Quest for the Blue Badger: An iPad Application for Language-Impaired Children with ASC

Developing Educational Games for Teaching Children with Autism

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Abstract

Autism Spectrum Conditions (ASC) are generally characterised by language impairment and deficits in communication, and observations of children with Specific Language Impairment (SLI) often reveal very similar language profiles to those with ASC. Studies reveal that the comorbidity between the two conditions is above chance level, suggesting that they may share some common aetiology. Complex sentences are an example of the sort of linguistic deficit language-impaired individuals tend to display.

For the purposes of this research, a tablet-based game was developed that was intended to aid users' understanding of commonly occurring complex sentence structures. It focuses on non-restricted relative adjectival clauses, as they tend to appear embedded between commas within a main clause and are, thus, easily identifiable within a narrative text. The prototype's design was informed by existing literature, expert input, and feedback from neurotypical children. Subsequently, the prototype was presented to similar cohorts of testers for evaluative purposes. According to the feedback received, alterations were made or suggested as future implementations. The results of the study largely support the use of technology and narrative in an educational tool to support language-impaired children with ASC.

Acknowledgements

First and foremost, I owe a huge debt of gratitude to Dr Helen Pain for her invaluable support and counsel throughout the year, and for taking numerous bus rides on cold and dreary days to get us to and from workshops full of rambunctious children. I also extend a huge thank you to the aforementioned children for always having brilliantly creative ideas and helpful feedback. And to the various experts and professionals who gave up their time at various stages of the project – know that its completion would have been impossible without your contributions.

Crucially, I would like to thank my parents, whose unwavering love and encouragement is always appreciated, even from 1200 miles away. And finally, my sincerest thanks to the most wonderful colleagues, friends and flatmates, who keep me grounded in both work and life.

Declaration

I hereby declare that this dissertation has been composed solely by myself and that this work has not been submitted, in whole or in part, for any other degree or professional qualification. Except where explicitly stated otherwise by reference or acknowledgement, the work contained herein is entirely my own.

(Tara Wudhiphan)

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1 Introduction

1.1 Comorbidity of ASC and SLI

Multiple studies identify a subgroup of children amongst those with Autism Spectrum Conditions (ASC) with both Specific Language Impairment (SLI) and ASC called the Autistic Language Impairment (ALI) group (Lindgren et al., 2009; Tomblin, B. 2011). The scope of this dissertation originates from results highlighting the above chance levels of comorbidity between the two conditions (Bishop, 2010); that is, they tend to co-occur within an individual significantly more than would otherwise be expected of two independent and unrelated disorders.

In related experiments, Kjelgaard and Tager-Flusberg (2001) found that IQ and language skills are independent of each other in individuals with ASC, since children with lower IQ scores sometimes possess normal range language skills while many with high IQ scores have impaired language skills. The language tests they performed on the children with ASC are more commonly used to identify SLI, and over three quarters of the children showed similar impairment levels as their SLI counterparts. The results from experiments by Loucas et al. (2008) aligned with this, revealing that 57% of children with ASC showed evidence of language impairment.

1.2 Objectives and Contributions

Based on the findings outlined in Section 1.1, the conclusion can be drawn that a significant proportion of individuals with ASC are also likely to be language impaired, thus exhibiting similar language patterns as those with SLI. It is this assumption that provided the motivation and basis for the study at hand, which was concerned with supporting the comprehension of complex syntax in children with ASC. The intention was to achieve this through the creation of a tablet-based application in the form of a narrative, detective-style game. To guide the study, the following research questions were formulated:

(a) **Is a tablet game appropriate for the target audience?**

(b) **How can an educational tool be enhanced so that it is engaging and fun?**

(c) **Is the detective narrative an effective way to frame a language game?**

The primary objective of this dissertation was to address these questions, for the purposes of which the following work was undertaken:

1. Various activities intended to inform the design of the subsequently developed application; including reviewing existing literature, conducting interviews and running workshops.

2. The creation of an iPad application in Unity 5 to support the acquisition and comprehension of complex language structures in children with ASC.

3. Multiple iterations of design testing in the form of prototypes, usability testing, evaluations with experts in relevant fields and observations of target-age, typically developing children interacting with the application.

1.3 Dissertation Structure

Subsequent sections of this report are structured as follows:

Chapter 2 presents a literature review of existing material on various aspects relating to the dissertation. It provides a background on ASC, SLI, complex syntax processing in neurotypical children and on the relationship between technology and individuals with Autism.

Chapter 3 describes and justifies the methodological approach undertaken for this research.

Chapter 4 outlines the primary findings in the pre-design phase. This includes observations from the design workshops with typically developing children and feedback from the interviews carried out with expert in related fields.

Chapter 5 uses the previous chapters and design guidelines to compile a series of design requirements, then goes on to describe and justify the various design decisions made in terms of game functionality.

Chapter 6 gives details about the implementation of the revised game design and discusses the choice of hardware and software used to create the game.

Chapter 7 covers the results from the evaluation methods used on the final prototype. This includes workshops with neurotypical proxies and interviews with relevant experts.

Chapter 8 provides a general conclusion to the dissertation, discussing the outcomes of the evaluation stage and proposing potential areas of further research and work to be carried out.

2 Literature Review

2.1 Autism Spectrum Conditions

ASC is a term that was coined to encompass an array of similar developmental, neurological conditions that are known to affect the manner in which an individual experiences the world. As the name implies, ASC describes a spectrum of possible disorders. This means it can manifest in a wide range of different ways, and with varying degrees of severity.

ASC was defined by Wing and Gould (1979) in terms of a triad of impairments; most notably, it is known to affect communication skills, the capacity for social interaction, and imagination, whereby impairment of the latter tends to manifest as a largely restricted range of interests.

The 5th Edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) (2013), as published by the American Psychiatric Association (APA) acknowledges that symptomatology lies on a continuum, and establishes certain criteria to be met before a diagnosis of Autism can be given:

- **Social communication and interaction deficits** that persist across multiple contexts.
- **Repetitive and restricted behavioural patterns**, interests or activities.
- Presence of symptoms in the period of **early development**.
- **Everyday functioning** (in social, occupational or other areas) is significantly **impaired**.
- Intellectual disability or developmental delay is not the root cause of the impairment.

In a study of the global pervasiveness of developmental conditions, it was estimated that 0.62% of the population have an ASC (Elsabbagh et al., 2012), and that males are between 2 and 5 times more likely to be affected than women overall. This is in keeping with earlier findings by Hill and Frith (2003), who place the figures at 0.6% and roughly 3 times more likely, respectively.

No cure exists for ASC, however there are many interventions which can not only lessen difficulties, but which can improve quality of life as well as enhance functional independence. Due to the vast amount of variability encountered in ASC, treatment is required to be tailored according to the individual child's needs and specific issues.

2.1.1 ASC and Written Language

One of the earliest observable signs of ASC in a child is a delay in their spoken language development (Mitchell et al., 2006). Nevertheless, Frith (1989) remarks that a significant proportion of children with ASC achieve reading fluency with adequate phonology in spite of their language delay. This is a phenomenon known as hyperlexia, characterised by precocious reading abilities relative to comprehension skills (Nation, 1999). And while hyperlexia is not unique to ASC (Snowling & Frith, 1986), there is a very strong association between the two conditions, with over 4/5 of cases occurring on the spectrum (Ostrolenk et al., 2017).

Frith (1989) attributes the observable comprehension deficit to the fact that these children pay more attention at the word-level, with little focus on the overall story. Brosnan et al. (2004) argue that this may be due to some impairment in Gestalt processing, resulting in a bias towards local as opposed to global processing in individuals with ASC. Vicker (2009) identifies the same pattern in the language characteristics of children with ASC, noting that they attend to keywords instead of the overall message conveyed by the grammar.

2.2 Specific Language Impairment

In order for a child to be diagnosed with SLI, they must exhibit significant delay in their ability to acquire and use language which cannot be accounted for by other causes, such as some more general developmental delay or a hearing impairment. Much like Autism, the disorder manifests differently in individuals and, thus, a uniform set of diagnostic criteria has not been created. However, Rapin and Allen (1983) were able to formalise a method of categorising the kinds of developmental language disorders that comprise SLI. These were defined as follows:

- **Receptive and expressive deficits:** Semantics, syntax and phonology are affected; children exhibit sparse, non-fluent speech or are entirely non-verbal.
- **Solely expressive deficits:** Comprehension remains intact; main impairment is found in phonological production. Individuals are sometimes non-verbal, for instance in cases of verbal dyspraxia.
- **Higher-order processing deficits:** Discourse, semantics and pragmatics are impaired.

2.2.1 Wh-questions

Van der Lely (1998) identifies wh-questions as one of the complex grammatical structures that pose problems for children with SLI. Long-object sentences were found to be harder to process – signalled by increased reaction time – than long-subject sentences (Deevey & Leonard, 2004). This is due to the increased gap between the relevant components contained in the sentence, which imposes more demands on working memory. According to these studies, it turns out that the issues exhibited in wh-question comprehension are the result of a deficit in linguistic processing capabilities.

2.3 Complex Sentence Structures

Complex sentences resemble wh-questions in that, as a result of the incorporation of dependent clauses and the increased complexity of inter-clausal relationships, they are also more demanding for working memory. For this same reason, they are also commonly found to be a source of difficulty for language impaired individuals. Within the classification frameworks described for ASC and SLI (see 2.1 and 2.2), an impaired ability to comprehend complex syntax is classified as a communication and higher-order processing deficit.

2.3.1 Complex Syntax in Neurotypical Development

Experiments by Dick et al. (2004) reveal that, in neurotypicals, comprehension of complex sentence structures increases with age, evidenced by decreasing reaction times and increasing levels of accuracy. More specifically, they found that accuracy significantly increases after age 9 compared to ages 5-8, and that children under the age of 10 displayed markedly lower correct reaction times than their 10-17 year-old counterparts.

2.3.2 Complex Syntax in Atypical Development

In terms of production, children with SLI were shown to spontaneously use a smaller number of complex sentences comprised of fewer clauses (Marinellie, 2004) than their typically developing, age-matched peers. Moreover, they tend to make more errors in complex sentences and include fewer total words per utterance (Scott & Windsor, 2000). With regards to comprehension, complex grammatical constructions are shown to be compromised in language-impaired individuals (Adams, 1990; Montgomery, 1995).

Dick et al. (2004) suggest that children with SLI suffer from profound and enduring problems when faced with non-canonical word order, evidenced by significantly lower accuracy than even the youngest TD children (age 5). Not only is it the case that school age children with SLI perform significantly worse than their age-matched peers, Montgomery and Evans (2009) also found that they show impairment in memory tasks. The results of their study confirm that comprehension of complex syntax is also a mentally demanding activity, which relies on the use of working memory.

2.4 Technology and Learning

2.4.1 Game-based Learning

Prensky (2002) argues that an unnecessary division exists between learning and fun. He proposes that the motivating factors involved in gameplay can, and should, be incorporated into education. As a result, a more relaxing environment can be created, promoting increased motivation, effort, and outcomes in the learner. Games build learning into their design, and it is the learning principles applied within them that can be generalised to academic and more formal pedagogical contexts (Gee, 2007).

In fact, there is considerable evidence in favour of the effectiveness of game-based learning (Blunt, 2007; Milovanović et al., 2009). Conceptual minigames for learning are one such approach, shown to result in increased enthusiasm. Conceptual minigames have been shown to have positive outcomes in areas such as memory development (Illanas et al., 2008) and mathematical calculation skills (Panagiotakopoulos, 2011; Panagiotakopoulos & Sarris, 2013).

2.4.2 Technology and Autism

There is evidence that children with ASC dedicate a large proportion of their time to electronic games and other media (Mazurek & Wenstrup, 2013), significantly more so than their typically developing peers (Mazurek & Engelhardt, 2013). In light of this, it makes sense to target technological media as a means of addressing their areas of impairment.

Furthermore, technology-based learning is an ideal platform for children with ASC. It allows them to experience a sufficiently accurate representation of the real world in which to practise social interaction while still in a secure environment, which is also familiar and highly predictable (Fletcher-Watson, 2014). Tablet-based apps in particular have been shown to have positive effects on social interaction in children with Autism (Hourcade et al., 2013), and while such devices do incur a sizeable one-off fee, they provide the user with countless affordable and useful apps, many of which are aimed precisely at individuals with ASC.

Various studies report that children with ASC are more likely to engage with the computer-based approach. In Moore & Calvert's (2000) experiments, this was the case for educational software that was designed to replicate non-computerised intervention methods, while Williams et al. (2002) found that autistic children willingly spent longer developing their reading skills when the material was presented on a computer than when it was in book form.

In terms of a specific focus on improving language and communication skills, it seems that the surge in popularity of handheld devices sets the scene for using technology to create visual-based support for individuals with ASC (Shane et al., 2012). Ramdoss et al. (2011) conclude that computer-based interventions offer a promising platform which deserves extensive future research, noting that tools are most effective when devised with the intent to encourage generalisation to the user's real world environment. However, rote learning via computerised training, specifically targeting grammatical

comprehension, proved to be an ineffective intervention method for language-impaired individuals (Bishop et al., 2006). In fact, the only visible improvement was found to be a result of increased familiarity with the computer game presented in the experiments.

Instead, Hirschman (2000) proposes a metalinguistic approach to language repair. By making a language-impaired child explicitly aware of the linguistic rules at play, a *metalinguistic bridge* is created, thus allowing the relevant information to avoid the damaged area via an alternative route. Such methods provoked noticeable improvements even in children with the poorest language skills, whose usage of complex syntax increased to at least standard levels exhibited by TD controls.

3 Methodology

3.1 Human-Centred and Participatory Design

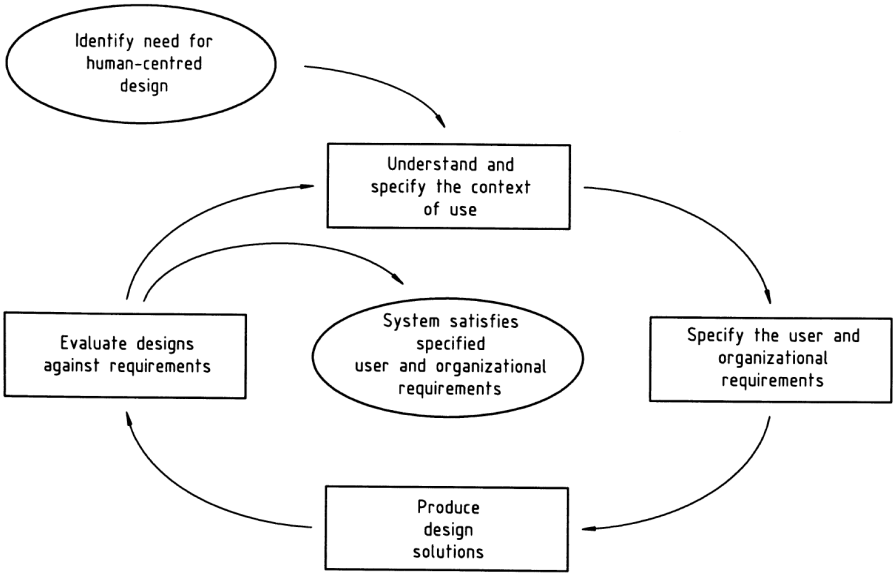

Figure 1. The interdependence of human-centred design activities (International Organization for Standardization, 1999)

The term Human-Centred Design (HCD) was first used by Norman (1986); it describes a design approach wherein the target user is considered at every stage of the process. According to the HCD approach for interactive systems (International Organization for Standardization, 1999), there are four interdependent core activities which are required to take place over the course of a system development project:

(1) Specify context of use.
(2) Specify requirements.
(3) Produce design solutions.
(4) Evaluate designs again requirements.

Participatory Design (PD) refers to a very similar concept, but places specific emphasis on the active participation of end-users in the design process (Schuler & Namioka, 1993). That is, the end-user is given the opportunity to contribute their own ideas and give input to the design, rather than serving simply as a source of data.

3.2 Why Involve Children?

For this research, children are the target users. And as technologies become more and more integrated into the everyday lives of modern-day children, Fails et al. (2013) argue that it is absolutely necessary to involve them in the design; for no one is more suited to help create technology intended for children than other children. Adopting methodologies of co-design such as Cooperative Inquiry (Druin, 1999; Druin, 2002) allows children to be actively involved throughout the entire process – as users, testers, informants and research partners.

Benton et al. (2011) presented IDEAS (Interface Design Experience for the Autistic Spectrum) method – a means of involving children with ASC in the design of technology by having them take part in regular PD activities in a one-off session. This was expanded on by involving them as design partners in a collaborative design team over multiple sessions (Benton et al., 2012). The outcomes of these sessions were such that the children left feeling confident and empowered, and with a sense of ownership over the resultant game. The results of these studies demonstrate that participatory design methods are, in fact, possible for children with ASC. However this was not feasible within the framework of the undergraduate dissertation.

Since access to the target population was not possible for this research, typically developing (TD) children acted as proxies. However, it is important to note that they would not display the same kinds of impairment as children with ASC, so their feedback was more useful for purposes of determining the usability of the game and whether the content (including storylines, characters and design) was appropriate, fun and engaging. In some cases, children in the workshops were familiar with ASC as a result of having siblings or friends with Autism and were able to provide insights based on this. Additionally, Fletcher-Watson (2014) points out the importance of involving parents or relevant professionals when designing for Autism. Thus, experts on ASC were among those consulted to provide information regarding the suitability of the game for the target users.

3.3 Stages of Development

Since the game consists of a virtual environment designed to support learning, the methodology undertaken (see Figure 2) is based largely on the five-stage approach outlined by Scaife and Rogers (2001). They argue that a "mix of methods and perspectives" is essential when faced with designing virtual environments, so the activities carried out at each stage were informed by the activities listed in the HCD procedure (see 3.1) as well as the PD practices described by Muller et al. (1997). Moreover, multiple perspectives are obtained by the inclusion of children of varying ages and experts across several related academic fields.

Scaife and Rogers (2001) also highlight that special attention must be paid to the initial stages of design. As a result, early opportunities arise for the resolution of particularly difficult problems prior to the implementation of any code. Within the scope of this research, this correlates with the first three methodological stages.

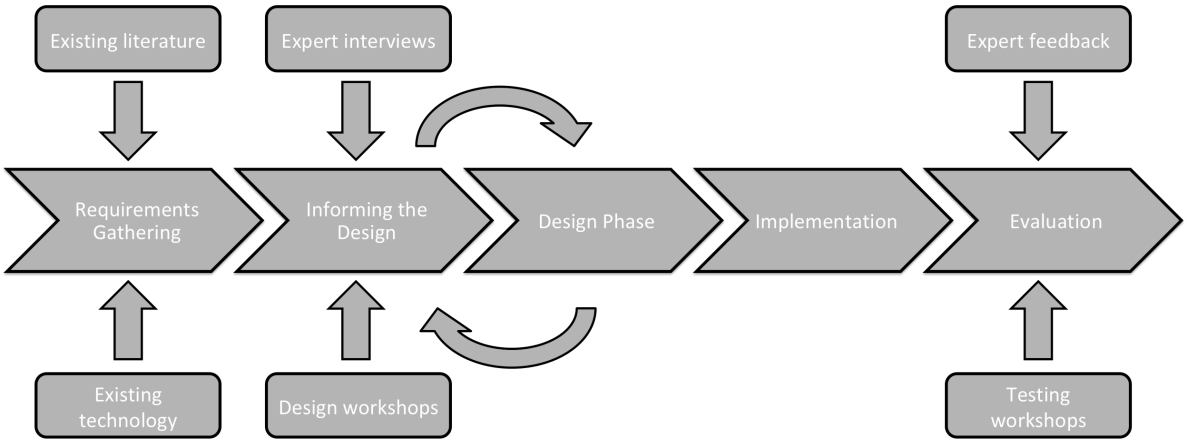

Figure 2. Methodological stages (adapted from Scaife and Rogers, 2001)

Stage 1: Requirements gathering
The first step was to identify a problem to target. In accordance with the first HCD activity (see 3.1), the context of use was defined in terms of:

- The end user's characteristics: This was achieved by reviewing the existing literature on ASC, SLI, complex syntax, educational technology and exploring existing intervention tools.
- The goals of the system: It was decided that the focus of this research would be language impairment in children with ASC, specifically with regards to deficits in comprehension of complex syntax.
- The target environment (i.e. hardware and software): The application was developed for an Apple iPad running iOS 11 using Unity 5.

The information gathered was later used to compile a series of requirements in the design phase.

Stage 2: Informing the design
Muller et al. (1997) described Collaborative Design Workshops as exemplar participatory practices. Based on these, design workshops with TD proxies were carried out, for which information sheets and consent forms were provided. Alongside these, interviews were held with experts in various fields in order to evaluate the interim design stages; verbal agreement to the audio recordings was requested from each expert. The data collected from these were additionally incorporated to the requirements outlined in the previous stage. In the time between the first and final informant sessions, changes were made to the design. Thus, stages 2 and 3 comprise an iterative process, as these alterations were based on feedback from previously held workshops and/or interviews.

Stage 3: Design phase
Design a series of requirements were finalised with input from the preceding stage (as required by the second HCD activity; see 3.1); some were specific to ASC, while others focused on technology aimed at children and general principles of human-computer interaction. Using these, low-fidelity prototypes in the form of paper sketches and digital graphics were created to outline the main style and functionality of the game. These constitute the proposed design solutions which form part of the third HCD activity (see 3.1); here an iterative process of revising the design based on stage two feedback takes place until requirements are met.

Stage 4: Implementation
Studies in the UK revealed that almost a third of children aged under five possess their own tablets, with the Apple iPad being the most popular (Marsh et al., 2015). This is a trend that continues throughout childhood, with almost half of all 5-15 year-olds in the UK owning one (Ofcom, 2017). Moreover, a longitudinal study by Tay (2016) revealed that iPad usage strongly correlates with increased levels of collaboration and engagement in learners, with noticeable positive effects on academic results. Therefore, the decision was made to implement the game as a touchscreen tablet application. Subsequently, the researcher was required to become familiar with the software (Unity 5) used to create a high-fidelity prototype, based on the final iteration of the design that was formulated in stage three.

Stage 5: Evaluation
In keeping with the fourth HCD activity (see 3.1), evaluation workshops were run with neurotypical proxies. These were based on the Cooperative Evaluations described by Muller et al. (1997). However, the evaluation teams differed slightly from those specified, as they comprised up to three TD proxies as opposed to only one end-user. Interviews were held, once again, with relevant experts across various fields in order to gather feedback on the functionality and usability of the prototype as well as further possible improvements.

4 Informing the Design

4.1 Design Workshops with Typically Developing Children

Design workshops were held with neurotypical children of similar ages to the target audience, who served as proxies for children with ASC, as per the methodology outlined in Chapter 3 (see 3.2). The principal goals of these workshops was to to narrow down the specific type of complex sentence that would be addressed in the game. Additionally, it was important to ascertain what features children of the target age would want to see, and how they would prefer a game about language comprehension be framed.

4.1.1 Aims

The following aims were established for the design workshops:

(1) Determine the kinds of complex syntax neurotypicals tend to use.

(2) Determine the sorts of characters to include.

(3) Determine the kinds of locations children like to visit.

(4) Determine suitable ways of keeping an educational game fun and engaging.

4.1.2 Materials

The materials used in the workshops were an Apple iPad, paper, pens, pencils, an Apple iPhone used for audio recording, and a whiteboard in workshops 1 and 2. The iPad was only used to show the children some short video clips.

4.1.3 Participants

The participants that took part in the design workshops were eleven typically developing children (4 boys and 7 girls) between the ages of 7 and 13 (see Table 1). The children in workshops 1 and 2 were recruited through the university; some were children of university staff, others were children who attend nearby schools. The children in workshops 3 and 4 were part of a local Brownies group. For the most part, the participants in all four sessions already had experience with the kinds of activities that were carried out, due to participation in similar workshops in previous years.

	Participant	**Age**	**Gender**
Workshop 1	P1	12	Female
	P2	13	Male
Workshop 2	P3	12	Male
	P4	12	Male
	P5	13	Male

Workshop 3	P6	9	Female
	P7	8	Female
	P8	7	Female
Workshop 4	P9	9	Female
	P10	9	Female
	P11	8	Female

Table 1. Design workshop participant information

4.1.4 Setting

Workshops 1 and 2 took place in the University of Edinburgh Informatics Forum. Workshops 3 and 4 were conducted at the Brownies' weekly meeting point: a local church hall.

4.1.5 Procedure

In order to ensure workshop participants were thoroughly informed of what was expected of them in the sessions, information sheets were provided for their parents/guardians (see Appendix A) as well as simplified versions of these sheets adapted for the children themselves (see Appendix B). These were given in the days leading up to the workshops so parents/guardians and children alike would have time to read through the sheets. Following this, the parents/guardians and children were given consent forms to sign (see Appendices C and D), which included giving permission for audio recording. On the day of the sessions, the children were asked to confirm whether they still wanted to participate, and reminded that they would be audio recorded. In the case that a child no longer wished to take part, they were able to sit out the sessions along with the other children who were not involved in the workshops. To address aim 1 (see 4.1.1), activities 1 and 2 were carried out.

Figure 3. Design workshop in local church hall: activity 1

Activity 1: Understanding complex sentences
To begin with, the children were briefed with a short explanation of typical Autistic symptomatology, and asked if they were familiar with the condition on any level. They were then told that the study at hand focused on understanding language, and were given examples of complex language structures in the form of short video clips taken from popular films. Next, the children were shown a single complex utterance:

> *On Saturday, I drove to the cinema to see a film with my cousin's friend who lives in Germany with her dog.*

This was written on a whiteboard in workshops 1 and 2, but on paper for workshops 3 and 4 (see Figure 3). To check whether they understood what a complex sentence looked like, the children were asked to create their own complex sentences, either in individually or in small groups. This was also done to gauge what kinds of complex sentence structures were more likely to be produced by children of a similar target age. If their sentences were not complex enough, the children were then instructed to include a certain number of characters, animals and locations.

Activity 2: Identifying wh-questions
The example complex sentence was subsequently used to elicit wh-questions from the children, which they were then told could be problematic for children with Autism. This was achieved by asking the children what sorts of questions they could ask someone who has just heard the sentence. Afterwards, they were asked to come up with follow-up questions to their own sentences, along with their corresponding answers. This should enable them to spot recurring patterns which would help them to identify where to find the relevant information.

Activity 3: Creating a story
This activity was carried out for the purposes of informing aims 2 and 3 (see 4.1.1). The children were asked to come up with a detective character and to outline a mystery for them to solve, including where the story would unfold. They were given paper, pens and pencils to draw their characters and possible clues that might appear throughout the story. They were also asked to suggest possible locations in which the clues might appear. Participants were then asked to present their ideas and give a short summary of their storylines. Between workshops 2 and 3, the notion of minigames as a reward for completing the language element of the game was suggested by an expert. So this was incorporated into Activity 3 for workshops 3 and 4; the children were additionally asked to design their own mini-games for each of the locations they came up with.

At the end of the sessions, all participants were thanked and presented with a participation certificate (see Appendix E).

4.1.6 Results

Aim 1: Determine the kinds of complex syntax neurotypicals use
For the most part, the children appeared to favour complex sentences that contained embedded clauses. These sentences were spoken as opposed to written down, so commas have been inserted where the speaker paused in their utterance.

1. The man's cousin and his kid went to a farm, where they saw a llama, last Saturday.

2. My best friend, who has a pet dog, came to the zoo with me and my sister.

3. Lucy, who is my mum's friend's daughter, played at the playground with me and my dog.

4. On Friday, my cousin's step sister's friend's boyfriend' mum's neighbour and her cat went to the zoo, where they saw a monkey and two gorillas, before they went to the vet.

5. My cousin's step sister went to the sweet shop, where she ordered a double scoop chocolate marshmallow ice cream with sprinkles, with her boyfriend.

5. On Monday, Izzy, who has a dog, and I went to the park.

Figure 4. Example complex sentences from design workshop participants

Aim 2: Determine the sorts of characters to include

Across all the workshops, there was an overwhelming preference for the detective to be a human character (see Figure 5). This is likely due to the ages of most participants, as the younger groups did produce some non-human characters, including personified animals and food (see Figure 6). Almost unanimously, the detective was a male character sporting some sort of identifiable hat.

Figure 5. Drawings of detectives from design workshops

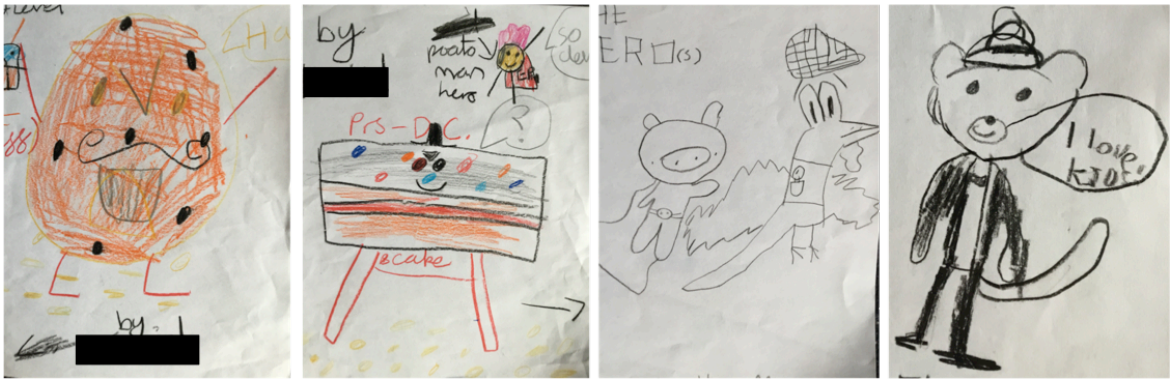

Figure 6. Drawings of non-human characters from design workshops

Aim 3: Determine the kinds of locations children like to visit

There were recurring themes throughout the workshops. When the children were asked to create their own mysteries, many of them chose very similar locations in which the crimes had occured. Table 2 outlines the frequency of each concept.

Theme	Frequency	Location
Animals	8	Zoo, farm
Food	5	Sweet shop, candy world
Shops	7	Toy shop, cake shop, sweet shop
Outdoors	9	Field, park, playground

Table 2. Recurring location themes in design workshops

In workshop 3, the participants proposed a roadmap to each location (see Figure 7), which would allow the player to choose where they would like to go. Their idea consisted of using minigames to unlock each of the locations. However, for the purposes of this game, this order is best inverted, since the minigames would not contain the educational language component.

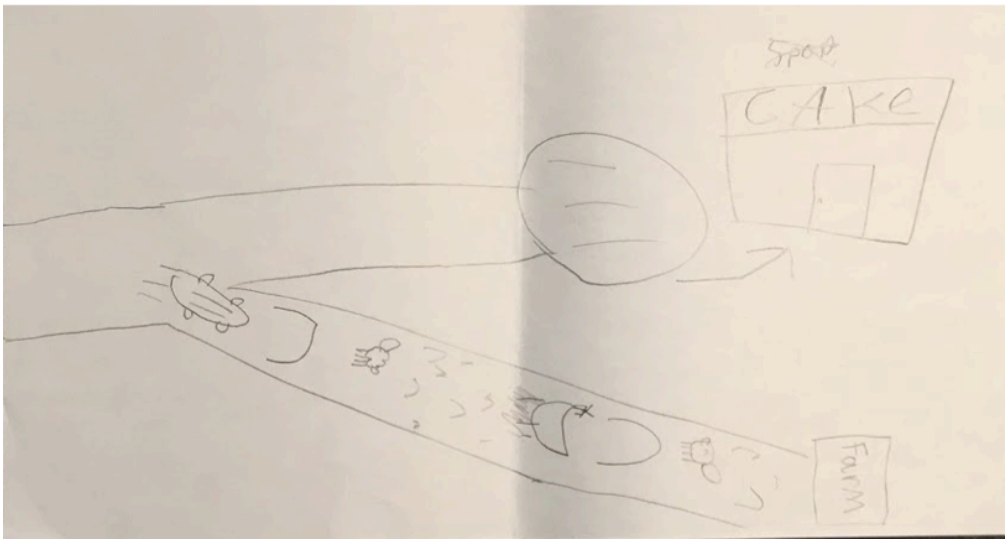

Figure 7. Roadmap to locations concept from design workshops

Aim 4: Determine suitable ways of keeping an educational game fun and engaging
It was determined in one of the expert interviews (see 4.2.4) that minigames would be implemented as rewards for completing the language aspects, so the participants designed their own minigames. In workshop 4, participants P9, P10 and P11 came up with an idea for a minigame in the farm. It revolved around the farmer's favourite sheep, who had fallen ill because she had been swallowing strange items around the farm. The aim of the minigame was to shear this sheep so that she could undergo an x-ray to determine what she had eaten. The next task would then be to spot the items in the x-ray.

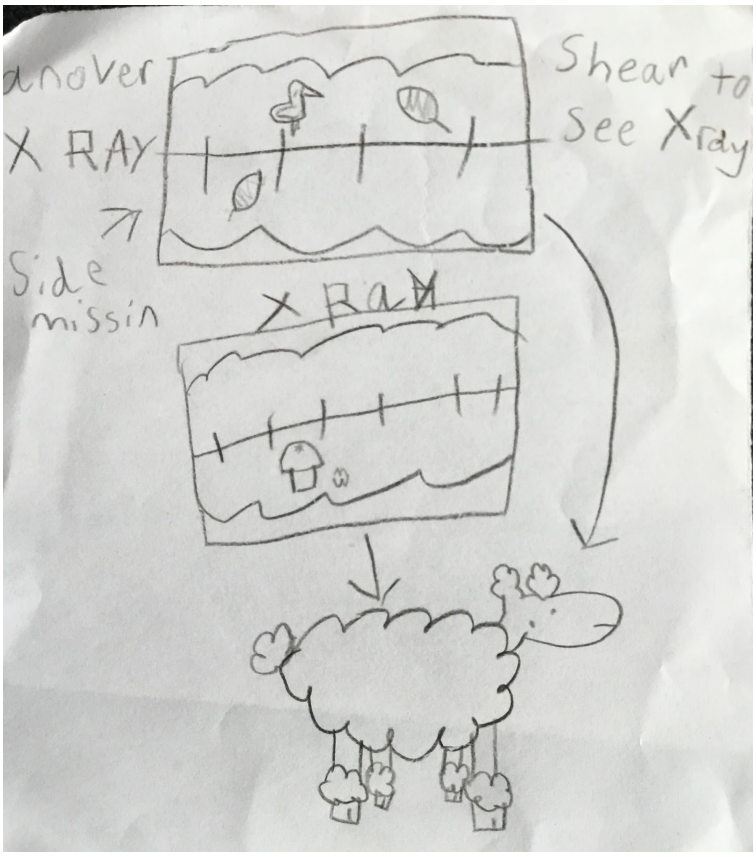

Figure 8. Shear the sheep game proposed in design workshops

4.2 Expert Interviews

Four semi-structured interviews were carried out with experts across several fields in order to obtain a wide range of contributions from various different perspectives. Each interview participant was given an overview of the initial design concepts for the prototype and their feedback was subsequently used to create the more advanced, high-fidelity, version.

4.2.1 Aims

The goal of these interviews was to inform elements of the game for which TD proxies could provide only limited insights. While the children were more than capable of recognising the things they enjoy in games, the educational nature of this application required expert feedback to help create an effective technology-based learning environment.

4.2.2 Participants

The participants were selected on the basis of their areas of interest and expertise, in order to obtain multi-disciplinary perspectives from the feedback. Between them, they were able to comment on the key design issues: human-computer interface, pedagogy relevant to language acquisition, as well as digital and game-based approaches to learning. The experts comprised one research postgraduate student (E1), one lecturer (E2), and one former lecturer (E3) at the University of Edinburgh. Their specific areas of expertise were as follows:

Participant	Background
E1	Research postgraduate student in Human-Computer Interaction and a member of the *Institute for Language, Cognition and Computation.*
E2	Lecturer in Cognitive Science with interests in language and usability, and member of the *Institute for Language, Cognition and Computation.*
E3	Former senior lecturer in Digital Education, with a background in biology and developmental psychology, and a particular interest in game-informed approaches to teaching and learning. Has a grandson with ASC.

Table 3. Expert interview participant information

4.2.3 Setting and Procedure

The interviews took place in various University of Edinburgh buildings within the central campus. The participants were contacted via email. To begin with, they were asked to give verbal consent to taking part and for the researcher to take notes. Next, the goals of the application were explained and the participants were informed that the core concept consisted of a detective-style narrative, with multiple choice questions used to test comprehension.

Figure 9. Original icon designs

The interviews were semi-structured, with **research question b** (*How can an educational tool be enhanced so that it is engaging and fun?*) used as the initial question, with the addition that it must still be effective as a comprehension tool. Participants were also shown the icons that would represent each of the locations selected for inclusion in the game (see Figure 9), as well as the proposed background motifs for some of these locations (see Figure 10). In the case of both the icons and backgrounds, the designs were kept colourful and simple, as encouraged by the literature (Hayes et al., 2010; Hussain, 2016). Subsequent questions varied between participants, and followed

on from their given responses. To conclude the interviews, participants were asked to provide any additional comments or suggestions that had not arisen over the course of the interview, and finally they were thanked by the researcher.

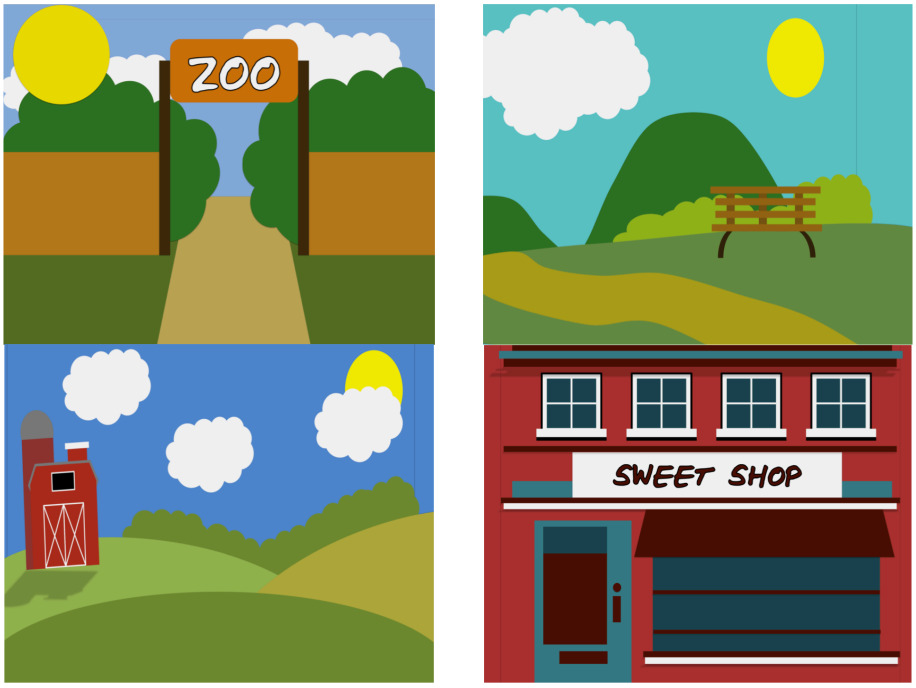

Figure 10. Original concepts for locations (Clockwise: zoo, park, sweet shop, farm)

4.2.4 Results

Detective narrative

All three participants agreed that a narrative storyline would be an effective way of formulating the game. E1 commented that the unsolved mystery allowed for a goal-based narrative which would engage the player and cause them to be invested in the outcome. The importance of playing a role was highlighted by E3, as it adds a more personal dimension to the game. E3's suggestion was to either let the player be the protagonist or to have them assist the detective as a sidekick.

Visible narrative text

E3 emphasised it was crucial to include the target sentences alongside the questions and multiple choice answers. The game should not rely on the player's ability to keep the narrative text in memory, which is likely to be impaired in autistic children. E2's comments corroborated this, stating that language-impaired individuals often suffer from a more general cognitive deficit in terms of working memory capabilities.

Open-world concept

The original idea was that only one location would initially be unlocked, with the rest becoming unlocked sequentially upon the completion of storylines in other areas. However, E1 suggested that having all locations available from the beginning would be beneficial, as allowing the user to choose the order in which they visit the locations would allow them more freedom and a sense of control over the progression of the story.

Tutorial with examples

E2 recommended that it would be helpful to the user to include a tutorial-style component with a break-down of the components of a complex sentence, with several examples of the target syntactic

structure. E3 added that this would be an effective way of illustrating where to look for the relevant parts of the sentence in response to the questions that would be asked.

Visible rewards system
The importance of ensuring rewards were visible to the player was agreed upon by E2 and E3, who emphasised that children like to be able to keep track of their progress. E2 commented that collected clues should be stored in a bag, or some bar/meter should display how close the player is to completing the game.

Positive feedback
The effects of different kinds of feedback were presented by E3, who claimed that while positive feedback is vital in educational games for children, negative feedback can be removed entirely. Instead, they propose it should be replaced with encouraging messages and should offer hints leading to the correct answers.

Minigames
E1 was the first to suggest the notion of an unlockable minigame as a reward for successfully completing the language aspects of the game. E3 advised that minigames should be related to the storylines lest they serve as an unfavourable distraction from the narrative.

Design and style
The consistency across icons and their bright appearance was well received by E1 and E3. However, E2 noted that the style of the icons and backgrounds images for the chosen locations appeared overly cartoon-like and, thus, aimed at quite a young audience. They indicated that a more realistic look would be better suited to the target age group.

Levels of difficulty
Both E1 and E2 put forth the idea of adding multiple levels of difficulty. E1 suggested that each level could correspond to the difficulty of either the target complex sentence structures, since different types of complex syntax might vary in terms of degree of complexity. On the other hand, E2 proposed varying the complexity in the questions used to check comprehension; or even a combination of both in the most difficult level. Nevertheless, the decision was made not to incorporate this feature into the prototype. The implementation of one complex sentence structure is sufficient as proof of concept, and replicating the prototype with additional forms of syntax would not offer much for the purposes of this research.

4.3 Summary

Design workshops with neurotypical children of similar ages to the target audience informed the decision to focus on embedded clauses. As a result of the preferences expressed by participants, the detective was created as a human character and the locations for the game were chosen. The creation of minigames to make the overall concept more engaging was a direct result of the input from these groups. The design concepts for the prototype were subsequently presented to experts with the objective of soliciting feedback about creating an effective technology-based learning environment. Suggestions covered the design and style, levels of difficulty, the narrative, the tutorial, the use of only positive feedback, the rewards system, and the incorporation of unlockable minigames. Most of these were incorporated into the design, with the notable exception of the introduction of levels of difficulty, as this was not considered critical to this research; a single level was sufficient as proof-of-concept.

5 Design Phase

5.1 Design Principles

5.1.1 Child-Specific Design Principles

In the words of Chiasson and Gutwin (2005): "Children are not miniature adults". Therefore, it seems illogical to design a tool aimed at children according to the exact same principles used to create adult interfaces. To address this concern, they assembled a series of design principles focused specifically on children's technologies. The following have been extracted as being relevant to this research:

(1) Interfaces should be strongly visual

(2) Instructions should be easy to comprehend

(3) Children are impatient and require immediate feedback

(4) Icons should be visually meaningful

(5) Interfaces should track exploration of the environment

(6) There should be no extensive menus or sub-menus

(7) Children's actions should map directly to actions on the screen

(8) Children enjoy being able to physically touch and manipulate devices

(9) Direct manipulatives allows for active exploration of the environment

(10) Children should be able to define their experience and be in control of interactions

(11) Entertaining diversions keep children engaged and motivated during learning

(12) Domain-specific agents provide pedagogical benefits

(13) On-screen characters should be supportive rather than distracting

(14) Extrinsic reward systems are important (e.g. scores)

(15) Children's technology should facilitate social interaction

(16) Children's technology should account for children's beliefs about computers

5.1.2 Autism-Specific Design Principles

To narrow down the principles even further, it is vital to consider the target population of children with ASC. For this, some of the guidelines laid out by Bartoli et al. (2014; see principles 1-5 below) and principles put forth by Hussain et al. (2016; see principles 6-10 below) are also incorporated:

(1) Goals should be explicit

(2) Instructions should be provided to facilitate understanding

(3) Rewarding stimuli should be offered after a good performance

(4) There should be evidence of repeatability and predictability throughout the game

(5) Graphics should be minimalist, cheerful and aesthetically nice

(6) The design should be simple without too much visual stimuli

(7) The user should be guided through the app

(8) The language used should be given careful consideration

(9) Images should match real life objects to facilitate recognition and learning

(10) Navigation buttons should be simple

5.1.3 Human-Computer Interaction Principles

Nielsen's (1994) usability heuristics are an integral part of the user interface design process, as they allow for the identification and resolution of baseline usability issues before beginning participant involvement. The following heuristics are relevant to this research:

(1) Visibility of system status

(2) Match between the system and the real world

(3) User control and freedom

(4) Consistency and standards

(5) Recognition rather than recall

(6) Aesthetic and minimalist design

(7) Help users recognise, diagnose and recover from errors

(8) Help and documentation

5.2 Design Requirements

Taking into account the reviewed literature (see Chapter 2), the results of the design workshops (see 4.1), feedback from the expert interviews (see 4.2), and the relevant design principles (see 5.1), the following requirements emerge:

N.B. Each requirement is listed with the corresponding child-specific, ASC-specific, and HCI-specific principles that infomed it.

		Child-specific	***ASC-specific***	***HCI-scpecific***
1	The game should be developed for a touchscreen tablet	8, 9, 16	-	-
2	The game should be playable for children with aged 8-12	-	-	-
3	There should be a virtual agent to guide the narrative	12, 13	7	1
4	Language in non-target sentences should be simple to ensure comprehension	2	2, 8	8

5	The game should use wh-questions to test comprehension of the accompanying narrative	-	-	5
6	The locations in the game should be places the user can relate to	-	-	2
7	It should be possible to visit these locations in any order	6, 9, 10	10	3
8	Each location's representative icon should be visually meaningful	4	9, 10	2, 6
9	The game should use minigames as rewards	11, 14	3	1
10	To be motivating, these minigames should be entertaining for the player	11	-	-
11	So they are not distracting, these minigames should tie in with the story	-	-	-
12	The game should not provide negative feedback for incorrect answers	3	2, 3	1
13	Feedback should be positive and encouraging	3	2, 3	1
14	Feedback should contain syntactic or pragmatic explanations of complex syntax	3	2, 8	1, 7
15	The game should be strongly visual with bright colours where possible	1	5	6
16	The game's overall style should be simple and consistent throughout	1	5, 4, 6	4, 6
17	Goals should be clear throughout gameplay	2	1	1

Table 4. List of design requirements with relevant informant principles.

5.3 Initial Design

The game focuses on helping the user recognise the structure of complex sentences, as well as understand how to correctly identify relevant information in them. Inspired by the "who done it?" game used in van der Lely and Battell's (2003) experiments, the game is formulated as a detective story. As the user answers questions, they are provided with clues that will help them solve the mystery at hand. Based on the findings outlined in 2.1.2 about the prevalence of hyperlexia in autistic individuals, we assume the target audience's reading capabilities are unimpaired.

Matthews and Haskill (2008) found that children with ASC and SLI were more likely to produce syntactically complex sentences in response to some prompt than when communicating spontaneously. Moreover, language experiments using wh-questions as a tool for response generalisation were shown to be effective (Krantz et al., 1981), as wh-words are uniquely recognisable. For these reasons, it made sense to use wh-questions to elicit a response in the user

(**requirement 5**), as this would require them to react in some way to the presented questions. While the user is not required to produce their own sentences, the logic is assumed to hold for the context of the app, since comprehension is said to precede production in both neurotypicals and children with Autism (Goodwin et al., 2012). To ensure their comprehension even by language-impaired individuals, the wh-questions are formulated such that the distance between the wh-word and its gap is kept short. When this is the case, language-impaired children perform just as well as their typically developing peers (Deevy & Leonard, 2004).

The name *The Blue Badger* is influenced by the media franchise *The Pink Panther*, which includes films wherein the theft of a diamond (the Pink Panther) is at the core of the plot. The game parallels this with the following introductory paragraph, which sets the scene and informs the player of the primary goal within the game (**requirement 17**):

> *"A diamond called 'The Blue Badger' has gone missing from the museum! The Inspector needs your help solving the mystery. Where would you like to search for clues?"*

5.3.1 Overarching Narrative

The idea is that one overarching storyline persists throughout the whole game. The user follows one character – an Inspector (see 5.3.3) – in their journey to solving a case. Mandler and DeForest (1979) identified this sort of coherent narrative structure as a crucial element in ensuring the comprehension of instructional messages. In fact, the learning behaviour resulting from educators imposing some degree of structure is much more focused and effective than learning from interactive tools lacking narrative structure (Laurillard, 1998).

5.3.2 Various Locations

There are six possible locations to visit within the game, each with their own sub-mystery to be solved. They should appear as though they are on a map (see Figure 11), as per a suggestion made by a participant in the design workshops (see aim 3 in 4.1.6) The toy shop, the sweet shop and the park were all suggested by several children in the design workshops as places that many of them enjoy visiting in real life (**requirement 6**).

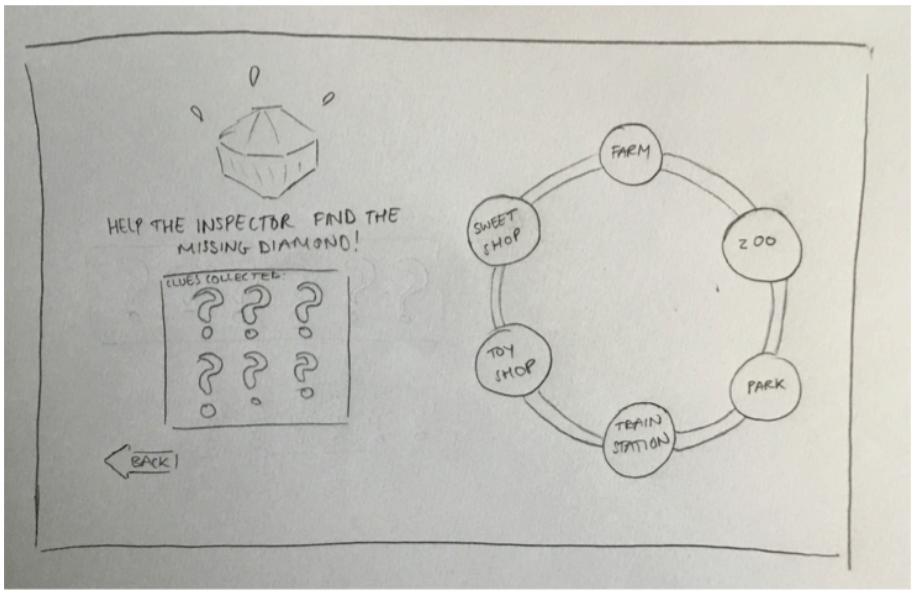

Figure 11. Initial concept sketch of location menu layout

The other three locations are based on the notion of special interests. These are prevalent in individuals with ASC, particularly in Asperger's Syndrome where they occur in over 90% of both adults and children (Attwood, 2003). Winter-Messiers (2007) highlights the importance of incorporating special interests into learning environments, since they encourage a more active level of engagement. Moreover, she identifies a series of recurring interest areas, including animals and transportations, especially trains. Thus, two animal-oriented settings (the zoo and the farm) were implemented, along with one transport-oriented destination (the train station).

Including multiple locations also makes the game more interesting and exciting overall to children, since they might get bored if everything happened in a single, constant setting. They can be accessed in any order, and the overall story remains the same regardless of which places the user chooses to visit first (**requirement 7**). Visiting a location allows the player to collect its corresponding clue, and so long as all areas are explored, the user is able to collect all the clues necessary to solve the mystery. This way, the child is given flexibility and control over the progression of the narrative.

5.3.3 Virtual Agent

Based on findings that children with ASC and SLI produce utterances containing complex structures more frequently in conversations with adults than with peers (Matthews & Haskill, 2008), the Inspector was made an adult character. The choice to implement the character as male was made due to the greater prevalence of ASC in males as opposed to females by a ratio of 3:1 (Loomes et al., 2007). Additionally, most of the characters created by the workshop participants were male.

In the game, the player accompanies the aforementioned Inspector, who serves as a virtual agent to guide them through the story (**requirement 3**). He interacts with other characters and speaks to the player directly. The comprehension-check questions are also asked by the Inspector, who then provides feedback (see 5.3.7) based on the multiple choice responses chosen by the player (see 5.3.6).

There is evidence that the use of a virtual agent is beneficial in autism interventions. Bosseler and Massaro (2003) found that the computerised agent 'Baldi' was not only effective in teaching vocabulary and grammar to children with ASC, but also enabled them to apply the acquired skills to novel situations. Similar instances of generalisation were observable as a result of interactions with virtual peer 'Sam', this time to natural environments involving peers (Tartaro & Cassell, 2008).

5.3.4 Minigames

The introduction of the minigames was prompted by suggestions in the expert interviews (see 4.2.4). Each minigame follows on from the narrative in its accompanying story (**requirement 11**), and is formulated as a reward for completing it (**requirement 9**). The fact that the player must unlock the minigames provides a sense of ownership and accomplishment. Additionally, this ensures that they must first tackle the language comprehension aspect contained in the story, which is the primary focus of the application. The instructions appears on the same screen as each minigame interface, making it clear what its self-contained objectives are (**requirement 17**). Feedback from expert interviews emphasised that minigames are a good way to keep the game entertaining (**requirement 10**), especially if the gameplay is inspired by the children's ideas or existing games which they enjoy playing.

5.3.5 Choosing Complex Sentences

For the purposes of this research, the focal complex sentence structure is the relative adjectival clause. In particular, the non-restrictive version was chosen, exemplified below:

(a) *The witch, who wears a pointy hat, flies on a broom.*

In sentence (a), "who wears a pointy hat" is the relative clause. It is non-restrictive because it provides additional information about the subject ("the witch"). Without it, the main clause ("The witch flies on a broom") still carries the same meaning but with less detail.

Scott (2009) posits that the reason language-impaired individuals are likely to make mistakes in this sort of syntactical structure is that they are unable to recognise the gap occurring between the subject and object. Instead of being able to filter out the post-modifying information (i.e. the embedded relative clause) and being able to correctly assign the subject role to "the witch", they simply take the noun closest to the verb as the subject; in this case, "hat". As a result, in response to the question *Who flies on a broom?*, a language-impaired child's reply could be: *The hat.*

This particular type of sentence structure was chosen because, as can be seen in (a), the clause is embedded between commas. This very obvious punctuation marker is easily identifiable in-text, and explanations can be facilitated by referring to the commas. They make it such that the user can quickly identify the other parts of the sentence, which will enable them to answer the comprehension-testing questions correctly.

5.3.6 Multiple Choice

At each location, there are context-specific characters (as per Chiasson & Gutwin, 2005) that explain to the detective and the player what they have seen, or what they know to be relevant to the location's sub-mystery. There is one target complex sentence contained within each of their discourse segments. Once a character has said their part, the detective addresses the player and asks them a question regarding the character's story. As per the results of the expert interviews (see 4.2.4), the narrative text reappears alongside the possible answers (see Figure 12), as the game is not intended to test the player's memory.

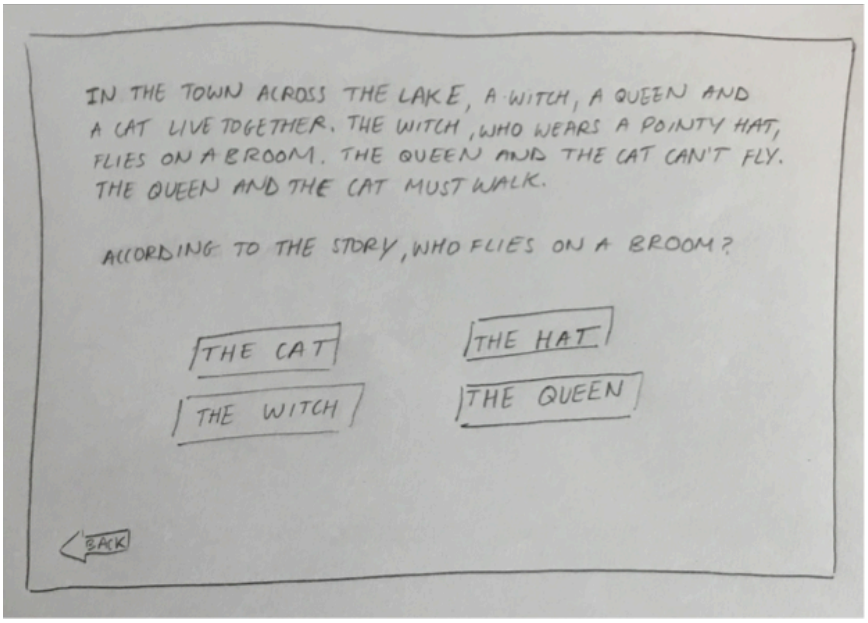

Figure 12. Sketch of layout: multiple choice answers and accompanying narrative text

In response to each question, a choice of four possible answers are presented, all of which appear in the immediately preceding narrative. Two of the incorrect answers are pragmatically or semantically incorrect; that is, they would not make sense in the context of the narrative. The final option is only syntactically incorrect, in the sense that it is of the same grammatical class as the correct answer, and therefore could serve the same role in a sentence as the actual answer. However, its placement in the target sentence makes it such that it is not the correct answer to the presented wh-question.

5.3.6.1 Response feedback

In light of observations made in the expert interviews, the decision was made to exclude negative feedback when the user chooses an incorrect answer (**requirement 12**). Instead, all feedback is made to be positive and encouraging (**requirement 13**). Additionally, errorless learning techniques are emulated – shown to be effective in children with ASC (Goldsmith et al., 2007) – by removing an incorrect answer after its selection. Eventually, only the correct answer remains, thus ensuring the player is able to complete the story. This avoids inducing an unresolvable feeling of frustration in the user.

Based on Hirschman's (2000) metalinguistic approach to language repair (see 2.4), it was decided that each user response would elicit either a syntactic or pragmatic explanation detailing why their choice was correct or incorrect (**requirement 14**).

5.4 Summary

In addition to the reviewed literature and the results of the workshops and interviews, the initial design of the game was informed by child-specific and autism-specific design principles, as well as the principles of human-computer interaction. All of these inputs fed into the set of design requirements that governed the subsequent creation of the game. Based on a single overarching narrative and a series of different locations with context-specific characters, a virtual agent in the form of a detective invites players to help him through the game, using complex sentences to try to unravel the clues, and providing positive feedback in response to players' responses.

6 Implementation

The high-fidelity prototype was developed as a touchscreen tablet application (**requirement 1**), an interface which allows the user to physically manipulate the virtual environment; more specifically, it was designed for an iPad running iOS 11, hardware that was readily available to the researcher.

6.1 Revised Icons and Location Backgrounds

Figure 13. Revised icon designs

Based on the comments by E2 in the preceding stage, alterations were made to render the aesthetic more age-appropriate, while still keeping a simple look (**requirement 16**). In keeping with recommendations by Hayes et al. (2010) the icons were redesigned with a more minimalistic and elegant style (see Figure 13). The cartoon illustrations became real photographs (see Figure 14) which were selected so that the screen would still remain colourful (**requirement 15**) and visually representative of the corresponding location (**requirement 8**). The style change was also supported by the literature; recognition is aided by images that resemble real life, which then promotes efficient and effective learning outcomes (Hussain et al., 2016).

Figure 14. Revised backgrounds (left-right: farm, zoo, park, train station, toy shop, sweet shop)

Notice that the 'play minigame' buttons are all inactive – this is because at commencement the stories have not been completed by the user, so the minigames can not yet be played. Once these unlock, they change to mimic the 'play story' button. Additionally, to keep things extremely simple, the only buttons on the screen are those which are necessary for navigation through the game's interface.

6.2 Main Menu and Locations Menu

Figure 15. Main Menu

Figure 16. Location Menu

The main menu (see Figure 15) is the first thing the user sees when they open the application. It includes the title and three buttons:

- The *Play* button initiates the game and leads to the location menu (see Figure 16).
- The *About the Game* button leads to a tutorial page (see Figure 17) explaining the syntax of the game's focal complex sentence structure. It is explained using relatively simple sentences (**requirement 4**) to ensure the target audience's (**requirement 2**) understanding.
- The *Quit* button shuts down the application.

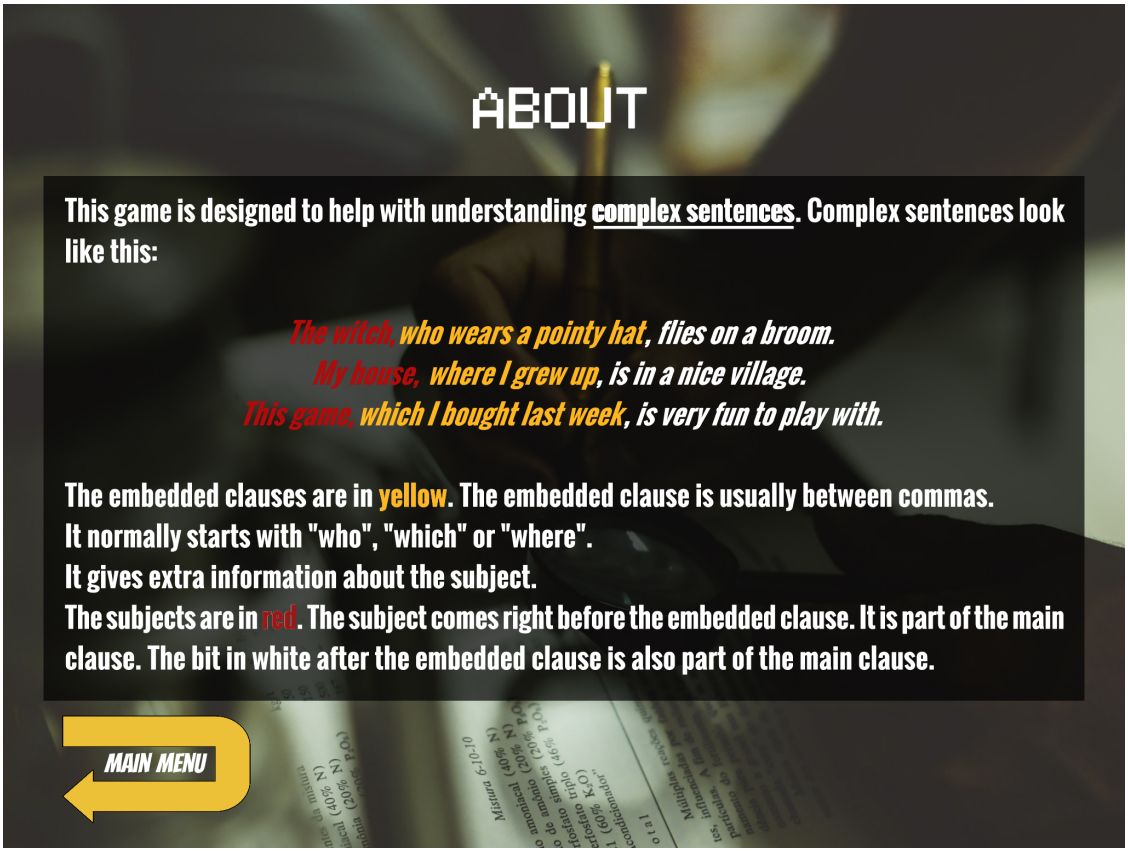

Figure 17. About the Game tutorial screen

Once the player reaches the location menu, there are seven interactable buttons. The arrow labelled *Main Menu* returns to the main menu page. The other buttons lead to each of the six visitable destinations. Since no clues have been found at this stage, the bag panel remains empty, with placeholder question marks in lieu of the collectable items (see Figure 18).

Figure 18. Empty bag panel showing placeholder images

Figure 19. Full bag panel showing all collectable clues

As the player collects items from each of their destinations, the bag panel fills up and the question marks are replaced with images representing the clues that have been found. Once all the clues have been collected, the bag panel resembles Figure 19.

6.3 Stories

Before beginning the story, the other character (in the case of the farm, the farmer) asks for help, the player is then able to choose whether or not proceed with the story (see Figure 20). If they decide not to help, the character insists with *"Please? I could really use your help"* and the player is given the choice once again. If they accept, the game continues to the story (see Figure 21). This feature is implemented to offer the player a sense of ownership and control, a recurring theme in the design principles (see 5.1).

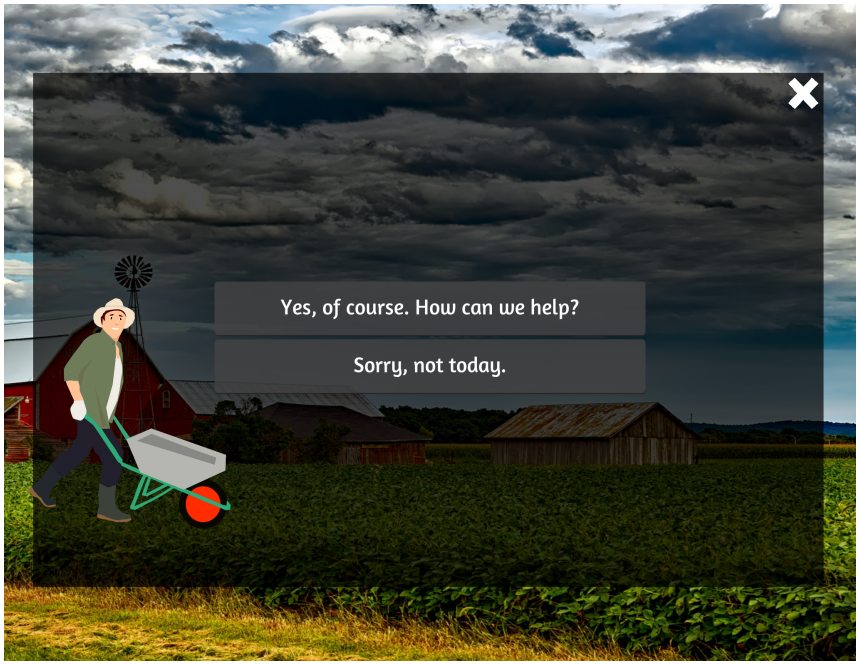

Figure 20. Options: to help or not to help.

Farmer: My favourite sheep has gone missing!
Inspector: Oh no! Tell me about the last time you saw your sheep.
Farmer: My wife and I went to the market yesterday. We bought fruit from the shopkeeper. My neighbour, who went to school with my wife, arrived and told us that the gate to the sheep's paddock was wide open! My sheep was gone when we got back!
Inspector: Don't worry, my sidekick and I will find the sheep thief.

Figure 21. Introductory narrative (pre wh-question)

The story appear on-screen as if it was being typed out, with an accompanying sound effect as the words appear. The user is in control of when the next segment of text appears, as it will not do so until they tap the screen. This is to accommodate for individual differences in reading speed across users, allowing the player to read and process the narrative text at their own pace.

As can be seen in Figure 22, the narrative containing the target sentence appears above the multiple choice answers and the corresponding wh-question. At this point, the character who told the story has already faded out of the screen, and the only visible character is the Inspector, as he is the one addressing the player.

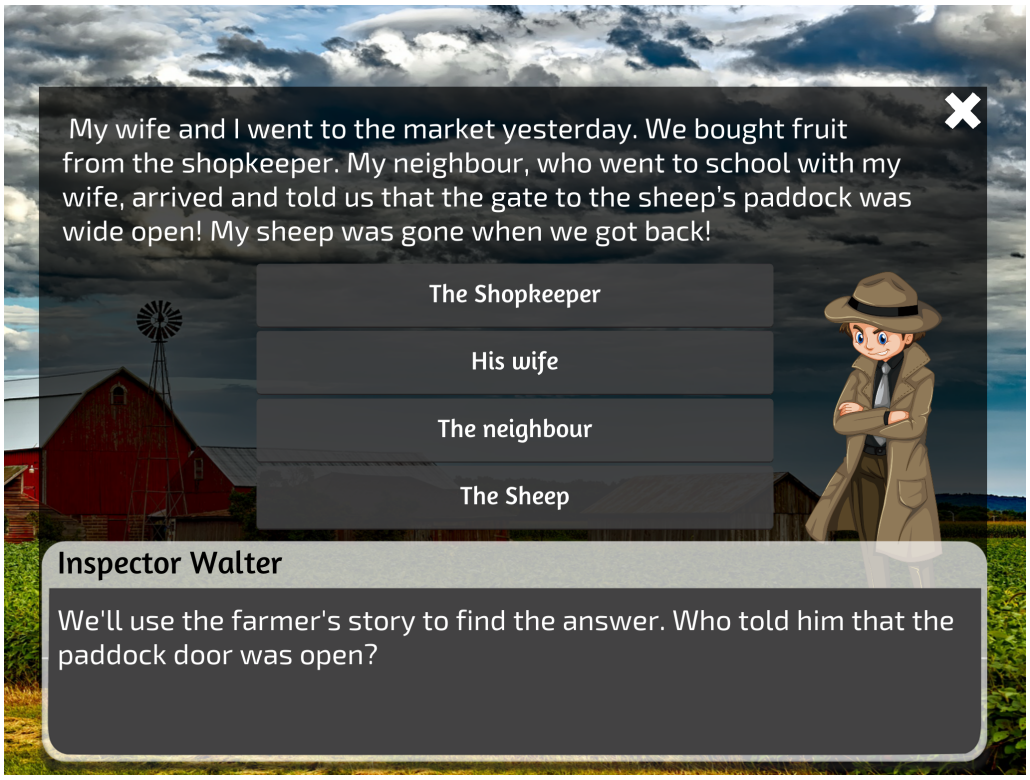

Figure 22. Farm multiple choice wh-question with accompanying narrative text.

For each question, the possible multiple choice answers appear in a different order, such that the correct answer is not always in the same position in the list. As explained in 5.3.6.1, each time the player selects an incorrect answer, this option disappears from the multiple choice list (see Figure 26), until only the correct answer remains. When incorrect options disappear, the remaining options also move. This is is to ensure the player is not getting the answer right by simply selecting the same button repeatedly.

In this example, the target answer is *the neighbour*. This option prompts the feedback From the Inspector which can be seen in Figure 23, containing praise, a syntactic explanation and reiteration of the target sentence.

```
Yes! Well done! The "neighbour" is the subject in the main clause.
He told the farmer about the sheep's paddock. We must speak with
him.

This is the sentence with the embedded clause:
My neighbour, who went to school with my wife, arrived and told us
that the gate to the sheep's paddock was wide open!
```

Figure 23. Correct response feedback.

The syntactically incorrect choice is *the wife*; this is the noun phrase that appears immediately before the part of the main clause that matches the wh-question. As a result, a language-impaired child is likely to interpret this noun phrase as the subject, and the sentence as saying: *"My wife arrived and told us that the gate to the sheep's paddock was wide open!"* Figure 24 shows the feedback prompted by this choice.

```
The farmer's wife is mentioned. But "who went to school with my
wife" is the embedded clause. It gives extra information about the
subject. The subject usually comes before the commas in complex
sentences. Which character is the subject?
```

Figure 24. Incorrect response: syntactic feedback.

The remaining two answers are pragmatically incorrect. While they do appear in the relevant text, and they are of the same grammatical class as the correct answer (i.e. nouns), they could not be the correct answer based on contextual factors. Selecting "the shopkeeper" or "the sheep" elicits the responses in Figure 25.

```
The shopkeeper - The shopkeeper was at the market. He doesn't know
about the missing sheep. Who else could have told him?

The sheep - The sheep is still missing. It can't tell the farmer
anything. Who else could have told him?
```

Figure 25. Incorrect response: pragmatic feedback.

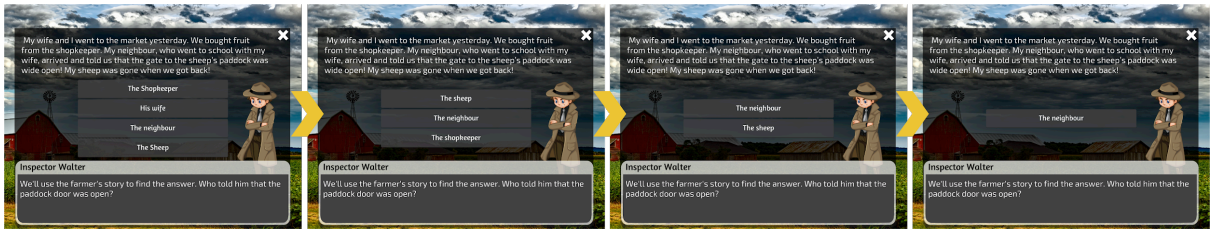

Figure 26. Deletion of incorrect answers.

Once the wh-questions have been answered correctly (there are currently two in each implemented level), the background changes as the characters move to a new location. At this point, the user searches for clues appearing on-screen. In this prototype, the objects are all highly noticeable as their clip-art style contrasts greatly with the backdrops. Tapping the clue collects it and adds it to the bag panel (see Figure 27), visible in the location menu.

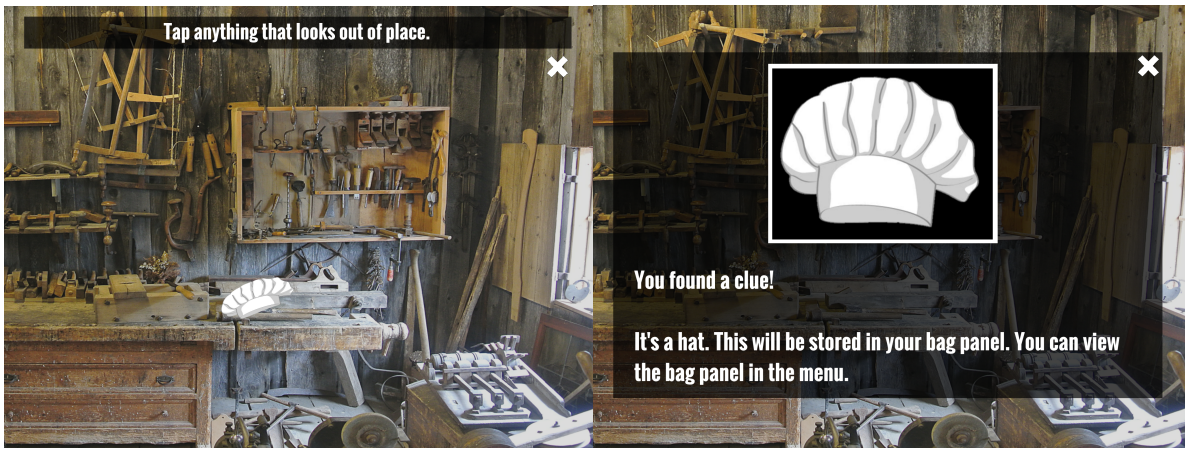

Figure 27. Collecting a clue.

6.4 Implemented Minigames

The minigames were created based on a combination of:

- Ideas put forward by the children in the design workshops.
- Existing games designed for touchscreen devices.
- Suggestions made by the participants in the expert interviews.

6.4.1 Shear the Sheep

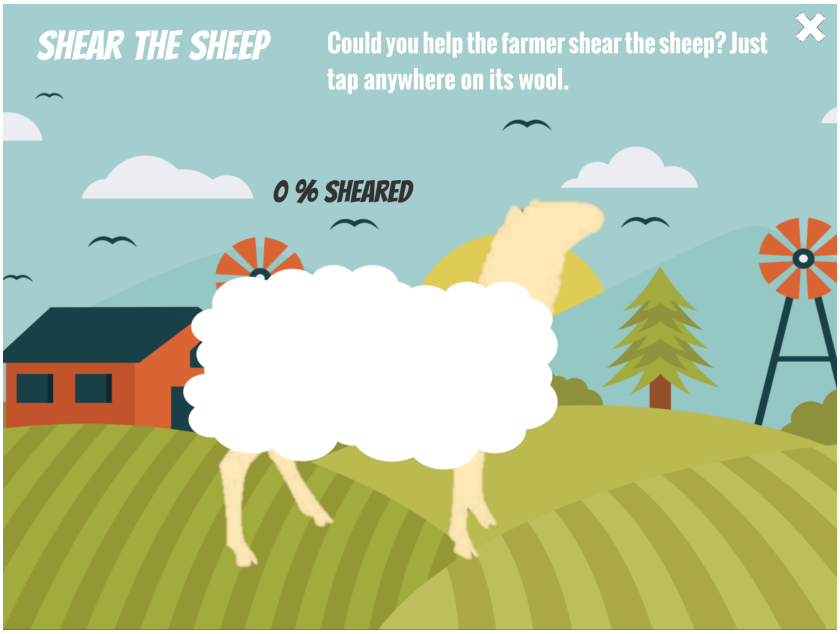

Figure 28. Shear the sheep minigame

Shear the sheep was developed based on the first part of an idea presented in workshop 4. In this minigame, the player must tap the screen in order to remove the wool from the sheep. It allows for multiple fingers to tap at once, meaning one player can use several fingers, or multiple players can tap at once to speed up the process. The continuous tapping interaction is often found in touchscreen games for children, for example in apps that require the user to take care of a virtual pet; note the finger/hand icons that appear on-screen (see Figures 29, 30 and 31). As the player continues tapping, the wool gradually disappears from the sheep's body in four incremental stages corresponding to it being 25%, 50%, 75% and 100% sheared (see Figure 32).

Figure 29. Tap to get rid of the fleas in "My Virtual Dog

Figure 30. Petting action in 'My Boo'

Figure 31. Toilet scene in 'My Tamagotchi Forever'

Figure 32. The sheep at varying stages of shearedness.

6.4.2 Catch the Monkey

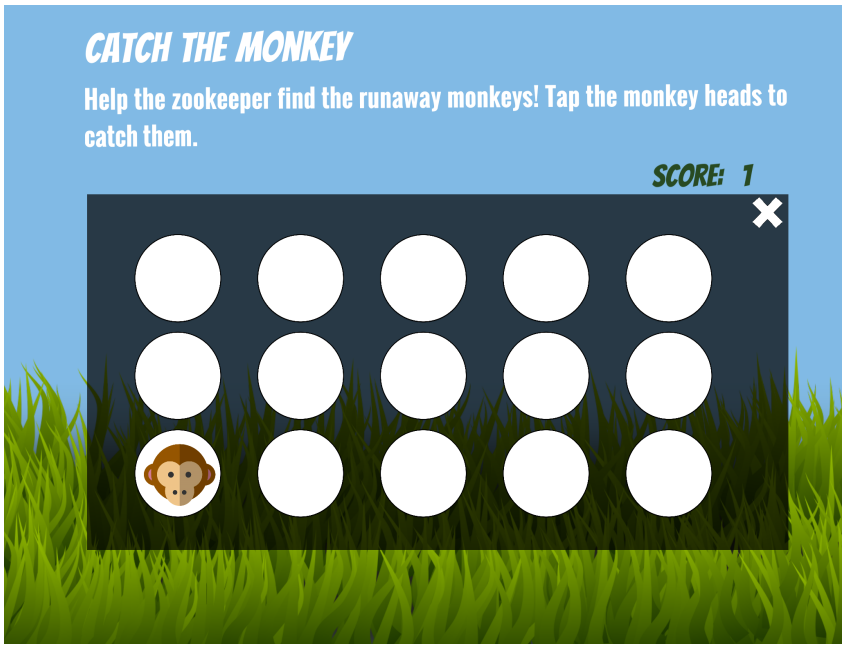

Figure 33. Catch the monkey minigame

Catch the monkey is based on the popular whack-a-mole style of game. It requires the player to tap on the monkey faces as they appear in the circles. In its current implementation, there are no time restrictions imposed on the minigame. Instead, the player is simply required to tap 15 monkeys in order to win. There is significant scope for expanding the gameplay, such as having the player tap as many monkeys as possible within a specific timeframe. Alternatively, other animals could appear in some circles, and the player would need to inhibit their actions by avoiding tapping a non-monkey. Another option is to have monkeys of different colours pop up, and ask that the player only select those of a certain colour.

6.4.3 Park Cleanup: Sort the Recycling

Figure 34. Park cleanup: sort the recycling minigame

The Park Cleanup minigame is a drag-and-drop game. Players are required to drag items into their corresponding bins. There are many existing games in the app store with this kind of draggable sorting interface (see Figures 35 and 36).

Figure 35. Tiny hands sorting game

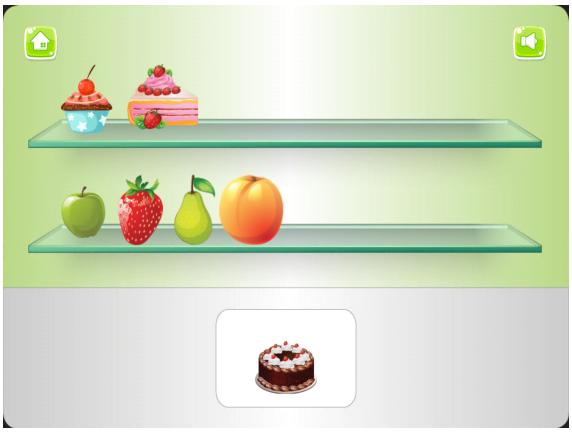

Figure 36. Sorting game

6.4.4 Train Block

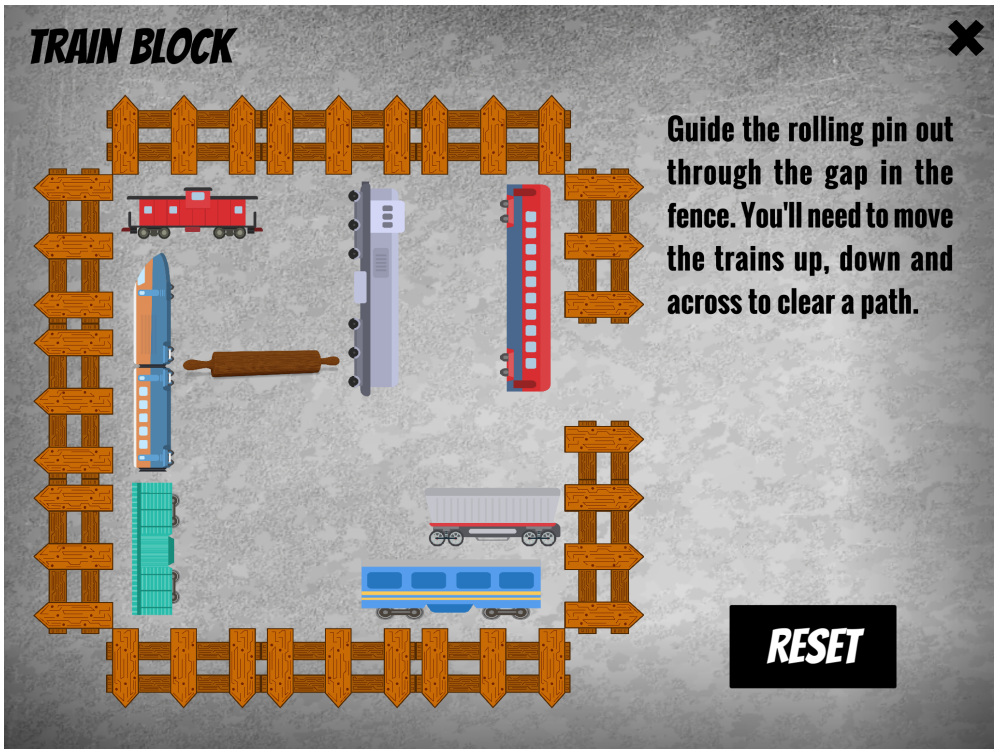

Figure 37. Train block minigame

Train Block is a puzzle game inspired by the board game *Rush Hour* (see Figure 38) and existing touchscreen games such as *Unblock Car* (see Figure 39) which have the same sorts of problem-solving puzzles but use cars and trucks instead of trains.

Figure 38. Rush Hour board game

Figure 39. Unblock Car app

6.4.5 Charge the Bot

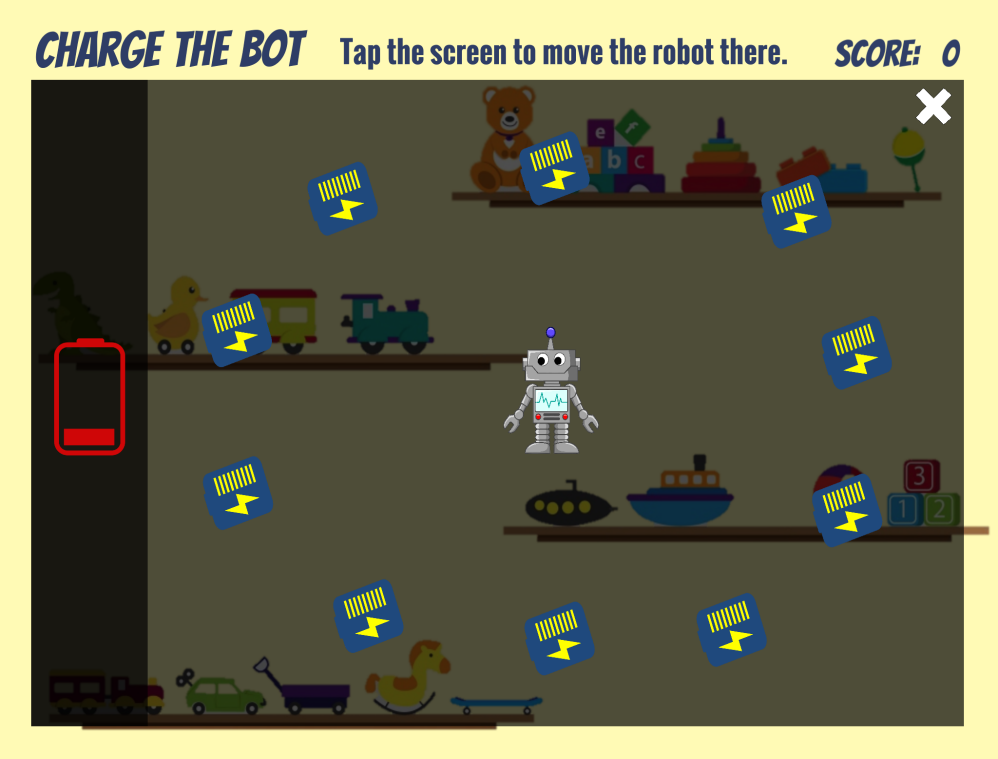

Figure 40. Charge the bot minigame

The robot character was taken from one of the workshops with neurotypical proxies, and Charge the Bot was implemented as a basic minigame requiring the user to move around the screen and collect all the visible batteries. To move somewhere they need only tap that spot on the screen. For every two batteries that are collected, the battery image on the left fills up and changes colour (see Figure 41), tracking the player's progress.

Figure 41. Increasing levels of battery charge

6.4.6 Knock Down the Jars

Figure 42. Knock down the jars minigame

Knock Down the Jars is a very simplified version of an *Angry Birds* style game (see Figure 43). Due to technical limitations, it is the only minigame with significant glitches. The goal is to swipe the ball on the left across the screen so that it knocks the jars off the table. However, the current implementation only successfully spawns two balls to throw and does not always correctly register the actual number of jars that have been knocked over.

Figure 43. Angry birds gameplay

6.5 Unity 5

The prototype of the game was developed using Unity 5, which includes an array of pre-existing functions, thus facilitating the creation of the game. Additionally, its integrated porting functionality makes it such that, once finished, the game could be used across multiple platforms. This is potentially useful for future expansion. Additionally, it is freely available on Mac and Windows

operating systems. This allowed for more flexibility during the development phases as the software could be run on a wider range of machines. Within Unity, any code was written in C# since this is the default scripting language supported by the game engine. The researcher already had experience with similar object-oriented programming languages, which reduced the amount of time required to learn the language.

Fungus – an open source visual storytelling tool developed specifically for Unity, created and maintained by Snozbot – was used for the narrative portion of the game. It provides purpose-built animations and functions, framed as intuitive visual scripting, which simplified the process of constructing the storyline containing the target complex sentences. Moreover, an incredibly thorough documentation website and tutorial videos are available online.

Graphics used in the game were collected from a variety of websites provide content with creative commons licenses, including flaticon.com, freepik.com, pexels.com, pixabay.com, and vecteezy.com.

6.6 Summary

The prototype was developed using Unity 5, supported by Fungus and using the C# programming language. During the implementation phase, the icons were improved to make them more age-appropriate and colourful photos of real locations substituted the original cartoon illustrations. The main menu was designed to take users to a tutorial screen – using colour to make the instructions more understandable – or directly to the location menu, which provides an overview of the available destinations and highlights the clues found in order to support the navigation process. The storyline was designed to maintain the engagement of the player by using devices such as visuals, sound effects, positive feedback and learning reinforcement, as well as the minigames, which successively unlock to provide additional points of interest.

7 Evaluation

In this chapter, the goals and procedures followed for the evaluation workshops with neurotypical proxies, as well as for the interviews with academic experts, are described. The findings from these workshops and interviews are subsequently reported and discussed.

7.1 Evaluation Workshops with Typically Developing Children

As with the design workshops, evaluation workshops were held with neurotypical children, once again acting as proxies for children with ASC, as per the methodology outlined in Chapter 3 (see 3.2). In these workshops, the children were asked to test the high-fidelity prototype. By observing their gameplay, the researcher would be able to deduce the children's primary intuitions with regards to the interface.

7.1.1 Aims

The aims of the testing sessions were to evaluate the design and content of the game prototype from the perspective of target-aged children; more specifically to:

(1) Determine whether the language content is appropriate for the target group.
- Is the overall narrative easy to follow?
- Are the non-target sentences simple enough?
- Are the methods of explaining complex syntax effective?

(2) Determine which mini-games are most effective at keeping the user entertained.
- Which ones did they like most, and why?
- Which ones did they like least, and why?

(3) Determine whether the navigation structure is intuitive to the target age group.

(4) Identify any significant bugs or issues.

(5) Obtain further suggestions for improvement.

7.1.2 Materials

The materials used in the workshops were: paper and pens for taking notes, an Apple iPhone used for audio recording, and an Apple iPad running the game prototype.

7.1.3 Participants

The participants that took part in the evaluation workshops were fifteen typically developing children (4 boys and 11 girls) between the ages of 6 and 12 (see Table 5). The children in workshops 5, 6 and 7 were part of the same local Brownies group as in the design workshops. The children in workshops 8, 9 and 10 were recruited through the university. Once again, many of the participants had participated in similar workshops previously.

	Participant	Age	Gender
Workshop 5	P9*	9	Female
	P10*	9	Female
	P11*	9	Female
Workshop 6	P12	8	Female
	P13	9	Female
	P14	8	Female
Workshop 7	P15	9	Female
	P16	9	Female
	P17	9	Female
Workshop 8	P18	10	Male
	P19	8	Male
Workshop 9	P20	6	Female
	P21	8	Female
Workshop 10	P3*	12	Male
	P4*	12	Male

Table 5. Testing workshop participant information

**These participants also took part in the design workshops that were held previously (see 4.1.3).*

7.1.4 Setting

Workshops 5, 6 and 7 were held in the Brownies' usual meeting place, while workshops 8, 9 and 10 took place in the University of Edinburgh Informatics Forum.

7.1.5 Procedure

For those who had already participated in the design workshops, information sheets and consent forms were not required to be given out again. For those that had not done so, the same procedure as the design workshops was followed. Information sheets were given to parents/guardians (see Appendix A), while simplified versions of these sheets were provided for the children themselves (see Appendix B). The parents/guardians and children alike were given consent forms to sign (see Appendices C and D), in which they were asked to give permission for audio recording. The children were asked to confirm whether they still wanted to take part, and reminded that they would be audio recorded. If a child changed their mind and decided they no longer wished to take part, they were able to sit out the workshop along with the other children who were not participating.

The groups of children were handed the tablet running the game. Once they reached the location menu (see Figure 16), they were told that only *The Farm* and *The Zoo* had full working stories, so they should start at either of those two locations. After this, they were given free reign over navigation through the game's interface. If any participant was seen to be struggling, guidance was

offered by the researcher. The groups were reminded to take turns and to allow all group members to be involved in the exploration of the game.

If the children had not navigated to the *About the Gam*e (see Figure 17) page from the *Main Menu* (see Figure 15) by the time they reached the end of the game, this was shown to them. If they were having a particularly hard time understanding the concept of complex sentences even with the provided explanations (as was the case with the youngest participants) the page was also shown to them.

After they had completed the workshops, all participants were thanked and presented with a participation certificate (see Appendix F).

7.1.6 Results

Language Content
Since P20 was only 6 years old, it was decided that the language content would not be evaluated during workshop 9. In the other five workshops, the majority of the participants had at least some previous exposure to the target sentence constructions, usually from grammar lessons at school. Generally, those aged 9 or over had minimal issues with answering the wh-questions, even before the explanations provided by the game. 8-year-old participants seemed to struggle more at first due to limited experience with the notions of sentences and clauses. However, since they were able to understand the syntactic explanations, they got progressively better as they continued to interact with the app. This is in keeping with the expected developmental trajectory of complex syntax in neurotypicals, whereby accuracy increases significantly after age 9 (see 2.3.1).

P3 and P4 noted that referring to the commas was useful in the explanation, as it gave them a good focal point to use when looking for the answers. They both felt that the text progressed at a reasonable speed, and P3 especially liked that the typing animation and accompanying sound would slow down around punctuation, as this gave a good sense of where to break up the sentence into clauses. P4 liked that he was able to read back over the text before continuing to the next bit of text, and that the target narrative could be seen alongside the questions. P19, however, would have preferred for the text to appear more slowly. This is likely due to his younger age; he is at the lower end of the target age group.

Minigames
For the most part, the minigames were well-received by all participants, with only minor suggestions for improvement. The glitches notwithstanding, the most popular minigame was *Knock Down the Jars* (see Table 6). This is because despite being difficult to win, it was eventually possible if the participants persevered. It is likely that a child with ASC might become frustrated quite quickly, so while the games should definitely be challenging, they should not be overly difficult or near impossible to solve. The current version of this minigame is somewhat unpredictable, and the fact that knocking down all the jars does not alway prompt the victory screen would be an issue with the target audience, as no real explanation could be given as to why.

Minigame	Frequency
Shear the sheep	3
Catch the monkeys	2
Park Cleanup	2
Train Block	3
Charge the bot	1
Knock down the jars	4

Table 6. Testing workshops: favourite minigames

One of the suggestions to make Charge the Bot more challenging was to add obstacles in the robot's path which the player would need to maneuver around (workshops 7, 8, 9 and 10). P20 added to this by saying that the robot could lose charge when colliding with an object, and would need to collect more batteries to make up for this. Alternatively, P18 and P19 thought the minigame could count how many movements it took for the player to collect all the batteries; the aim would be to try to collect them in as few taps as possible.

Shear the Sheep also received praise from most participants. P18 particularly liked that the interface responded to multiple taps at once, since this allowed him to control how quickly he was able to complete the shearing. This is in accordance with the child-specific design principle that states how actions should map directly onto the screen (Chiasson & Gutwin, 2005). While all participants eventually tapped the wool away, it seems this is not the most intuitive approach, as over half of them first attempted to perform a rubbing action. This is reminiscent of the Nintendogs games, designed for touchscreen game consoles (see Figure 44).

Figure 44. Nintendogs: cleaning a puppy

Navigation

Overall, the navigational structure appeared quite intuitive for the target age group. They were all able to navigate the application confidently without requiring input from the researcher. A recurring issue was that the participants seemed prone to forgetting which locations they had already visited. This occurred in five of the six workshops. In four of the workshops, participants exhibited obvious joy at the presentation the victory screens (see Figure 45) presented upon successful completion of a minigame.

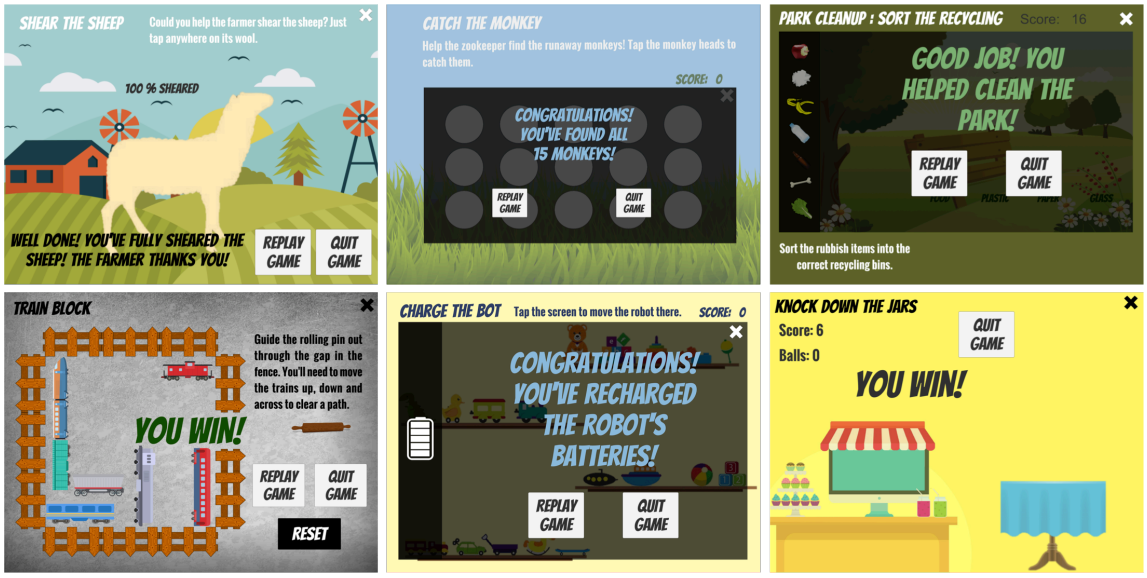

Figure 45. Minigame victory screens

Significant Issues

In the Park Cleanup game, there was some confusion regarding how to sort the bone object. It is not strictly edible, but it was intended to be sorted into the 'food' bin. While the participants were happy enough to accept that it could be classified as food, an autistic child might be more rigid in their opinion. Similarly, some of the children remarked that, in the toy shop scene, it was not very clear what the crumbs were supposed to be. It would be important to ensure all clues resembled the real life object which they are intended to represent (Hussain et al., 2016). They might focus on the inconsistencies with their own mental model of the world and refuse to continue as a result. For reasons such as this, the prototype should be tested by individuals with ASC.

Further Suggestions

Most suggestions concerned the final scene in the game, where the player is told that the baker was the thief. P3 and P4 thought it was important that the baker himself show up on-screen, which is in accordance with ASC-specific principles of images matching the real world. P15 and P17 proposed leaving it up to the player to figure out who stole the diamonds, to which P16 added that they could guess from a line-up of potential thieves. Other suggestions revolved around the addition of a short animation; either showing the baker being chased, caught and arrested (workshop 5). The notion of animation came up again in workshop 9, where it was suggested that a short introductory clip could be added to the very beginning of the game in order to set the scene.

The end-scene amendment made in workshop 9 was even more dynamic; they would have liked for a new minigame to become available. P20's idea was a cooking game, where the player's character would need to move around to collect the ingredients necessary for a given recipe. P21 proposed a game where the user had to run a bakery and ensure that customers received their corresponding orders. Similarly, P18 said he would have liked there to be some notion of currency in the game. It could be gained by completing the stories with as few incorrect responses as possible, or by setting records in the minigames, and could then be used to bribe witnesses or make purchases in the final bakery scene.

P19 suggested that the baker could escape, which P18 remarked was a good way to pave the way for further levels to be implemented, with different syntactic structures. P3 and P10 both had similar ideas, but instead of implementing multiple levels, they thought the cliffhanger was a good way to lead to a sequel game targeting a different complex sentence structure. The idea of levels within other aspects of the game was also put forward; P4 suggested making finding the clues progressively

harder as the game goes on, while P3, P12, P16 and P18 would have liked to see the mingames implemented at varying levels of difficulty.

P4 pointed out that he very much liked the incorporation of the sidekick; this was something he had put forward in the design workshops. But he suggested that instead of making the player the sidekick, the sidekick could be the one to help the player, who is the detective. He proposed the creation of a customisable avatar, which is also one of Bartoli et al.'s (2014) recommendations.

7.2 Expert Evaluations

7.2.1 Aims

As in the pre-design stage (see 4.2.1), the purpose of carrying out the evaluations with experts was to widen the scope of possible feedback beyond the limitations of the group of TD proxies. Experts in related fields would be able to provide feedback based on relevant design principles in their specialist fields. The aims of the expert evaluations sessions were as follows:

(1) To evaluate the application as a learning tool.

(2) To evaluate the application as a game aimed at children.

(3) To evaluate the design aspects of the application.

(4) To assess the navigation structure.

(5) To identify any significant bugs or issues.

7.2.2 Materials

The materials used in the evaluation sessions were: papers and and a pen for taking notes, an Apple iPhone used for audio recording, and an Apple iPad running the game prototype.

7.2.3 Participants

The participants were one research postgraduate student (E1), one former lecturer (E3), one lecturer (E4), and one former student (E5) at the University of Edinburgh. Their areas of expertise were as follows:

Participant	Background
E1*	Research postgraduate student in Human-Computer Interaction and a member of the *Institute for Language, Cognition and Computation*
E3*	Former senior lecturer in Digital Education, with a background in biology and developmental psychology, and a particular interest in game-informed approaches to teaching and learning
E4	Lecturer in Adaptive Learning Environments, with a special interest in supporting learning and communication in children with ASC

	through game-like environments. Member of the *Institute for Language, Cognition and Computation*.
E5	Former Informatics student with a specialisation in designing educational technologies for children with ASC. Has experience with Dyslexic and Autistic individuals of varying ages.

Table 7. Expert evaluation participant information

**These participants also took part in pre-design interviews that were held previously (see 4.2.2).*

7.2.4 Setting and Procedure

The evaluation sessions took place in various University of Edinburgh buildings within the central campus. They were conducted in two stages. The experts were asked to follow a think-aloud inspired protocol as they interacted with the high-fidelity prototype, followed by a semi-structured interview based on their comments about the game. Before concluding the interviews, the participants were asked if they had any further suggestions for improvement. Finally, they were thanked by the researcher.

Having previously taken part in the pre-design phase (see 4.2.2), both E1 and E3 were already familiar with the concept of the application, and needed only a brief reminder of its main goals, together with a quick briefing about the purposes of the evaluation session. E4 and E5 had not been involved in the pre-design phase. For this reason, the purpose and original concept of the application were explained in significantly more detail.

7.2.5 Results

The application as a learning tool

E4 commented that the game had a good degree of focus on complex sentences, which are the main goal of the application. She also noted that providing reinforcement of the language aspects within the context of the story would be beneficial for children with ASC.

One of E1's concerns was regarding the syntactic explanations given in the stories. He proposed that a visual representation of the syntax might be more effective. At the most basic level, accentuating the key components was suggested by either emboldening or highlighting the target sentence. Alternatively, colour coding or some form of graphical representation could be created. In fact, several of these could be incorporated, with some being more informative than others. This idea revolved around the notion of making the explanations increasingly helpful with each attempt; later hints would be more revealing than if the user were to select the correct answer sooner. This type of incremental feedback was pointed out to be more adaptable to the specific needs of the player, since those who struggle more would receive more thorough explanations. E5 concurred with the idea proposed by E1, that a visual approach to the syntactic explanations might be more suited to children with ASC.

The tutorial material provided on the *About the Game* section was noted as being very well explained by E3. He particularly liked the colour-coded sections, and commented how visual explanations tended to be an effective method for teaching children. E5 also highlighted the colour-codedness shown on the About the Game screen as a positive feature and suggested presenting

each explanation in that way, as this would make it very clear where the relevant parts were and which commas the explanations were referring to. Alternatively, she suggested that the About the Game page appear after the user incorrectly answers a questions twice. She noted that autistic individuals tend to be visual thinkers, with reference to the Picture Exchange Communication System (PECS), often used in autism interventions. She proposed the use of pictures to show the relationships between clauses.

The application as a game

The detective storyline was described by E5 as fun and engaging. She appreciated that the game was not framed in a condescending way, noting that the feedback is informative and encouraging. E4 also found the overall game experience to be positive.

In terms of the unimplemented stories, E4 felt that incorporating the final stage where the clue is found was a good decision at this stage, since it still allows for progression of the overall narrative. Unlike the other experts, E5 felt that the whole process of the game made it feel like reaching the end was an achievement. However, she did add that a 'finish' button should be added to the end of the game, perhaps with an accompanying recap of what the player has achieved throughout the game for an added sense of satisfaction and accomplishment.

E1 questioned the completion scene at the very end of the game. He felt that a more dynamic and engaging end was required. Tying in with the detective element, he put forward the idea of providing the player with several potential culprits and having them decide who was guilty based on the collected evidence. Suspects could give their defense statement, and the user would be able to identify the actual thief by their incorrect usage of the target sentence structure. This way, the player is additionally tested on their ability to recognise the complex syntax they have learnt about.

The final scene was also brought up by E4, who felt that the ending offered insufficient resolution. The suggestion offered by this expert was to add an animated scene showing the detective chasing and finally catching the baker as he tries to run away with the stolen diamonds.

The incorporation of minigames

E1 was the one to put forward the use of minigames as rewards in the pre-design phase (see 4.2.2) and was, therefore, glad to see them included in the prototype. He thought that the minigames themselves were "short and sweet", and tied in well with the story. E4 confirmed that the minigames were an effective way of making the game fun. E5 liked that they were related to the narrative, since this made it easy to transition between stories and minigames. She recognised and commented on the potential for expanding each of the minigames. They served as a good base level, but their design made it such that they could be made more challenging; the notion of levels could even be introduced for the minigames instead of just the sentence complexity (see 4.2.4).

With respect to the minigame instructions, E3 approved of their placement directly on each scene, since presenting them beforehand on a separate screen might be problematic. An impatient child is likely to skip it, and those that did not might not even retain the information until the subsequent minigame scene. E4 commented that even if the children did not immediately read the minigame instructions, there is nothing wrong with allowing them to experiment with the interface at their own pace.

Design

E3 commented that the game was very aesthetically pleasing and was particularly fond of the bright and colourful nature of the background images for each of the locations. In line with this, he thought

that some of the darker scenes (e.g. the *About the Game* page) might benefit from the use of lighter colours.

E1's overall impression of the interface was a positive one. From an HCI perspective, the consistency of the style throughout was praised, and he commented that the screens were appropriately minimalist, and not overly crowded with unnecessary content.

The sound which accompanies the text in the narrative sections was well-received by E4, and she suggested that more sound effects could be included in the game. E5 also proposed the inclusion of sound effects in the minigames. For example, as part of the Park Cleanup game, the corresponding sounds could accompany items being sorted into the correct recycling bins.

An additional suggestion made by E4 was to add a voiceover to the text, either with a voice synthesiser or through actual recordings. E5 was also of the opinion that it might be helpful to have some voiceover reading out the narrative text. She even suggested that a recorded voice might be particularly useful, since intonation and other prosodic elements might provide an additional layer of support.

Navigation

E3 felt that the navigation was mostly intuitive, and liked that it was not overly complex. He also noted that the *About the Game* section with details about the syntax of embedded clauses was easily accessible and, thus, a button was not required to get to it from other areas of the game.

E5 especially liked that the user has the option of leaving minigames (and the stories, for that matter) at any point if the decided they would rather explore a different location. However, E3 did note that when exiting the stories, the user might prefer to be redirected to the main menu as opposed to the specific location's menu. Nonetheless, it was eventually concluded that doing so might cause the user to skip the minigames entirely – as they are not necessary to complete the game – which would detract from the overall game experience.

The system's visibility of status was called into question, since the game did not make it clear which locations had already been visited. E1's recommendation was to add a star shape to the completed levels, as this is often used as a reward in children's games and offers an additional feeling of accomplishment. E4 also commented on the lack of feedback provided by the game about which locations had been visited. Her recommendation was to change the colour of the icons based on whether the stories and minigames had been completed, perhaps in accordance with a traffic light system (red if neither have been completed, yellow if the story has been completed, and green if both have been completed).

Significant issues

E3 commented that it would be important to go through all the written text and ensure that all non-target syntax was simple enough to be understood by a language-impaired individual. Otherwise comprehension issues might arise before the user even reached the target complex sentences, which would defeat the purpose of the application.

E4 highlighted that the dragging in the Park Cleanup game (see 6.1.1.3) was sometimes troublesome, and posited that sorting by clicking might be a good alternative. Another problem was identified within the same game, namely that there appeared to be too many objects to sort, which rendered the scene too visually stimulating for children with ASC. E4's recommendation was to reduce the number of recycling that appear on-screen at a time.

E4 also picked up on the fact that in some parts of the narrative, things were said that did not match what appeared on screen. For instance, when the narrative says that the sheep is in the big shed, the sheep should actually be visible (see Figure 46). For children with ASC, it is essential that these align, or they might focus on the inconsistency and halt the progression of the story. E5 noticed the same issue in some of the narrative text; that the images did not always align with what was said. She agreed that ensuring all things explicitly stated in the text should be visually represented on-screen.

Figure 46. Mismatch between narrative and visible scene

7.3 Summary

The prototype was tested in workshops with neurotypical children, some of whom had formed part of the groups involved in the design workshops. They were intended to determine the appropriateness of the language content, to confirm the entertainment value of the minigames, to test the intuitiveness of the navigation structure as well as to identify any other significant issues. Generally the feedback was positive, and some improvements were suggested, particularly to the final scene in the game, to make it more dynamic and exciting and to reinforce a sense of completion. Some small bugs were also fixed. Experts felt that the application overall was an effective learning tool, were generally happy about the overall design and navigation structure, found the game itself to be fun and engaging, and thought the mini-games constituted a fun reward. They picked up on specific issues, such as ensuring that all non-target syntax was easy to understand, correcting some minor inconsistencies between screens and narrative, and making small improvements to the minigames.

8 Discussion and Conclusion

The original research questions laid out at the beginning of the dissertation are addressed based on the body of work that was undertaken. The three core questions, which were used to guide the overall study, were formulated as follows:

(a) **Is a tablet game appropriate for the target audience?**

(b) **How can an educational tool be enhanced so that it is engaging and fun?**

(c) **Is the detective narrative an effective way to frame a language game?**

Research question (a) was explored through an examination of the existing literature. Findings highlighting the very similar language profiles of children with ASC and those with SLI suggested significant scope for the intended application. The promising nature of unifying gameplay and education were also explored within the context of game-based learning. In line with this, an array of studies were found supporting the use of computerised interventions for children with ASC, as these make the most of the particularly strong affinity they have for technology. Moreover, tablet-based learning was reported to be especially widespread and beneficial for both neurotypicals and autistic individuals. While previous attempts at creating technology-based interventions specifically for language-impaired children proved ineffective, it is the incorporation of the more promising metalinguistic approach to language repair that sets apart the application developed for this research.

Based on expert feedback in the pre-design phase, it was decided that minigames would be incorporated into the application to answer research question (b). It was determined that adding minigames as rewards for successful completion of the educational language aspects would be an effective way to keep the user engaged. To ensure that the minigames would be fun for the player, their design was informed by existing games enjoyed by children in the target age group as well as suggestions made by neurotypical proxies in the informant workshops.

Reviewed literature revealed that a structured narrative was necessary to ensure effective comprehension. The final prototype included an overarching narrative in the form of the detective storyline, and provided two fully-implemented locations, each with their own sub-plot. The partially implemented game serves as proof-of-concept for the proposed design. Based on the work carried out for this dissertation with neurotypical proxies, it can be concluded that the narrative aspect was effective in supporting the participants' comprehension of the target syntax. Thus, research question (c) is answered within the context of the current study.

While the game shows promise, to assess whether the application is an effective tool overall would necessitate further research. A comprehensive study investigating the long-term effects on comprehension would need to be undertaken, which is outwith the scope of this research. Moreover, participants of the actual target population would preferably be involved in further studies, to determine if comprehension is also facilitated in autistic language-impaired individuals. Additionally, the issue of generalisability would need to be considered; does the game encourage autistic children to transfer the skills learnt beyond the restricted context of the game?

One of the changes from the evaluation stage was immediately added in to the prototype. While the clues in the bag panel did indicate how many areas has been successfully completed, it was unclear which ones these were. This was observable in other sessions (both in the interviews and workshops) when testers unintentionally revisited areas they had already explored. Chiasson and Gutwin (2005) posit that interfaces should track exploration of the environment, so a **progress**

tracking element was added to the game to make it clear which locations had already been visited. In the re-implementation, a star appears over the icon signalling that the player has successfully completed the story in a location, (see Figure 47). Note that the user still able to revisit starred locations. This sort of progress tracking could also have been incorporated within each individual location screen, to keep track of which minigames had been completed. However this was decided against, since the minigame button already quite obviously changes from non interactable to interactable when the story is completed. Moreover, the focus of the game is on the language component contained within the story, with the minigames serving as rewards.

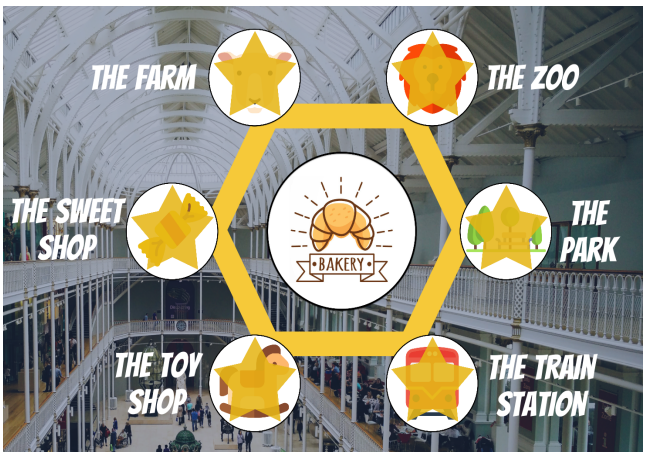

Figure 47. Re-implemented location menu with progress stars

8.1 Further Work

Numerous additional suggestions for improvement were made throughout the evaluation stage. They are subsequently summarised and discussed in relation to the literature:

Voiceover
Multiple experts suggested using some sort of voiceover to read out the stories, as opposed to relying on the player's ability to read the text. Some even considered that recording actual speakers reading out the scripts would allow for prosodic features such as intonation to provide hints. However, Bishop et al. (2006) found that acoustic cues provided no additional benefit over just reading in comprehension training for language-impaired children. In fact, Fey et al. (2003) argues that for acquiring higher level language forms such as complex syntax, written language is more appropriate, especially for older children. So while voiceover might be an attractive feature to incorporate, it should not be implemented with the goal of improving comprehension skills.

Customisation
It was mentioned both in the testing workshops and expert evaluations that the game would benefit from being more customisable. For one, the narrative text could include personalised responses using the player's name, which Fletcher-Watson (2014) argues has proven useful in the contexts of language acquisition and social stories. The idea of a customisable avatar also came up, supported by Bartoli et al. (2014) for enforcing a notion of self in the player. This encourages the user to become more invested in the game and, as a result, promotes more successful outcomes.

Interactable Bag Panel
The think-aloud portion of the expert sessions, as well as the observations of the TD proxies revealed that many users attempted to tap the items in the main menu bag panel. Currently, the bag has no functionality; it serves merely as a record of the clues that have been collected. Based on the propensity of users across all ages to interact with the displayed items, it might be wise to

implement some interaction with the items. Perhaps tapping on the bag contents could give information about them, such as what they are and where they were found. Or for undiscovered clues, there could be some indication of where to look for it.

Visual Representations of Explanations
The visual nature of the Picture Exchange Communication System (PECS) is argued to be one of the reasons it has served as an effective intervention for autistic children (Charlop-Christy et al., 2002). Therefore, the recommendation by experts to create a visual representation of the target syntax should be incorporated in future implementation of the game. Further research would need to be carried out to determine the specific layout of such a representation; that is, whether colour, shape, pictures, or some graphical format would be most effective.

Various Levels
Including varying levels of difficulty would enable the user to tailor the game to the degree of impairment exhibited by the individual with ASC. This sort of adaptability is vital for ASC, since the nature of the spectrum makes it such that there is great variability across individuals. As suggested in the workshops, this could be done such that each level targets a different sentence construction, giving the player a fuller picture of complex syntax as a whole.

Audio and Animation
A number of experts advocate the use of audio and animation in technologies developed for both neurotypical children and children with ASC (Bartoli et al., 2014; Chiasson & Gutwin, 2005; Hussain et al., 2016). The current prototype only includes these when the narrative text appears; it looks and sounds like it is being typed out. Some positive remarks were made about these features, but many of the workshop participants and experts would have liked to see more of both. The creation of an introductory clip to set the scene at the beginning of the game could incorporate both audio and animation, and be a good way to provide background information pertaining to the narrative. However, a consideration to be made concerns the over-stimulation of individuals with ASC. For flexibility, there should be options to deactivate these features.

Input Instead of Multiple Choice
If the wh-questions were to elicit actual input from the user instead of multiple choice answers, a clearer picture might be obtainable of the specific types of comprehension errors that occur in language-impaired children with ASC.

More Dynamic End Scene
The final location would provide a good opportunity to add sound and animation, either in the form of an outro clip or another minigame. Alternatively, the “who done it” format could be taken a step further and the child could be asked to decide who the culprit is based on the collected evidence. Suggestions by experts were made that would add an additional layer of language reinforcement by incorporating the language element to the selection of suspects; the thief would be identifiable by his incorrect use of the target syntax. By doing so, the user can be tested not only on their comprehension skills, but also on their ability to recognise grammaticality. This would, in turn, determine whether the game enables the user to internalise what they have learnt and apply it across situations.

8.2 Summary

Overall, the first and third research questions posed at the beginning of this dissertation were answered in the affirmative, with the caveat that children with autism should test the concept, as this was not possible during this research. The detective narrative was found to be an effective way

to frame a language game and the tablet an appropriate medium for the target audience. The literature, workshops with neurotypical children and interviews with experts provided the necessary inputs to create a game with an appropriate scope, approach and design. They also suggested ways to make the educational tool engaging and fun for the target audience, which addresses the second research question. It was decided not to implement some of the suggestions, the reasons for which are explained, and further work that could improve the game are discussed in this closing chapter.

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Designing Educational Games for Children with Autism

Information sheet for parents and guardians

This information sheet is for parents and guardians; it explains a research project at the University of Edinburgh, in which we would like your child to participate. It gives information about the project in the form of questions you might have and their answers. If you have further questions, we are happy to discuss them and give you more information.

The researchers on this project and their contact details are as follows:

- Ms. Mai Anh Nguyen, lead researcher
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Please return the parent consent form to one of the researchers if you give permission for your child to participate in the project.

Overview of the project

We are four UG4 and one UG5 students from the University Of Edinburgh working on educational games for children with autism as a part of our Honours projects. Each student pursues research in their chosen area and will develop their own game.

What is the goal of the project?

Mai Anh: A very high proportion of people with autism spectrum condition (ASC) have a co-occurring condition called alexithymia, which makes it difficult for them to identify, describe and process their emotions. At the same time, they do not experience similar problems identifying emotional content in music, and often have a special interest in music due to its characteristics. This project aims to tap into this affinity to help children with ASC better understand and cope with their emotions through the use of music.

Nicole: Social interactions might come easy to many people, but for children on the Autism Spectrum it represents a major difficulty in life. For autistic children approaching new people, asking for help or making friends is a struggle. Especially, in a new environment. To improve the ability to enter social interactions more freely, we are designing an educational game to encourage autistic children to start communication and interaction with other people.

Orisa: We are investigating how to design an effective social game to teach children with ASC how to pretend play. Pretend play is a significant diagnostic indicator of childhood autism and is closely related to critical developments such as symbolic thinking, language and social interaction. To encourage more spontaneous pretend play in children with ASC, we will be incorporating augmented reality and social support into a tablet game to expand their imagination and improve their cooperative play skills.

Stanislava: We are investigating how to design an educational game for children with Autism Spectrum Condition (ASC) which aims to promote the better understanding and casual use of non-literal language forms such as metaphors and idioms. People with ASC often interpret language literally, rather than with the intended meaning, which may lead to communication problems. The game will present a narrative story, aiming to introduce non-literal expressions in common situations and a number of minigames focusing on specific phrases to promote learning through repetition.

Tara: Research shows that Autism Spectrum Conditions (ASC) and Specific Language Impairment (SLI) co-occur within individuals at above chance level. For this reason, it is

unsurprising that many children with ASC struggle to understand complex language structures such as wh-questions (who/what/when/where/why/how), as well as embedded and subordinate clauses. They also often cannot focus on details or parts of a whole, something known as Gestalt perception. This can be seen in the fact that they often attend only to keywords instead of the actual meaning conveyed by a narrative. We aim to develop a game that can help children tackle such difficulties by applying them within a narrative context.

What is the purpose of the workshop?

Mai Anh: The workshop will help in gathering examples of situations where emotions of sadness, anger, happiness and fear might occur and how one can identify those. The role of music in symbolic depiction and enhancement of emotional states will be explored to see their relevance towards children. This information will be incorporated into designing the game.

Nicole: The workshop is intended to gather information on children social interaction in order to develop the game based on actual experience. As the act of making friends will be in the focus of the project, the workshop aims to develop ideas corresponding to it. Therefore, the different brainstormed ideas, scenarios and created comic strips will be evaluated and incorporated into the game's design.

Orisa: The aim of the workshop is to find out how the children would respond to the game mechanics, i.e. the 'charades' component (guessing game) and the augmented reality demo on the tablet. The amount of pretend play and interaction between players will be noted down for evaluation (to improve current draft design). Also, the game's main storyline will be customised to fit the children's interests and opinions.

Stanislava: The aim of the workshop is to evaluate how effective the current design strategy is at encouraging children to use more non-literal language and to provide more design ideas for game characters, storylines and minigames. It will also explore the children's comprehension of non-literal expressions and their interpretation of their meaning.

Tara: The workshop is intended to inform the design process of the game. The children's opinions regarding characters, rewards/feedback and storyline ideas will be invaluable to the design and implementation of the app. The kinds of questions the children spontaneously come up with in response to the narrative will be helpful in determining specific ways of testing the user's understanding of the narrative.

How can my child help?

Mai Anh: The workshop will help in investigating what kind of situations elicit emotions of fear, happiness, sadness and anger, which will be done by the child through drawing or writing. These examples will be used to discuss more generally how one can identify such emotions in themselves. The child will also participate in brainstorming ideas for music-centred mini-games.

Nicole: As friend-making is natural to most children, their experience and expertise is invaluable to give the project a new angle. Over the course of the workshop, the children will engage in brainstorming activities, in which different scenarios and common way to start conversations will be explored. Then, the children will be asked to find a solution to an alternative scenario, which will be based on the brainstorming session. Learning about the experiences of children in the same age group as my focus group will help me to create a real life related game.

Orisa: To improve conditions and features of a cooperative augmented reality application game so that the children will be supported socially and build on their pretend play skills, I will be trying to discover factors in social and pretend play that evokes a child's imagination and his/her enthusiasm to play cooperatively. By interacting with the augmented reality system and designing the object/characters, your child will be helping me gain insight and ideas from a user's perspective for the game development stage later on in the research project.

Stanislava: The children's thoughts and ideas on the workshop's activities will help evaluate the current design stage and provide basis for future design decision. They will be asked to draw characters given a short background, tell a story with the intention of using figurative language their peers can recognise, point out non-literal phrases they recognise from a list and brainstorm ideas for interesting ways to explain these phrases to someone else.

Tara: In small groups, the children will be asked to take part in several activities. Some of these will involve brainstorming, while others will be more art-oriented and require them to create drawings for characters or other design elements. Discussion and general conversation with the children about their thoughts and opinions will also provide insight with regards to effective and appropriate design choices.

Workshop Information

What happens during the workshop?

We will always spend some time before the workshop session to talk to the children, in order to get to know them better and allow them to get to know us, with the aim to make them more comfortable. At an agreed time, we will walk your child from the main area to a quiet place where a particular workshop stand will be set up. Your child will get to participate in a design workshop, play with the prototype or participate in related activities for 15-20 minutes, as well as participate in other activities, or until they want to stop (whichever is first). If your child is willing to talk to us about the activities, we will ask them a few questions.

Video recordings

We would like to video record the session, to provide a record for later analysis and allow us to freely interact with your child during the session without worrying about taking notes. If you prefer that we do not use videos or pictures of your child for publications, presentations or teaching purposes, you can indicate this on the permission form. In that case, the video would be seen only by us during the analysis. If you're not comfortable with your child being videoed at all, then your child should not participate in this particular study.

Additional Study Information

Will this project teach my child new skills?

This project is not a type of therapy or intervention. We will not be teaching children new skills or improving existing skills. The information we learn from this project may be used in future games/websites that could help children with ASC.

What happens when the project is over?

After the study has finished and we have analysed the information we collected, it will be used to evaluate and further develop the design of the game/website and eventually be presented in a final report. This report along with the data and recordings may be shared or presented in scientific journals or conferences. We never share children's names, schools or other personal information.

How will personal information be protected?

Confidentiality is extremely important to us. Recordings and other information (such as forms with children's names) will be stored safely on password-protected computers or in locked cabinets. Access will be limited to the people involved in the research (listed above). Recordings and other information will be identified only by participant codes or pseudonyms, and will be separated from identifying information (such as name or birth date).

Can I have a copy of the games?

The game prototypes your child would play with in this study are merely proof-of-concept; that is, they are pieces of research software designed to help answer specific questions. They do not have the same type of functionality, amount of content, or style of documentation that you may expect from commercial games. However, once the study is over the games may be made publicly available online, for free unlimited use. If so we will send you a link and instructions for installation.

Who paid for this research?

This study is part of the undergraduate work for the main researchers (listed above). It is indirectly paid for by the University of Edinburgh and the funding is not attached to a specific project or to any outcomes of that project. Conducting this research brings no financial benefit to the researchers or to the university.

Would you like to participate?

We ask parents to read this information sheet so you can make an informed decision about whether participation as a game designer is a good idea for your child.

If you say "yes" when returning the permission form, we will explain the game developer role to your child, and ask him/her if he/she wants to help. We will remind your child that they can stop being a developer at any time, without having to give any reason, and that we will always listen to them. We will check that the child agrees to be audio recorded. This explanation will be based on the child information sheet included in this packet. We feel strongly that children should be given a real choice about whether to participate. Even if you say "yes" on the permission form, your child may still say "no" if s/he does not want to be a game developer. We will respect your child's decision.

If you say "no", we will not contact you again about this study and will not speak to your child about being a games/web designer.

Once again, this study is completely voluntary and you and your child are under no obligation to take part. Even if you say yes now, you may withdraw your child from the study at any time and for any reason by contacting us. Your child may also withdraw at any time by saying that s/he does not want to be a game developer any more.

Thank you for taking the time to read this.

If you would like to know more about this research and/or if you have questions, please contact one of the main researchers listed above.

Appendix B. Child Information Sheets

New computer games to help children
(to be read aloud to the child)

This page is for children. It is about some people who are organising an **event at University of Edinburgh**. It says who they are, and what they will do **during the event**.

The organisers will ask for your help. You can help by playing a new computer game, **participating in different activities**,listening to some music and answering a few questions. You can decide if you want to say "yes" or "no" to helping, and can change your mind at any time.

The researchers on this project and their contact details are as follows:

- Ms. Mai Anh Nguyen, lead researcher
  - s1456537@sms.ed.ac.uk; 07405886454
- Ms. Nicole Meng, lead researcher
  - s1513402@sms.ed.ac.uk; 07857074813
- Ms. Orisa Ngampakdeepanich, lead researcher
  - s1309783@sms.ed.ac.uk; 07895863725
- Ms. Stanislava (Stasi) Borisova, lead researcher
  - s1432790@sms.ed.ac.uk; 07478298595
- Ms. Tara Wudhiphan, lead researcher
  - s1427786@sms.ed.ac.uk; 07467789073
- Prof. Helen Pain, research advisor (helen@inf.ed.ac.uk)

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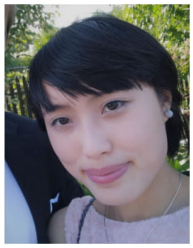
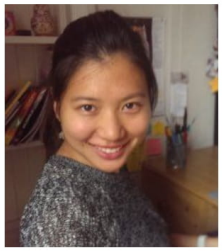
Who is organising the event? This is Helen, Mai Anh, Nicole, Orisa, Stasi, and Tara. Their job is to learn about how children use computers, and how to make computer games that can help children. They will ask you to help them by playing a new computer game, participating in different activities and answering a few questions.

Helen

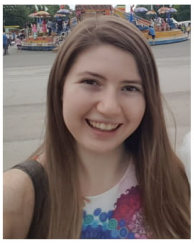


Mai Anh

Nicole



Orisa



Stasi

Tara

Why are we organising this event?

Mai Anh: Some children might find it difficult to understand and describe what they are feeling. By using music, they can get more comfortable with their emotions and learn to identify them. In this event, you can help me understand how you know about and behave when you feel different emotions. I can then use your ideas to teach other children do the same in my game.

Nicole: Some Children with autism find is hard to make friends, because they feel uncomfortable talking to people or do not know what to say. To help them learn how to do it, Nicole and Helen will develop a game that is fun to play but will also teach them how to make friends. In order to do so, they will need to understand how you get to know people and what you would do in a certain situation. By participating in the workshop, you can be a game designer by giving Nicole and Helen good ideas.

Orisa: To solve the problem some children face when trying to engage in peer supported pretend play, Orisa and Helen will be creating a game to encourage children to become more motivated to be cooperative and creative during their play time. By becoming our game designer, you will be trying out an augmented reality tablet application, designing new character objects and main storyline for the game.

Stasi: Some children find it hard to understand others when they use phrases with different meanings to what the words would suggest. Like saying your homework was a piece of cake would mean you found it very easy, rather than actually having cake as homework. Stasi and Helen are making a game to help them learn the meanings of these phrases. As a game designer, you would help come up with the characters, stories and activities the game will have.

Tara: Some children struggle with complicated sentence structures, so Tara and Helen are making a game that is designed to support these children; so they can also understand exactly what is going on in a story. As a game designer, it's your job to help make decisions about characters, storylines, and the kinds of questions and interactions that we will include in the game.

What is the game?
Mai Anh: In this game, you will follow a character that has problems understanding his emotions. You will follow his story, where different situations will happen and the character needs to find out how to describe what he is feeling. To find out what the emotion is, you will help him in musical mini-games, where he will collect different clues.

In the workshop, you will help me come up with examples of situations where you would feel happy, sad, angry and scared, which I can use in the main character's story.

Nicole: In this game, you are the main character. You will encounter situations in which you have to talk to unfamiliar people, ask for help or make a friend in new places like school, the play ground or the afterschool club. In every of these situations, there will be a minigame to teach you how to deal with this situation before you can move on to the next story and explore new areas.
In this workshop we will share our experience of making friends and, therefore, come up with different areas of the game. Additionally, you can help by coming up with different situations and what you would do then.

Orisa: The game is about expanding your imagination while you are playing with your friends. To play the game, you will be using the game application on a tablet or a phone to see “augmented reality”. Augmented reality is the result of adding a digital layer of animation objects onto the real world. It can change the way we see the environment around us through our cameras.

In this workshop, you will be playing with an augmented reality demo, engage in a few rounds of charades (guessing game) and suggest some ideas for the game’s main storyline. It is alright if you don’t have many ideas, it’s all about having fun.

Stasi: The game is about a character from a magical land where they always mean exactly what they say. You need to help them get back home by using phrases which mean something different from what the character expects. The story will lead you and the character on different adventures where you talk to others. Every time the character uses a phrase correctly, a special level of the game opens up and it contains a short game focused on the phrase.

In this workshop, you will be drawing your ideas for what the main character of the game could look like. You will then try using and recognising phrases that mean something different to what we say so that you can power up the portal for your characters to go home. In the end, you will have the chance to come up with stories and special levels for a few phrases that will likely be used in the game.

Tara: The game will follow a character that you will help us create. There is a mystery that must be solved, and when you play, it will be your job to help our new character with this. You will go through the story and answer questions about what’s going on; the idea_is that we want to make sure no one has gotten confused along the way! Every time you answer correctly you can collect clues that will let you solve the mystery.

Today, we’ll have a look at some long and complicated sentences, and even form some of our own. You’ll notice that sometimes they can be quite tangled and confusing, but you’ll soon discover that a few simple questions are very helpful when it comes to working out what they’re actually saying. You will also get the chance to create some drawings to help us design our main character and any other friends they might make on their journey.

What will happen if I help? They will prepare a workshop at the University of Edinburgh. When you arrive, you will be told more information and then you will go to one of the areas that will be set up. There, you will get to play with game prototypes, take part in design workshops and participate in other activities.

You can tell Helen or one of the researchers if you want to stop doing any of the activities. You do not have to tell them why. Please tell them if you need the toilet, or if you want to take a break. You can also say you do not want to be a game developer any more, and that is OK. They will always listen to you.

The researchers will ask if it is OK to make an audio recording of you playing the game, and answering questions. This is because it is too hard for them to write down everything that happens. They will listen to the recording later to help them understand what you said, and what happened when you played the game.

What will happen after I am finished helping? They will learn a lot about children and computers from the things you make, do and say when you play with the games, take part in the design workshops and do other activities. After all the children have finished participating in activities, the workshop will be over. They will listen to the recordings of children playing with the prototype, taking part in the design workshops and doing other activities. They will write about what they have learned. Sometimes they will show people recordings of children taking part in the different activities.

Your mum or dad said it is OK for you to help us.

Do you want to be a games developer? You can say "yes" or "no". It is OK to say "no". It will not hurt the researchers' feelings.

Do you want to ask a question about being a games developer? It is OK to have more questions. You can ask them as many questions as you want about being a game developer. Ask your mum or dad to help you call them on the phone or write an email with your question.

Appendix C. Parent Consent Form

Research consent form (for parents)

	Please Circle
Have you read the information sheets?	YES / NO
Have you received enough information about the study?	YES / NO
Do you understand that participation is completely voluntary and your child can leave the study at any time, without having to give a reason?	YES / NO

Please sign this page to indicate that you understand and accept the conditions of this study, including audio and video recording. By signing, you agree that the researchers may explain the study to your child and invite him or her to take part as a game/web designer.

With reference to further anonymous use of photographic,audio or video data, please circle yes or no in response to the following:

> I AGREE that short videos/images of my child can be used as examples in documents and presentations for research and/or teaching purposes.
>
> YES / NO

If you give permission for this study, please return this form to the researchers.

If you DO NOT wish to give permission, you do not need to return this page. We will not ask your child to participate.

Full name of participating child:

Child's date of birth (DD/MM/YYYY): _____/_____/_____

Your relationship to the child:

Your name (please print clearly):

Contact telephone number: _____

E-mail address: _____

Best time and method to reach you?

Signature:

Date: _____/_____/_____

Parent design workshop consent form November 2017

Appendix D. Child Consent Form

Child Consent Form

To be used as a guide for securing consent or refusal, after the child has had a chance to get information about the study. The child may mark (or be helped to mark) this form, or the child's consent/refusal may be video-recorded.

I can choose to be a games developer.

I do not have to help if I don't want to.

I can decide to stop taking part or take a break if I want to.

I do not have to say why.

It is okay if I change my mind later, and say I do not want to be a games developer anymore.

It is okay if some parts of the game are hard for me!

There are no wrong answers to questions.

Anything I can do is helpful.

Do you want to be a games developer? **YES** ◻ **NO**◻

Mai Anh, Nicole, Orisa, Stasi, Tara and Helen will listen to/watch the recordings later.

They will show them to other people who make games for children.

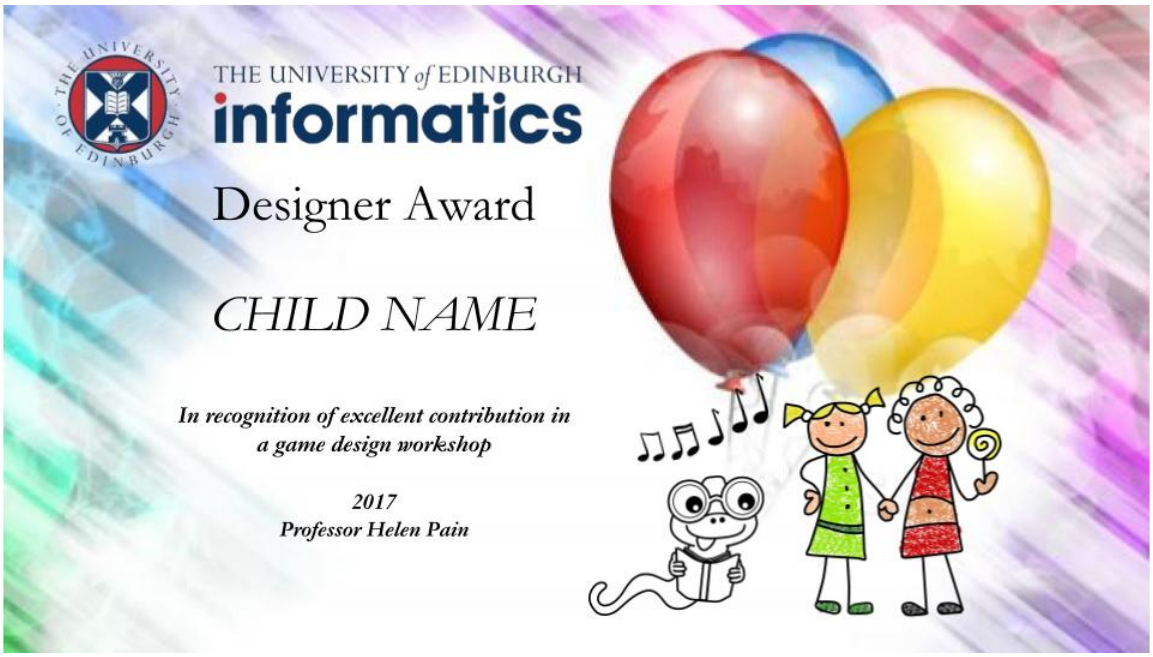
Is it okay to take audio/video recordings? **YES** ◻ **NO**◻

Write your name: _____

THANK YOU!

Child consent form November 2017

Appendix E. Design Workshop Certificate



Appendix F. Evaluation/Testing Workshop Certificate