraction during use, allowing the participants to focus on the intended interaction – drawing with the chalk.

For these users, distraction is a major obstacle in using software design for neurotypical children. This effectiveness of this minimalist interface suggests that when designing interfaces for children with ASD, particular care should be taken to avoid 'feature creep'. To put it bluntly, if there is not a truly compelling reason for an element of the interface to exist – it probably shouldn't.

This minimalist interface implemented within the Neon Chalk prototype also seems likely to reduce the chance of an adverse reaction from a child with ASD based on a particular sensory sensitivity possessed by him or her, or a fixated dislike associated with a particular representational piece of graphics.

- The use of colour and sound within the Neon Chalk prototype appeared successful in promoting engagement and 'enjoyment' for the participants.

Crucial to the successful use of colour and sound within the Neon Chalk prototype was the facility to configure their use for each child. In order to respect the sensory sensitivities that each child may possess, every effort was made to ensure that no colour or sound choice is compulsory. Within the Neon Chalk prototype it is possible to configure the game environment from one extreme of stimulus use to the other, e.g. the game environment can be configured to use only white chalk and have no sound, or it can be configured to use rainbow-like multicoloured chalk that sounds like a motorcycle as it drawn with. Many pieces of software designed for use with children with ASD lack this facility to customise the stimuli used for individual children; instead they make the same decision for every child. The use of profiles to configure software for children with autism offers a way of returning some of that choice back to them and the staff who work with them.

- Interaction that makes rewarding output from the software contingent on input from the participant appeared successful in increasing focus, engagement and activity levels.

While it is acknowledged that the play activity of drawing made this interaction strategy suitable, the strategy's effect on the focus, engagement and activity levels seemed promising. This result in particular would benefit from further testing of the Neon Chalk prototype, to see if the increases observed will persist over repeated use of the Neon Chalk software.

Due to the small size of the participant group (6), caution needs to be applied in assigning cause to the results summarised above and when attempting to generalise these summarised findings away from the Neon Chalk prototype specifically. That qualification aside, the results gathered look promising.

9.4 Contributions Made

This thesis acted as a preliminary study that suggested means through which children with ASD can be involved in the user-centred design of software. Motivated and informed by the design and development of Neon Chalk, a prototype piece of software developed to support drawing as play for children with ASD, user-centred data gathering techniques were assessed for suitability and their ease of application with this challenging group of users.

From investigations that used observation and ethnographic analysis of video, working hypotheses were constructed and applied to the design of the Neon Chalk prototype. A short evaluation with a small group of children with ASD displayed promising results based on the design decisions made.

This thesis is a small-scale study that involved a small group of children. It lays the groundwork for further testing and investigation with the Neon Chalk software specifically, and with other software projects that support different goals. Studies with larger numbers of participants and with a different sampling of diagnoses on the Autism spectrum are warranted; these further studies will begin better informed, based on the work undertaken during this thesis.

References

American Psychiatric Association. (2000). *Diagnostic and Statistical Manual of Mental Disorders – Fourth Edition-Text Revision (DSM-IV-TR)*. American Psychiatric Association, Washington D.C., USA.

Barendregt, W. (2006). *Evaluating fun and usability in computer games with children*. Department of Industrial Design.

Baron-Cohen, S. (2000). The cognitive neuroscience of autism: implications for the evolution of the male brain. *The Cognitive Neurosciences*.

Baron-Cohen, S. (2006). The hyper-systemizing, assortative mating theory of autism. *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, 30 (5), 865-872.

Bell, A. (2007). Designing and testing questionnaires for children. *Journal of Research in Nursing*, 12 (5), 461-469.

Caronna, E. B., Milunsky, J. M., & Tager-Flusberg. (2008) Autism spectrum disorders: clinical and research frontiers. *Archives of Disease in Childhood*, 93(6), 518-523.

Dailey, T. (1984). *Art as Therapy: An Introduction to the Use of Art as a Therapeutic Technique*. Routledge.

Dautenhahn, K. (2000). Design issues on interactive environments for children with autism. *Proceedings International Conference on Disability, Virtual Reality and Associated Technologies (ICDVRAT)*, 153-161.

Davis, M., Otero, N., Dautenhahn, K., Nehaniv, C. L., & Powell, S. D. (2007). Creating a software to promote understanding about narrative in children with autism: Reflecting on the design of feedback and opportunities to reason. *International Conference on Development and Learning, 2007. ICDL 2007. IEEE 6th*, 64-69.

Druin, A. (2002). The role of children in the design of new technology. *Behaviour and Information Technology*, 21(1), 1-25.

Frith, U. (2004). Emanuel Miller lecture: Confusions and controversies about Asperger syndrome. *Journal of Child Psychology and Psychiatry*.

Gollop, M. M. (1999). Interviewing Children: a research perspective in A. B. Smith, N. J. Taylor, and M M Gollop (Eds.), *Children's Voices: Research Policy and Practice*. Auckland: Longman.

Happé, F., & Frith, U. (2006). The Weak Coherence Account: Detail-focused Cognitive Style in Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders*, 36 (1), 5-25.

Healy, J. (1998). *Failure to connect: how computers affect our children's minds*. New York: Simon & Shuster.

Herrera, G., Alcantud, F., Jordan, R., Blanquer, A., Labajo, G., & De Pablo, C. (2008). Development of symbolic play through the use of virtual reality tools in children with autistic spectrum disorders: Two case studies. *Autism*, 12(2), 143–157.

Hill, E. L. (2004). Executive dysfunction in autism. *Trends in Cognitive Sciences*, 8, 26-32.

Jordan, R. (2003). Social Play and Autistic Spectrum Disorders: A Perspective on Theory, Implications and Educational Approaches. *Autism*, 7(4), 347–360.

Keay-Bright, W. (2007a). The Reactive Colours Project: Demonstrating Participatory and Collaborative Design Methods for the Creation of Software for Autistic Children, *Design Principles & Practices: An International Journal*, 1(2).

Keay-Bright, W. (2007b). Can computers create relaxation? Designing ReacTickles© software with children on the autistic spectrum. *NCDN*, 3(2), 97-110.

Klin, A. (2006). Autismo e síndrome de Asperger: uma visão geral / Autism and Asperger syndrome: an overview. *Rev Bras Psiquiatr*. A translation into english is available at: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1516-44462006000500002&lng=en&nrm=iso&tlng=en

Kuusikko, S., Pollock-Wurman, R., Jusilia, K., Carter, A. S., Martila, M., Ebeling, H., Pauls D. L., & Moilanen, I. (2008). Social Anxiety in High-functioning Children and Adolescents with Autism and Asperger Syndrome. *Journal of Autism and Developmental Disorders*, 38(9), 1697-1709.

Leslie, A.M. (1987) 'Pretense and representation: the origins of theory of mind', *Psychological Review*, 94(4), 412–426.

Levin, D., & Rosenquest, B. (2001). The Increasing Role of Electronic Toys in the Lives of Infants and Toddlers: should we be concerned? *Contemporary Issues in Early Childhood*, 2.

Lord, C., Cook, E. H., Leventhal, B. L., & Amaral, D. G. (2000) Autism Spectrum Disorders. *Neuron*.

Losche, G. (1990). Sensorimotor and Action Development in Autistic Children from Infancy to Early Childhood. *Journal of Child Psychology and Psychiatry*, 31(5), 749-761.

Morgan, S. (1986). Autism and Piaget's theory: Are the two compatible? *Journal of Autism and Developmental Disorders*, 16(4), 441-457.

Muller. (2003). *Participatory Design: The Third Space in HCI. Handbook of HCI.* Mahway NJ USA: Erlbaum.

National Autistic Society website. (2008). http://www.nas.org.uk.

Neilsen, J. (1994). *Usability Engineering*. Morgan Kaufmann.

Newschaffer, C. J., Croen, L. A., Daniels, J., Giarelli, E., Grether, J. K., Levy, S. E., Mandell, D. S., Miller, L. A., Pinto-Martin, J., Reaven, J., Reynolds, A. M., Rice, C. E., Schendel, D., & Windham G. C. (2007). The Epidemiology of Autism Spectrum Disorders. *Annual Reviews*.

Noyes, J., & Barber, C. (2001). *User-Centred Design of Systems*. Springer.

Papert, S. (1996). *The Connected Family: Bridging the Digital Generation Gap*. Longstreet Press.

Parés, N., Carreras, A., Durany, J., Ferrer, J., Freixa, P., Gomez, D., Kruglanski, I., Parés, R., Ribas, J. I., Soler, M., & Sanjurjo, A. (2005). Promotion of creative activity in children with severe autism through visuals in an interactive multisensory environment. *Interaction Design and Children*, 110-116.

Piaget, J. (1962). *Play, dreams and imitation*.

Plowman, L. & Stephen, C. (2003). A 'benign addition'? A review of research on ICT and pre-school children. *Journal of Computer Assisted Learning*, 19(2).

Preissler, M. A. (2006). Play and Autism: Facilitating Symbolic Understanding, 231-250. In *Play = Learning*. Oxford University Press.

Ramloll, R., Trepagnier, C., Sebrechts, M., & Finkelmeyer, A. (2004). A gaze contingent environment for fostering social attention in autistic children. *Proceedings of the Eye tracking research & applications symposium on Eye tracking research & applications,* 19-26.

Rutherford, M. D., Young, G. S., Hepburn, S., & Rogers, S. J. (2003). Cognitive Underpinnings of Pretend Play in Autism. *Journal of Autism and Developmental Disorders*.

Strickland, D. (1996). A virtual reality application with autistic children. *Presence: Teleoperators and Virtual Environments*, 5, 319-329.

Strock, M. (2007). Autism Spectrum Disorders (Pervasive Developmental Disorders). *National Institute of Mental Health (NIMH)*.

Volkmar, F. R., Lord, C., Bailey, A., Schultz, R. T., & Kiln, A. (2004). Autism and pervasive developmental disorders. *Journal of Child Psychology and Psychiatry*.

Whitehouse, A. (2006). *Atypical Information Processing in Children with Autism: Links with Inner Speech Deficit*. University of Western Australia.

Williams, D. (1996). *Autism-An Inside-Out Approach: An Innovative Look at the Mechanics of 'Autism' and Its Developmental 'Cousins'*. Jessica Kingsley Publishers, England.

Williams, E., Reddy, V., & Costall, A. (2001). Taking a Closer Look at Functional Play in Children with Autism. *Journal of Autism and Developmental Disorders*, 31(1), 67-77.

World Health Organization. (1992). *The ICD-10 Classification of Mental and Behavioural Disorders Diagnostic criteria for research*, Geneva.

Appendices

Appendix 1: Patricia Avenue School Research Consent Form for Investigation 1

The University of Waikato · School of Computing and Mathematical Sciences

Research Consent Form

This consent form, a copy of which has been given to you, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned, or information not included here, please ask. Please take the time to read this form carefully and to understand any accompanying information.

Research Project Title

Exploring user-centred software design for children with autistic spectrum disorders

Researcher

Grant Shannon under the supervision of Dr Sally Jo Cunningham.

Experiment Purpose

The purpose of this observational study is to view children on the autistic spectrum going about their regular activities, both directed and undirected, within an environment they are familiar with.

Participant Recruitment and Selection

I will observing the children of the [Site 1] as well as the children at the [Site 2].

Procedure

Observing and manually recording on paper, the details of classroom activities and interaction. No video or audio recording will take place at this stage of the research.

Staff in the class room will be informed of their right to ask the researcher to leave at any time without a need for explanation. At no time will the researcher be in a room with one or more children but no qualified School staff.

Data Collection

Emphasis will be placed on how children interact with artifacts, how long they are normally engaged in an activity for, and also if any trends can be derived from periods where the children seemed engaged or 'to be having fun'.

Data Archiving/Destruction

Data will be kept secure stored in the HCI Laboratory until the end of my study in February 2009, when it will be destroyed.

Appendix 1: Patricia Avenue School Research Consent Form for Investigation 1

Confidentiality

Confidentiality and participant anonymity will be strictly maintained. All information gathered will be used for statistical analysis only and no names or other identifying characteristics will be stated in the final or any other reports.

Likelihood of Discomfort

There is no likelihood of discomfort or risk associated with participation.

Researcher

Grant Shannon is completing a Masters of Science within the School of Computing and Mathematical Sciences at the University of Waikato. Grant has a great passion for playing in general (he never really grew up) and for playing on computers especially. He would love to improve the quality of digital play available to children on the autistic spectrum and hopes that his studies with reflect this.

His supervisor in these activities is Dr Sally Jo Cunningham.

Grant can be contacted in the HCI laboratory (G1.31) of the School of Computer and Mathematical Sciences building at the University of Waikato. Alternatively, he can be reached by calling 021 247 2688 or by email at gjr5@cs.waikato.ac.nz.

Finding out about Results

The Participants can find out the results of the study by contacting the researcher after February 31 2009.

Agreement

Your signature on this form indicates that you have understood to your satisfaction the information regarding your participation in the research project and agree to the observation study taking place. In no way does this waive you legal rights nor release the investigators, sponsors, or involved institutions from their legal and professional responsibilities. You are free to not answer specific items or questions in interviews or on questionnaires. You are free to withdraw from the study at any time without penalty. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation. If you have further questions concerning matters related to this research, please contact the researcher.

__________________________ __________________

Principal Date

Patricia Avenue School

__________________________ __________________

Investigator/Witness Date

A copy of this consent form has been given to you to keep for your records and reference.

Appendix 2: Patricia Avenue School Research Consent Form for Investigations 2-4

The University of Waikato · School of Computing and Mathematical Sciences

Research Consent Form

This consent form, a copy of which has been given to you, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned, or information not included here, please ask. Please take the time to read this form carefully and to understand any accompanying information.

Research Project Title
Exploring user-centred software design for children with autistic spectrum disorders

Researcher
Grant Shannon under the supervision of Dr Sally Jo Cunningham.

Experiment Purpose
The purpose of this experimental observation study is to gain a software interaction baseline with respect to children on the autistic spectrum.

Participant Recruitment and Selection
I will observing the children of [Site 1] as well as the children at [Site 2].

Procedure
I will video record the children as they use a piece of software of their choice. Staff in the classroom will be informed of their right to ask the researcher to leave at any time without a need for explanation. At no time will the researcher be in a room with one or more children but no qualified School staff.

Data Collection
Emphasis will be placed on how children interact with the software, what physical inputs they provide (i.e clicking, dragging, use of buttons, keyboard use etc.) and where and when alternate methods of interactions are attempted (touching of the screen, banging of the mouse, directed speech 'at the screen' etc.).

Data Archiving/Destruction
No footage or still images gained from this investigation will be used for anything other the purposes mentioned above without first seeking additional permission from the Principal of the Patricia Avenue School and the Parents/Caregivers of the children concerned. Data will be kept secure stored in the HCI Laboratory until the end of my study in February 2009, when it will be destroyed.

Confidentiality
Confidentiality and participant anonymity will be strictly maintained. All information gathered will be used for statistical analysis only and no names or other identifying characteristics will be stated in the final or any other reports.

Appendix 2: Patricia Avenue School Research Consent Form for Investigations 2-4

Likelihood of Discomfort
There is no likelihood of discomfort or risk associated with participation.

Researcher
Grant Shannon is completing a Masters of Science within the School of Computing and Mathematical Sciences at the University of Waikato. Grant has a great passion for playing in general (he never really grew up) and for playing on computers especially. He would love to improve the quality of digital play available to children on the autistic spectrum and hopes that his studies with reflect this.

His supervisor in these activities is Dr Sally Jo Cunningham.
Grant can be contacted in the HCI laboratory (G1.31) of the School of Computer and Mathematical Sciences building at the University of Waikato. Alternatively, he can be reached by calling 021 247 2688 or by email at gjr5@cs.waikato.ac.nz.

Finding out about Results
The Participants can find out the results of the study by contacting the researcher after February 31 2009.

Agreement
Your signature on this form indicates that you have understood to your satisfaction the information regarding your participation in the research project and agree to the observation study taking place.
In no way does this waive you legal rights nor release the investigators, sponsors, or involved institutions from their legal and professional responsibilities. You are free to not answer specific items or questions in interviews or on questionnaires. You are free to withdraw from the study at any time without penalty. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation. If you have further questions concerning matters related to this research, please contact the researcher.

______________________________ ______________________

Principal Patricia Avenue School	Date
Investigator/Witness	Date

A copy of this consent form has been given to you to keep for your records and reference.

Appendix 3: Research Participant's Bill of Rights

The University of Waikato · School of Computing and Mathematical Sciences
Research Participant's Bill of Rights

The following is a list of your rights if you participate in a research project organised within the School of Computing and Mathematical Sciences at the University of Waikato.

As a research participant, you have the right:

- To be treated with respect and dignity in every phase of the research.
- To be fully and clearly informed of all aspects of the research prior to becoming involved in it.
- To enter into clear, informed, and written agreement with the researcher prior to becoming involved in the activity. You should sense NO pressure, explicit or otherwise, to sign this contract.
- To choose explicitly whether or not you will become involved in the research under the clearly stated provision that refusal to participate or the choice to withdraw during the activity can be made at any time without penalty to you.
- To be treated with honesty, integrity, openness, and straightforwardness in all phases of the research, including a guarantee that you will not unknowingly be deceived during the course of the research.
- To receive something in return for you time and energy.
- To demand proof that an independent and competent ethical review of human rights and protections associated with the research has been successfully completed.
- To demand complete personal confidentiality and privacy in any reports of the research unless you have explicitly negotiated otherwise.
- To expect that your personal welfare is protected and promoted in all phases of the research, including knowing that no harm will come to you.
- To be informed of the results of the research study in a language you understand.
- To be offered an range of research studies or experiences from which to select, if the research is part of fulfilling your educational or employment goals.

The contents of this bill were prepared by the University of Calgary who examined all of the relevant Ethical Standards from the Canadian Psychological

Appendix 3: Research Participant's Bill of Rights

Association's Code of Ethics for Psychologists, 1991 and rewrote these to be of relevance to research participants.
Descriptions of the CPA Ethical Code and the CPA Ethical Standards relevant to each of these rights are available at http://www.cpa.ca/ethics2000.html and http://www.psych.ucalgary.ca/Research/ ethics/bill/billcode.html if you would like to examine them. The complete CPA Ethical Code can be found in Canadian Psychological Association *"Companion manual for the Canadian Code of Ethics for Psychologists"* (1992).

Appendix 4: Parental Consent Form Sent Home to Parents for Investigation 1

Hi There,

My name is Grant Shannon. I'm a master's child at the University of Waikato undertaking my thesis year. My thesis project is exploring interactive environments for children on the autistic spectrum. As part of this project I am working with the children of [Site 1] and [Site 2] to build a prototype piece of software. Included in this project is a period of observation, where I shall watch the children as the go about their everyday activities in the classroom. During this investigation I shall be taking notes with pen and paper, these notes will then be used inform the next stage of my project, a software prototype. All references to specific children shall be anonymous. At the end of my thesis year (February 2009) all notes shall be destroyed.

If you would be kind enough to give this consent, please fill out the form below in the affirmative and sign and date it. If, for whatever reason, do not wish your child to be involved in this project, please fill out the form below in the negative and sign and date it.

Please be aware that in the coarse of my project I may ask for your consent for your child to participate in other investigations. If and when this occurs, another consent form giving details of the investigation will be provided.

If you have any enquiries, please feel free to email me (at the university) at gjr5@waikato.ac.nz or call me on my cell on 0212472688.

Grant Shannon

Appendix 4: Parental Consent Form Sent Home to Parents for Investigation 1

Parental Consent Form

I ____, the parent / caregiver of ____ declare that I have read and understood the project description given above. Please tick the appropriate box below:

☐ I thereby, **do** agree to the participation of my child in the research study that will be conducted in his / her class by Mr Grant Shannon.

☐ I thereby, **do not** agree to the participation of my child in the research study that will be conducted in his / her class by Mr Grant Shannon.

________________________ ________________

Parent/Caregiver Date

NB: The researcher wants to remind you that you are entitled to withdraw your child/children from participating in this study at any time without explanation. At no time will the researcher be in a room with one or more children but no qualified School staff.

Appendix 5: Parental Consent Form and Computer Experience Questionnaire Sent Home to Parents for Investigations 2-4

Hi There,

My name is Grant Shannon. I'm a master's child at the University of Waikato undertaking my thesis year. My thesis project involves developing interactive software for children on the autistic spectrum. As part of this project I am working with the children of [Site 1] and [Site 2] to build a prototype piece of software.

As part of this project, the software prototype produced will need to be evaluated. As part of this evaluation process, I need to know how the children use software that they are familiar with. Once I have this information, I can then compare how the children use the software I create during the course of my project with it. I propose to gather this data by video taping the children of Green Room/Room 16 while they use software they interact with often. This video footage will then be reviewed by myself, where I will look for key indicators of how they are using the software that they enjoy.

No footage from the video obtained in this investigation will be used for anything other than gathering the baseline data mentioned above, without gaining further consent from the parents concerned.

If you would be kind enough to give this consent, please fill out the form below in the affirmative and sign and date it. If, for whatever reason, do not wish your child to be involved in this project, please fill out the form below in the negative and sign and date it. In addition, I have also included a short questionnaire with this letter. Its purpose is to find out how much experience each of the children has with computers and also what amount of access they have to computer equipment at home. This information will allow greater accuracy when I review the data from the rest of this investigation, as the amount of experience each of the children has with computers will be a known quantity.

Please don't feel compelled to answer any of the questions you are uncomfortable with, but the information would be appreciated.

Appendix 5: Parental Consent Form and Computer Experience Questionnaire Sent Home to Parents for Investigations 2-4

As my project progresses, I may ask for your consent for your child to participate in other investigations. If and when this occurs, another consent form giving details of that investigation will be provided.

If you have any enquiries, please feel free to email me (at the University of Waikato) at gjr5@waikato.ac.nz
or call me on my cell on 0212472688.

Grant Shannon.

Appendix 5: Parental Consent Form and Computer Experience Questionnaire Sent Home to Parents for Investigations 2-4

Parental Consent Form – Software Interaction Investigation

I ______________________________________, the parent / caregiver of ______________________________________ declare that I have read and understood the project description given above. Please tick the appropriate box below:

☐ I thereby, **do** agree to the participation of my child in the research study that will be conducted in his / her class by Mr Grant Shannon.

☐ I thereby, **do not** agree to the participation of my child in the research study that will be conducted in his / her class by Mr Grant Shannon.

____________________________ ____________________

Parent/Caregiver Date

NB: The researcher wants to remind you that you are entitled to withdraw your child/ children from participating in this study at any time without explanation. At no time will the researcher be in a room with one or more children but no qualified School staff.

Appendix 5: Parental Consent Form and Computer Experience Questionnaire Sent Home to Parents for Investigations 2-4

Questionnaire - Computing Experience

Does your child have access to computer equipment at home? If yes, what kind of equipment? (no need to be too exact, for example 'Windows PC' or 'Xbox 360' is fine).

Does your child use any specialised equipment when using the computer? (specialised input devices, etc.).

How much time per day does your child spend on a computer (on average)?

For how long has your child has been using computers?

What software does you child use when they use the equipment described above?

Does your child have a favourite piece of software or a favourite activity inside the software they use?