Toward a Technology to Overcome Anxiety in Children with Autism

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Abstract

Anxiety stands as one of the most prevalent comorbidities of Autism Spectrum Disorder (ASD), often leading to significant difficulties for children on the spectrum in daily situations at home and school. Moving to new places, encountering unfamiliar people and being in unexpected social situations can all prompt feelings of intense anxiety and stress, and can often lead to stunted social development. Previous research has indicated that transforming conventional educational approaches, like mindfulness coping strategies, into gamified experiences for children with autism may aid in cultivating skills to manage challenging situations calmly. In addition, there is evidence that technology holds a unique appeal for children with autism and brings several benefits, such as providing a structured and predictable environment, offering opportunities for individualised learning, and serving as a platform for practising social skills in a controlled setting.

Therefore, this project explores how a technology-based game can be developed to present a novel and engaging solution to assist children with autism in managing anxiety in difficult daily situations. A tablet-based game has been developed to simulate challenging situations and present strategies for staying calm. The participatory approach of Informant Design was used to involve stakeholders, including 3 typically developing (TD) children and one child undergoing an autism assessment, and experts in HCI, ASD and education, to help design the game. Empirical data gathered from the summative evaluation suggested that the game was fun, engaging and easy to use, and had the potential to support children with ASD in overcoming anxiety in challenging daily situations. However, a longer-term study involving more children with ASD is needed to thoroughly test the tool's applicability in real-life settings.

Research Ethics Approval

This project obtained approval from the Informatics Research Ethics committee.
Ethics application number: 818448
Date when approval was obtained: 2023-11-08
The participants' information sheets and a consent forms are included in the appendix.

Declaration

I declare that this thesis was composed by myself, that the work contained herein is my own except where explicitly stated otherwise in the text, and that this work has not been submitted for any other degree or professional qualification except as specified.

(*Benjamin Norman*)

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Chapter 1

Introduction

1.1 Autism Spectrum Disorder and Anxiety

Autism Spectrum Disorder (ASD) is a set of lifelong neurodevelopmental conditions typically characterised by difficulties in social communication and repetitive, restricted patterns of behaviour and interests [1]. ASD has been increasing in prevalence, due in large part to awareness about the condition [2], and is estimated to affect about 1% of children globally [3], 1.5% of children in the UK [4] and nearly 2% of children in the USA [5]. Anxiety is one of its most prevalent comorbidities, appearing in 40% of cases of ASD [6] and exacerbates problem behaviours such as social skill deficiencies, reluctance towards change, and repetitive behaviours.

There is no universally applicable cure for ASD or anxiety, so research has focused on improving their quality of life through educational and technological interventions. Educational interventions, such as mindfulness, used early in the child's development can help reduce the negative effects of autism's main symptoms [7], particularly when combined with technology. Children with autism are often very comfortable with technology, as it can provide a stable and predictable environment that promotes learning [8]. While there are a growing number of apps that attempt to help children with autism, few address the specific comorbidity of anxiety while ensuring it is tailored to the specific needs of the population, as many have communication challenges and preferred coping strategies. Even fewer current solutions closely involve children throughout the design and testing process to help inform its development.

1.2 Research Questions

The fundamental aim of this project is to design, develop and evaluate a technology-based game that can help children with ASD cope with anxiety in difficult situations. This approach used informant design, where stakeholders such as children and experts in Human-Computer Interaction (HCI), ASD and Education collaborated with the researcher in ideation, design and evaluation. The following research questions are addressed to determine whether the project's goal was met:

RQ1: What are the most common challenges that might elicit anxiety in children with autism?

- **RQ1.1:** What challenges commonly arise at home?
- **RQ1.2:** What challenges commonly arise at school?

RQ2: How can a technology-based game be designed to present strategies to help children with autism cope with anxiety?

- **RQ2.1:** What requirements are needed to effectively design the game?
- **RQ2.2:** How can we involve stakeholders in creating the game?

RQ3: To what extent does the game help children with autism cope with anxiety in daily situations?

- **RQ3.1:** Is the game enjoyable for the target population?
- **RQ3.2:** Is the game engaging for the target population?
- **RQ3.3:** Is the game easy to use for the target population?
- **RQ3.4:** Are the activities in the game suitable for the target population?
- **RQ3.5:** To what extent could the game be a success in presenting strategies to help cope with anxiety for the target population?

1.3 Dissertation Structure

The dissertation is divided into the following chapters:

Chapter 2. This chapter provides a literature review of autism and anxiety as a comorbidity of autism. It then presents traditional educational interventions, technological interventions and design principles for autism. The chapter ends by detailing the project's motivation and methodology.

Chapter 3. This chapter focuses on the design workshop undertaken with children to inform initial design decisions for the game.

Chapter 4. This chapter details the design and development of the low-fidelity prototype. The chapter then describes the formative evaluation with experts and its impact on the design.

Chapter 5. This chapter describes the design and implementation of the high-fidelity prototype, including the technical decisions made and the relevant details of the game.

Chapter 6. This chapter focuses on the summative evaluation of the high-fidelity prototype, which was divided into a usability study with higher education students and academic staff members, an evaluation with experts and an evaluation with children.

Chapter 7. This chapter concludes the dissertation by answering the research questions, discussing its limitations and proposing future work.

Chapter 2

Literature Review

This chapter provides an overview of autism, including anxiety disorder as a comorbidity, and reviews traditional and technological interventions for mitigating the negative effects of anxiety. The chapter closes with the motivation and the methodology for the project. The findings of this chapter help to partially answer **RQ1:** *What are the most common challenges that might elicit anxiety in autism?* and **RQ2:** *How can a technology-based game be designed to present strategies to help children with autism cope with anxiety?*.

2.1 Autism Spectrum Disorder in Children

Autism Spectrum Disorder (ASD) is a set of lifelong neurodevelopmental conditions. ASD is typically characterised by difficulties in two key domains: social communication and interaction and repetitive, restricted patterns of behaviour, interests and activities [1]. Struggles with social communication often encompass challenges in understanding and responding to social cues, difficulties initiating and maintaining conversations and struggles understanding social norms and rules. Restricted patterns of behaviour refer to engaging in strict routines that cannot be disrupted, intense, narrow interests in topics, preference for sameness and unusual sensory interests and sensitivities. ASD encompasses a range of conditions, including autistic disorder (AD), Asperger's disorder, pervasive developmental disorder not otherwise specified (PDD-NOS), childhood disintegrative disorder, and Rett Disorder [9].

The term "spectrum" represents the variability in the severity of symptoms ranging from mildly autistic, high-functioning individuals to severely impaired cases requiring long-term specialist support [10]. This variability in condition among those affected implies a heterogeneous group [11]. ASD is a lifelong condition, with initial symptoms typically manifesting in early childhood and persisting throughout adult life [12]. Children with ASD struggle to be independent and most will consistently require support and care from family members, even well into adult life [13]. As a result, there are often significant financial costs for these families, with education usually the major cost component [14].

The degree of impairment in children can widely differ. Most children can be diagnosed

before the age of 3 years, but ASD can often not be diagnosed for many years due to the subtleties of their impairment [15]. The diagnosis of children with autism presents further challenges on both ends of the spectrum, as cases of severe ASD can be misdiagnosed as a severe intellectual disability, and similarly milder symptoms are often diagnosed as cases of social anxiety or language difficulties.

The prevalence of diagnosed ASD cases has significantly increased over time, especially since the late 90s [16]. A major cause has been autism's evolving definition, as well as increased awareness about the condition [2], meaning more individuals and their families will seek treatment and professional help. About 1% of the worldwide population is affected by ASD [10], with ASD being 4 times more likely in boys than in girls [17]. In a review of 54 studies, the overall male-to-female ratio was 4.2 (95% CI 3.8-4.6) [18]. There have been further higher quality studies, however, which measured the ratio closer to 3:1. This could indicate a diagnostic gender bias, suggesting girls meeting the criteria for ASD face a heightened risk of not being clinically diagnosed [18].

In a study by Karst and Vaughan Van Hecke [19], ASD has been shown to have negative consequences for the family as well as the diagnosed individual. Parents have suffered increased stress and reduced mental and physical well-being when compared to caregivers of both typically developing children and children with other developmental conditions. Further to this, high rates of divorce and lower overall family well-being [20] indicate the burden having a child with ASD can have on families.

ASD is a condition that infrequently occurs in isolation, and is typically linked with psychiatric disorders like depression and anxiety, altered sensory perceptions, attention-deficit/hyperactivity disorder (ADHD), obsessive-compulsive disorder (OCD) and others [10]. Anxiety disorders, particularly social anxiety disorders, are among the most common comorbidities for children with ASD [21] and can significantly impair assertive and responsible social skills.

2.2 Anxiety in Autism

Anxiety is an emotional state marked by feelings of tension, worry and persistent thoughts or preoccupations [22]. Anxiety is a common occurrence in the development of a child, but initially, the subject was under-researched by child psychologists due to most cases being over a short period [23]. This rhetoric changed after further research began to show that a substantial number of children experienced disproportionate levels of fear and anxiety to the extent that a disorder was diagnosable [24]. Children with an anxiety diagnosis can exhibit symptoms not just in fearful situations, but in everyday life [25]. Children can develop phobias when interacting with certain animals, or from a doctor's trip. Anxiety can manifest with separation anxiety from parents when going to school and combine with social anxieties when at school or other busy venues, or as a more general worry about the future and everyday activities.

Anxiety has been one of the most apparent symptoms of autism since studies of autism began. As autism occurs on the spectrum, so does the degree of anxiety experienced by individuals with autism, and it is still argued whether the anxiety experienced is a separate type of anxiety unique to autism, or simply a comorbidity of autism

[26]. Feelings of anxiety can commonly plague children with ASD, often with the potential to worsen during adolescence because of more complex social interactions. As discussed, typically developing children can develop phobias of everyday activities and unpredictable settings, the effects of which only worsen for children with autism.

A study by White et al. (2009) concluded after a review of the literature that anxiety impairs 11-84% of ASD children and adolescents. Despite reporting a vast possible range, further reviews of an additional 24 studies supported the validity of this range [26], which indicated that its extensiveness was dependent on sampling methods. A more precise figure of 42% of UK ASD youth was found to meet the criteria of anxiety disorder in a study by Simonoff et al. (2008), perhaps suggesting that the true figure lies close to the middle of the initial range provided.

While children with autism often prefer minimal social interaction and isolation, many will be extremely aware of their social inabilities and wish it were not the case [27]. Social impairments from ASD seem to engender anxiety, stunting further social development and therefore require early intervention.

2.3 Traditional Interventions

Developing a range of strategies to help children with autism cope with feelings of anxiety has been crucial for augmenting these children's quality of life. Educational interventions are widely used as an initial intercession to help alleviate feelings of anxiety. Research has shown promising results through the use of Social Stories™ (SS) in reducing anxiety and improving the behaviour of some children with autism [28] [29]. SS are short descriptions of a social event often encountered by autistic children with specific details on what to expect in that situation and why, and can be tailored to a specific child's ability and need [30].

Mindfulness is another strategy that is often used with autistic children to help reduce anxiety. Mindfulness can be defined simply as awareness that emerges from paying attention to the present moment nonjudgmentally [31]. This method of stress management is well-researched and has shown promise in reducing anxiety and thought problems, increased social responsiveness and improved psychological well-being in children with ASD. A review by Cachia, Anderson and Moore (2016) [32] studied the effectiveness of mindfulness interventions across six studies. While they did not analyse their methodological weaknesses, two studies were marked as designed strongly. One of these was a study by Hwang et al. (2015) [33] that investigated a two-stage mindfulness intervention with child-parent dyads and found promising results for both the child and parent. The children had a reduced Total Problems score on the Child Behaviour Checklist, along with reduced anxiety, and long-term reduction of stress levels for the parents. This study was limited to having to train the parents in anxiety who would then coach the children; however, a study from Varnava et al. (2020) [34] found that other mindfulness interventions such as counting, breathing exercises and listening to a favourite song can also help reduce anxiety in children with autism.

Other avenues of intervention have been widely researched and proposed, such as sensory and motor interventions. Children with autism can often have erratic responses

to sensory stimuli and display unusual motor behaviour, with these struggles often prominent in social scenarios [35]. One proposed intervention method from Karim and Mohammed (2015) [36] was to use a sensory integration program that helped young children with autism learn and practice different motor skills. Though the study did not have a control group or mention the possible influence of other factors such as possible concurrent therapies children may have received, the results were positive, indicating that it was an effective treatment that could help children with ASD gain greater independence and participate in daily activities.

2.4 Technological Interventions

One of the most innovative fields of ASD intervention is using a technology-based treatment. Technological solutions have grown in importance due to the particular interest of individuals with ASD in computerised learning and activities. Computer-based learning games and social robots can provide a more comfortable learning environment for children with ASD, as technological tools can provide predictability and repeatability [37]. Research is constantly evolving in this field, with applications of modern technologies such as augmented reality [38] improving social communication and behavioural impairments for children with ASD.

A developing area of intervention is the use of video games. Children with autism tend to spend twice as much time playing video games as typically developing children [39], with evidence that computer-based games can improve cognitive and social skills in children with ASD [40]. Games and learning activities that incorporate computer-based rewards can enhance motivation for children with autism and help maintain interest in their current activity [41]. Digital technologies that can offer children with ASD a blend of personalised visual and auditory rewards that evolve to reflect their progress is key to high engagement and providing positive reinforcement. One project found that using Minecraft was a suitable avenue to simulate social situations and present coping strategies to children while incorporating rewards to incentivise play [42]. Using a calm progress bar the children had to keep full, children were encouraged to use ”calming rooms” to keep their levels of calm high, and found that there was evidence to suggest that this game could help children with autism cope with anxious feelings.

Tablet and Smartphone Interventions. Research has consistently shown that smartphone and tablet applications can provide effective coping strategies to help reduce anxiety for children with ASD, as children with autism often better process information visually than verbally [43]. Children with ASD do not seem to have a specific preference for larger screen sizes [44], so a choice of smartphones or tablets likely depends on the child’s individual needs and preferences. A review of different mobile device applications by Moon et al. (2020) [45] found that available studies showed promise for the treatment of individuals with ASD.

Digital implementations of SS have been successful, as seen with the Stories Online For Autism (SOFA) application. A study from Smith et al. (2020) [46] found that SS developed by teachers for autistic children improved behaviour and anxiety in the classroom, and that with digital support SS could help children with ASD without

the support of a researcher. However, research has indicated that there is a significant variation in efficacy for SS across specific story targets [47]. Despite this, the positive impact of implementing SS digitally is clear to see. Further research has shown how the SOFA-app has developed social-emotional skills in autistic children [48]. Digitally-mediated SS were used to support ten children with ASD to adapt to change when attending a summer camp and managed to significantly reduce anxiety levels and increase understanding.

Alexa Interventions. Alexa is Amazon's flagship home product and acts as an Intelligent Personal Assistant (IPA). Most research on voice assistants is not focused on catering to special needs, however, a study from Senette et al. (2022) trialled using a custom Alexa skill to support autistic children's oral care. This skill both encouraged the child to go the bathroom to brush their teeth at the scheduled time and persuaded the child to use the correct brushing procedure with a timer. Through customization features and an interactive model, it allowed the child participants to activate the skill using simple utterances and help coach them through the process. While the technology failed to support dental hygiene at home, it did help to mitigate some anxiety when visiting the dentist. This study showed great promise in the area and suggested improvements in several key areas, such as avoiding verbosity and dialogue personalisation depending on autistic profile to improve results.

2.5 Design Guidelines

2.5.1 ASD Design Principles

As the application is for autistic children, it is crucial to account for the specificity of their needs. A set of design principles recommended for autistic children are outlined in a study by Bartoli et al. (2014) [49] and act as a set of general guidelines. The following principles are relevant to this project: **ASD-1:** Each game must be customisable to address individual capabilities and needs; **ASD-2:** The game must enable progression by increasing difficulty; **ASD-3:** Play sessions must have a unique and explicit game goal to reach; **ASD-4:** Clear instructions before and during play must be facilitated; **ASD-5:** Rewards must be offered after a good performance; **ASD-6:** Tasks must be repeatable and predictable; **ASD-7:** It must be easy to replay and move between tasks; **ASD-8:** Graphics and visual stimuli must be strictly relevant to the task; **ASD-9:** Sound elements must be functional, cheerful, clear and simple; **ASD-10:** Dynamic stimuli (such as animations and music) should be provided; **ASD-11:** Avatars should be incorporated into the game; **ASD-12:** Text should be clear and simple to understand, images should be large and easy to see, and colours should have a soft tone.

2.5.2 Human-Computer Interaction Principles

Human-Computer Interaction (HCI) principles are also critical when designing interfaces, as users of HCI-influenced systems can more easily identify system needs and increase ease of use [50]. Nielsen's Usability Heuristics [51] are a popular set of guidelines that help inform decisions for the design of interfaces and systems. The

heuristics are as follows: **HCI-1:** Visibility of system status; **HCI-2:** Match between system and real-world; **HCI-3:** User control and freedom; **HCI-4:** Consistency and standards; **HCI-5:** Error prevention; **HCI-6:** Recognition rather than recall; **HCI-7:** Flexibility and efficiency of use; **HCI-8:** Aesthetic and minimalist design; **HCI-9:** Help users recognise, diagnose, and recover from errors; **HCI-10:** Help and documentation.

2.6 Conclusions and Motivation

Autism Spectrum Disorder (ASD) is a neurodevelopmental condition that requires early intervention to mitigate the negative effects of associated comorbidities, with anxiety disorder being particularly prevalent among affected children. Social situations can be challenging and confusing for children with ASD, exacerbating their anxiety levels. Research has highlighted the effectiveness of technological and gamified interventions in helping children with ASD cope with and manage their anxiety.

Video games and digital SS implementations have emerged as promising avenues for reducing anxiety levels and fostering healthier developmental trajectories in children. Recognizing the potential impact of such interventions, this project aims to design and develop a technology-based game tailored specifically to meet the unique needs of children with ASD. The game will immerse players in simulated social scenarios, designed to replicate situations that commonly trigger anxiety while equipping them with strategies to cope adaptively.

Drawing upon Piagetian stage theory [52], which has been instrumental in understanding children's cognitive development, the project targets children in the Concrete Operational stage, typically aged 7 to 11 years old. This developmental stage is characterised by the ability to solve problems, think logically about concrete operations and events, and improve numerical and spatial abilities. These cognitive skills make children in this age group well-suited to understand and follow game rules and instructions, enhancing the effectiveness of the intervention.

It is crucial to acknowledge that interventions for children with ASD must be tailored to individual needs, as one-size-fits-all approaches are inherently limited. Each child possesses unique strengths, challenges, and preferences, necessitating personalized interventions to maximize effectiveness and engagement. Therefore, while the proposed game holds promise as a supportive tool, it is essential to recognize that multiple interventions, each tailored to specific profiles and preferences, may be required to address the diverse needs of children with ASD comprehensively.

By harnessing the power of technology and gamification, this project aims to offer a novel and engaging solution to assist children with ASD in managing their anxiety. Through interactive gameplay, children will acquire valuable coping strategies and refine essential social skills, fostering their overall well-being and enhancing their quality of life in meaningful ways.

2.7 Methodology

The methodology for this project is an adaptation from the work of Scaife and Rogers (2001) [53] and mirrors the approach used by Ghira (2021) [42], which found promising results using Minecraft to help children with ASD overcome anxiety. This methodology uses a participatory approach through informant design, which incorporates end-users and other stakeholders to collaboratively design technology to better meet the needs and expectations of the target audience.

Stage 1: Background research. The first stage consisted of reviewing the relevant literature on autism, anxiety and approaches taken to help this population of children cope. This research allowed the gathering of high-level requirements needed to design an appropriate solution for the target population. Stage 1 has been fulfilled through this chapter and partially answers **RQ1** and **RQ2**.

Stage 2: Pre-design workshop. The second stage involved children who were typically developing (TD) and one with an ongoing autism assessment to help inform the design of the prototypes. The high-level requirements were then refined by using the ideas and experiences of the children. Chapter 3 describes this stage and partially answers **RQ1** and **RQ2**.

Stage 3: Low-fidelity prototype and evaluation. The third stage used the research collected and requirements acquired to create a low-fidelity prototype. This prototype was evaluated by experts in HCI, Autism, Education and other relevant fields to identify issues and changes required to make a more suitable final game. Chapter 4 describes this stage and further answers **RQ2**.

Stage 4: Development of high-fidelity prototype. The fourth stage brought the previous three stages together to create a high-fidelity prototype. This prototype used the feedback gathered from the low-fidelity prototype and was developed to include the features that would meet the high-level requirements. Chapter 5 describes this stage.

Stage 5: Evaluation of high-fidelity prototype. The final stage evaluated the high-fidelity prototype with Informatics students and academic staff, experts and children. The evaluation with Informatics students and academic staff established the usability of the prototype and provided other feedback for a final iteration presented to the children and experts. This final group of evaluators focused on identifying whether the game was suitable for the target population and indicated possible future work. Chapter 6 describes this stage and answers **RQ3**.

Chapter 3

Design Studies

This chapter presents the design study carried out with children to help inform the high-level requirements of the low-fidelity prototype. This chapter further helps to answer **RQ1:** *What are the most common challenges that might elicit anxiety in autism?* and **RQ2:** *How can a technology-based game be designed to present strategies to help children with autism cope with anxiety?*.

3.1 Design Workshops

3.1.1 Aims

This study had the following key goals:

- Establish which situations elicit anxiety in children.
- Establish solutions and techniques to help cope with anxiety in those situations.
- Generate ideas for components of a game storyline and environment.
- Determine what game rewards motivate and engage children.

3.1.2 Participants

Four children participated in the two workshops, as seen in Table 3.1. P1, P2 and P3 were typically developing (TD) children and P4 had an ongoing autism assessment.

Session	Participant Number	Age	Gender
1	P1	12	Female
1	P2	12	Female
1	P3	7	Female
2	P4	10	Male

Table 3.1: Design workshop participants

3.1.3 Methods and Procedure

The first session had P1 to P3 participate in an in-person workshop at the University of Edinburgh. Due to P4's preferences, we conducted the second session with him through Microsoft Teams [54].

The materials used for both workshops were: Participant Information Sheets (PIS) (Appendix B.1) and Consent Forms (Appendix B.2) for parents/guardians, PIS (Appendix B.3) and Consent form (Appendix B.4) for children, blank A4 paper, coloured pens and pencils, the script for the researcher, PowerPoint slides of the persona (Appendix B.6), and certificates of attendance (Appendix B.5). Additional materials used for the in-person workshop: video recording camera, and sticky notes. Recording for the online workshop used built-in Teams recording functions.

The parents were contacted through email, and upon agreement for their child to participate, Consent Forms were signed and returned before the session. The first workshop conducted in person used a video camera to record the session and the second online workshop used the built-in Microsoft Teams recording functionality. The contents of both workshops followed the same activities, which are detailed below.

Icebreaker. The session started with an icebreaker to make the children feel more comfortable with the activities to come and to familiarise them with the format of the workshop. Each child was asked to draw two pictures: one drawing of an activity that makes them feel happy, and a second that makes them feel sad. The PR also participated to encourage an environment of group participation and discussion.

Before the subsequent activities, children were presented with the persona of Alex. They were told that Alex is 10 years old (the mean age of the participants in session 1 and the same age as P4) and often gets worried when around people they do not know, in new places and sticking to daily routines. The participants were asked to frame their subsequent answers with Alex in mind for relevant activities.

Activity 1: Stressful Scenarios. This activity asked the children to describe three scenarios where Alex might be stressed or worried. They were told to write or draw anything that could help convey the situation and an example was given to help their understanding of the task. After, the group presented the ideas to the rest of the group and the situations were discussed for the next activity.

Activity 2: Intervention Techniques. This activity asked the children to take three of the situations previously described, including any of the situations presented by other children, and describe a potential coping technique to help reduce the anxiety prompted. An example was also given before they commenced, and answers were discussed after.

Activity 3: Environments, Characters and Narratives. This activity focused on taking a difficult situation and solution they had previously described and creating a story around it. The children were prompted to draw or write anything that came to mind, and to think of characters, environment and any other aspects that would help convey the story. An example story was given prior.

Activity 4: Rewards. The final activity had the children try to both use their stories and the other students to think what type of rewards could be given. They were told to

think of potential rewards throughout the story as the characters completed objectives and tasks, and rewards upon successful completion of the story.

3.1.4 Data Collection and Analysis

The data was collected through recordings of the sessions, digital/physical copies of the children's ideas and notes from the PR. The recordings were transcribed, and together with materials the children created, Thematic Analysis [55], a research method used to identify, analyse and interpret patterns in qualitative data as themes, allowed the results for each activity to become apparent. Thematic analysis was used as it is a powerful yet flexible method that can help understand experiences, thoughts and behaviours and can construct themes to help answer research questions. The procedure used consisted of the following: data familiarisation, initial coding, generating initial themes, reviewing the themes, defining and naming themes, data extraction to illustrate themes and reporting the results. This analysis revealed the following themes: **1)** Stressful Situations; **2)** Techniques and Strategies to Cope with Anxiety; **3)** Game Components: Environments, Characters and Narratives; **4)** Rewards.

3.1.5 Results

Stressful Situations. The first activity of the workshop indicated that distinct situations were occurring both at school and home that caused anxiety for the participants. Some answers framed meeting new people and being in unexpected social situations, or moving to or encountering unfamiliar places as being stressful.

Both P1 and P2 found moving school to be difficult, with P1 remarking that *"I think moving school, [it] can be tough to make new friends* and P2 stating that *"you don't really know anyone there, it would make me feel a bit worried"*. P2 echoed similar sentiments when moving house, as did P4. Other situations in the school environment were discussed, such as P1 also mentioning starting a school project with people they do not know, and P3 finding it worrying to sit next to people she does not know at lunch.

Other answers encompassed encountering information imbalances both at home and in social situations as often causing stress. P4 mentioned hearing *"weird and scary sounds in your room"* as sometimes being troubling and found it particularly worrying when an adult shouts at him, saying *"I don't really get why they're doing that"*. P1 cited how it was worrying when *"someone knows who you are but you don't know them"* and P3 said that they *"don't like it when everyone knows the answer to a question but I don't"* when at school. P2 similarly found it worrying to go to parties with people they're not familiar with and visit someone's house whom they do not know well.

Techniques and Strategies to Cope with Anxiety. P1 and P2 emphasised that being introduced to a good group of new friends can help in social situations, with P2 saying that you can *"try to make friends with people you think are nice and introduce themselves to you"*. When asked if there was anything that could be done without outside help for the persona Alex, P1 mentioned reading or listening to music, stating that *"they could excuse themselves and go take 5 minutes and listen to a song or read so they can calm themselves down."*

P3 also thought initially about solutions based around other people accepting Alex and making them feel welcome. When asked to think about what Alex could do, she said Alex could *"take four deep breaths"*. P4, like P1, opts to take a moment for himself: *"I ask to go away and I sit and I count*, saying that [counting] *"calms me because after I count I tell myself it's ok it can't really be that bad."* He also mentioned speaking to someone he knows closely helps calm him down, specifically a parent or teacher he trusts.

Game components: Environments, Characters and Narratives. All participants for this exercise decided to ground their story in a more realistic and familiar setting. Instead of opting for a fantastical setting with strange characters, they all seemed to prefer to think about their situations in the home or school setting they were initially conceived. The participants' bedroom was a familiar theme, with some participants finding comfort in calming themselves there.

P1's story was wary of unfamiliar and scary adults at home and stated that the character *"doesn't know her parents' jobs and one day they bring back sketchy people"*, where one of the men *"was always gambling"* and the women *"seemed nice but were actually full of venom"*. Her character then asked to go to her bedroom to play a song and breathe. P2's story had similar worries about unfamiliar people: *"The teacher introduces them to new people, and Alex realised one of them was being mean. They invited Alex to their house so Alex politely declined, but that made it worse"*.

P3 emphasised the importance of her bedroom in her story, stating that the character, after getting the question wrong in school, went home that afternoon to take *"a quick nap, get a drink then go back to bed. In the morning, she went back to school and wrote the answer on the board and it was right"*. P4 also used the school setting where he detailed a school lunch where *"at lunch, two people want to sit with Jack, but one of the people doesn't like the other, so to help calm himself he goes to breathe"*.

Rewards. P1 suggested that the character could unlock different items or characters, providing an example of *"less sketchy neighbourhood and better parents"*. P4 suggested a wide assortment of rewards for the player, mentioning *"trophies...medals...coins for finishing an activity or answering questions right... achievements, even for getting answers wrong"*. He suggested using rewards and coins to decorate a room with *"all the coins you get for the end of the game"*.

3.2 Design Decisions

Based on the literature review, including the HCI and ASD guidelines in Section 2.5, and the empirical data from the workshops, a series of initial design requirements for the low-fidelity prototype were derived. While Amazon Alexa was seriously considered as a solution from the literature, a tablet-based game was decided because children such as P3 who do not possess strong or clear spoken English may struggle to interact with Amazon Alexa. Its prevalence among the target audience is also far lower, as up to 75% of young children own a tablet [56] while only 20% of children talk to IPAs for more than 5 hours a week [57]. Other design decisions for the prototype have been summarised in Table 3.2, with a unique identifier before each design implication.

Design Decision	**Justification**
DD-1: Centring the game in the player's bedroom	P1 and P3 from the design workshop
DD-2: A customisable bedroom	P1 and P4 from the design workshop, ASD-1, Literature Review [58]
DD-3: Using customisable characters for both the player and other characters	P1 from design workshop, ASD-11
DD-4: Stressful situations are grounded in real-life and familiar school or home settings	All participants from design workshop, HCI-2
DD-5: Taking deep breaths, counting, listening to music and speaking to familiar people as calming methods	P1, P3 and P4 from design workshop, Literature Review [34]
DD-6: Clearly displaying instructions on how to play the game with simple language	ASD-4
DD-7: The target age group will be children aged 7 to 11 years old	Literature Review [52]
DD-8: A form of currency will be used as a reward for finishing activities	ASD-5, P4 from design workshop
DD-9: All visual and audio elements must be consistent and relevant in all game scenes	ASD-6, ASD-8, ASD-9, HCI-4, HCI-8
DD-10: Buttons will be easy to remember and clearly indicate their function	HCI-6, ASD-7
DD-11: Music and appropriate animations will be included throughput various points in the game	ASD-11, P1 from design workshop
DD-12: Include a portal for caregivers to create custom situations for children.	ASD-1

Table 3.2: Initial design decisions for low-fidelity prototype

Chapter 4

Low-Fidelity Prototype and Formative Evaluation

This chapter concerns the development of the low-fidelity prototype based on the requirements gathered so far and its subsequent evaluation with experts in the formative evaluation. This chapter aims to further answer **RQ2:** *How can a technology-based game be designed to present strategies to help children with autism cope with anxiety?*.

4.1 Prototype Design Description

A low-fidelity prototype is an initial mock-up used to quickly and inexpensively test ideas. The low-fidelity prototype combines these ideas, requirements and research already gathered into a basic prototype that gives a high-level indication of what the final product could look like. This prototype can then be evaluated with experts to gain more insight into what would be suitable for the final game.

The low-fidelity prototype was created using Figma, a tool used to create mock-ups for games and applications [59]. Figma was chosen for several reasons: the researcher's previous experience using Figma to create wireframes for applications, the ability to create multiple screens that were easily navigable, reusable components used across the entire application could be designed and easily edited depending on feedback, and the development and editing process would be far faster than drawing each scene by hand.

Overall Game Concept. The overall game concept was based on simulating situations that could cause stress at home and school. The user can create a customisable character with unlockable clothes and items and use this character to play as themself throughout the game's situations, as shown in Figure 4.2. When in a difficult situation, the child would be encouraged to keep their calm level high by completing coping strategies to keep their 'calm bar' full, as shown by the '1' in Figure 4.3. Upon successful completion of a situation or achievement, coins would be rewarded and available to spend on the player's character or on customising their room. A portal for adults to view the child's progress and create custom stories was also created.

Opening Screen. The beginning of the game tutorial was the first screen that the initial

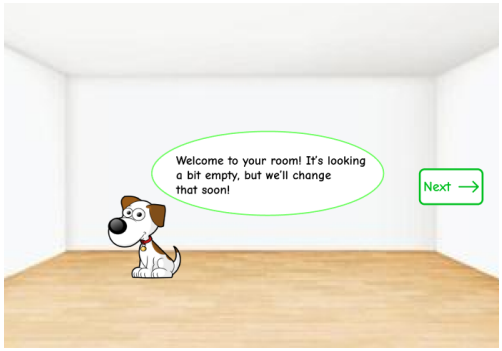


Figure 4.1: Opening screen of the tutorial

Figure 4.2: Character creation page

wireframe had all users land on. As shown in Figure 4.1, it displays a dog that acts as the player's assistant throughout the game in an empty bedroom, which uses **DD-1**. The player is then encouraged to tap through the "Next" buttons to the subsequent scenes, where further details about the game are explained. The assistant is used to help the new player understand how each feature works and give clear instructions on how to progress through the game, adhering to **DD-6**. The main contents of the tutorial teach the player how to: create a character, play through a situation and edit their room.

Creating a character. In line with the decision to use customisable characters (**DD-3**), an essential game aspect was to allow the player to create and customise an avatar to play with. The assistant points the child to the character creation scene, shown in Figure 4.2. Due to the wireframe's high-level nature, full character customization was not fully functional. However, the ability to scroll between different cosmetic options and select preferences allows the player to have full control over their character's appearance and provides an incentive to earn more coins for items by completing situations.

Playing through and completing situations. Having created a character, the player is introduced to the achievement system and receives their first achievement for creating a character. This achievement gives the user 100 of the in-game currency, which will be referred to as 'coins', and is in line with **DD-8**. The player is then guided to complete their first situation entitled 'School Lunch'. Situations are the game's most important component and the medium used to present and practice different coping strategies for the child to use to stay calm in real-life situations.

This situation is used as an example to familiarise the player with how the calm bar (Figure 4.3) and calming mechanics work in the game. This situation is directly modelled on the story that P4 gave in his workshop, adhering to **DD-4**. The situation's overall story is that at a school lunch, the player wants to sit with their friend, but the friend does not want to sit next to them. This makes the player's character feel worried and reduces their calm bar's fill. Using one of the calming options from **DD-5**, as shown in Figure 4.4, helps the player to regain their calm. Strategies for breathing, counting and listening to a song were all included, as well as the ability to talk to a trusted teacher. Successful completion of this story prompts a congratulatory pop-up, gives the player 500 coins as a part of **DD-8**, and returns them to their room.

Editing the bedroom. From here, the player is given the option to customise their

Figure 4.3: Calm bar, as indicated by '1'

Figure 4.4: Calming options in 'School Lunch' situation

room. As decided in **DD-2**, giving children with ASD the opportunity to customise parts of their game to fit their specific likes and preferences is crucial. Figure 4.5 shows how they can do so by clicking on different parts of their room to place decorations and save their choices, though in this mock-up the decorations are not saved.

Completing the tutorial. When finishing the tutorial, the player is encouraged to keep completing situations after the tutorial is over in line with **DD-6**. The player is then left in their designed room and is free to complete situations, edit their room further or design their character. Through an option in the Settings, an adult could navigate to the adult portal and create custom situations for the child or view their progress in the game, as in line with **DD-12** and shown in Figure 4.6.

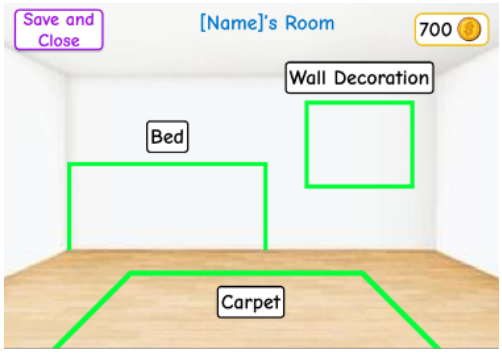


Figure 4.5: Edit room screen

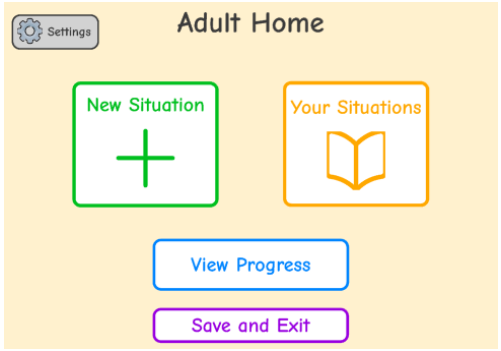


Figure 4.6: Adult home page

Buttons were kept as the same dimensions in the same location throughout the wireframe, adhering to **DD-9** and **DD-10**. It was considered unnecessary to add audio elements such as sound effects and music to the mock-up for simplicity, so these elements were not included at this stage. Some animations, such as completing a situation or an achievement, were included. For similar reasons to the music, other potential character and situation animations were not included. The tone and language throughout tried to stay friendly, welcoming and relaxing to help give a sense of ease to the child while playing the game. Instructions attempted to stay strictly relevant to the task to not overload the player with information, especially those on the younger side of the target age range. Several situations were conceived using answers from the design workshop to be examples to be played through and on which caregivers could model their own

custom stories. School situations that were included were: a school lunch, having a new classmate, having a new teacher and moving schools. Home situations that were included were: moving house, a family gathering, brushing your teeth and hearing loud noises. The 'School Lunch' and 'Moving House' situations were fully designed to demonstrate one home situation and one school situation.

4.2 Formative Evaluation with Experts

Per the methodology laid out, the formative evaluation was next conducted on the low-fidelity prototype. Experts in relevant fields of study, including HCI, Autism and Education, were contacted to step through the wireframe to discuss the suitability of the proposed design for the target population and discuss usability issues and proposed improvements for the current design.

4.2.1 Aims

The aims of the formative evaluation were to:

- Determine if the design is suitable for the target population.
- Determine if the example situations outlined are suitable for the target population.
- Identify whether the flow of events should be changed or improved in any way.
- Identify whether the coping mechanisms presented are suitable.
- Determine if the current reward system is suitable.
- Identify any usability issues.

4.2.2 Participants

Six different experts in relevant fields participated in the formative evaluation, as summarised in Table 4.1. Each expert was allocated a participant number for anonymity.

4.2.3 Methods and Procedure

Evaluations with E1, E3 and E4 took place in person and the others were conducted over Microsoft Teams [54]. The materials used for the evaluation were: a Consent Form (Appendix C.1) and a PIS (Appendix C.2), a computer with the Figma prototype installed and a backup mobile phone to record sessions.

Evaluations took place individually, with each expert signing and returning the Consent Form before the session. Each expert was given an overview of the project, the purpose of the low-fidelity prototype and a summary of the evaluation. Each evaluation followed the 'cooperative evaluation' technique [60], which is a version of the think aloud method [61] used to achieve greater insight into a user's thinking process. The participants are not only requested to verbalise their thoughts aloud while interacting with the

Participant Number	Occupation	Area of Expertise
E1	Lecturer at the University of Edinburgh	HCI, ASD and developing technology for ASD
E2	Software Engineer	HCI and Accessible Design
E3	Reader in Design Informatics at the University of Edinburgh	HCI, Sociology of Technology and Accessible Design
E4	Reader in Computer Science Education at the University of Edinburgh	Computing Education and Access to Computing Education
E5	Software Engineer	HCI
E6	Lecturer at the University of Edinburgh	Software Engineering and HCI in Usability Contexts

Table 4.1: Participants for the formative evaluation

product but also to ask questions when seeking to clarify user behaviour. Similarly, the researcher can ask questions to the participant, hence the cooperative nature.

The expert would play the Figma simulation, either on the researcher's laptop in person or by following the link online, and step through the prototype as if playing as a child. After finishing testing all relevant features, the researcher asked each expert several questions in a semi-structured interview. The questions (Appendix C.3) referred to: the design's suitability for the target population; the appropriateness of the example situations; the coherence of the flow of events; the suitability of the coping strategies; and the engagement of the proposed reward system.

4.2.4 Data Collection and Analysis

The data was collected through recordings of the sessions and notes from the researcher. Thematic Analysis [55] was used on the data and highlighted the following themes: **1)** Calm bar; **2)** Clarity of Text; **3)** Situation Feedback; **4)** Coping Strategies; **5)** Reward System; **6)** Adult Portal; **7)** Usability.

4.2.5 Results

General feedback given about the prototype from the experts was positive. The experts considered the features appropriate and necessary with room to improve and expand for the high-fidelity prototype and potential future work.

Calm Bar. The first evaluation session with E1 pointed out that the proposed implementation could lend itself to including the calm bar from Ghira's (2021) [42] study, which was used in Minecraft to encourage the player to stay calm. Implementing this after this evaluation led to positive feedback about the calm bar, with E4 stating *"this is a nice touch"* and E6 saying *"Ok, I like this"*. The calm bar, however, was not explicitly introduced as being an important part of situations so other experts recommended the calm bar be made more noticeable. E3 said that *"you could make a better reference to the calm bar"* and E5 asked if it could be made *"more noticeable, maybe you could*

add colour changes like light blue to dark blue, or even percentages".

Clarity of Text. As the game uses text and dialogue to convey information about how the game is played and the content of situations, all experts had suggestions on possible word choice improvements. E1 and E3 had conflicting thoughts on how to refer to the situations being played through. The design initially referred to the playable situations as 'stories', but E1 opted for the word 'situations' as being more representative of the task, whereas E3 thought the word 'situations' would be too complicated for a younger player. Though E5 *"likes the simple wording used"*, there were other simple wording changes they would make like *"being more specific about the end of the tutorial"*.

Other experts wanted the language to be more explicit about the information it was trying to convey. E1 and E2 both wanted achievements to have a clearer reference to the task required and reward given, with E1 advising that *"in achievements, you could say 'you get 100 coins'* and E2 stating that *"you should be more explicit about why they're getting coins"*. E2 and E3 wanted to ensure that language is not condescending to the upper end of the target age range, as E2 warned to *"not make the language patronising"* and E3 recommended the game make sure that *"language explaining situations or giving encouragement isn't condescending... try to stay colloquial"*.

Situation Feedback. Both the 'School Lunch' and 'Moving House' situations were considered relevant and appropriate for the target audience. E2 remarked that *"the scenarios I've used are quite relevant and the word choices overall seem good. Maybe focus on adding a school project or presentation story next"* and E5 said that *"the situations are good and relatable... day to day cases. Parents and carers can add more which are specific"*. E6 also thought they were suitable and that the 'School Lunch' situation was the most appropriate in particular. They enjoyed the diversity of characters selected and stated that overall it was *"excellent"*. A change E6 wanted to see made was having different versions of the situation depending on the age of the child: *"maybe the school one would be too young for an 11-year-old"*.

Having adaptable and more intuitive situations was a sentiment echoed by other experts. E1 asked if the first situation could be *"less complicated and offer more freedom of choice to the child... don't put words in their mouth... make it flexible... don't say 'this upsets you'"*. E4 stated that they *"really like the first story, I think it's really nice"* but recommended it be considered what happens in the scenario the situation does not end positively. In the prototype, the 'School Lunch' situation always finishes with a positive resolution, so E4 mentioned: *"it won't always be a positive ending, otherwise in real life they'll only be prepared for the optimal scenario"*. Striking a balance between a situation that provides options and customisability with simplicity and development time constraints would therefore be crucial when designing the situations for the high-fidelity prototype.

Coping Strategies. The coping strategies were received well by the experts with largely only minor tweaks recommended to improve them. E2 said they think *"the counting one is good"*, E5 thought that they were *"definitely suitable"* and E6 similarly said: *"I think they are good, well-known relaxation techniques. The songs are a great idea - you need to add something where they can upload the songs"*. E1 agreed with E6 as they also believed having personalised songs would tailor the strategy to each child.

The experts recommended two changes to improve the coping techniques: more visual aids and the ability to edit or add new ones. E2 stated that *"some extra visual help like displaying the numbers... as well as being able to skip... would go a long way"* and E5 recommended adding *"animations to expand and contract the text for each breath"* for the deep breathing coping technique. E1 suggested setting a default strategy to use for coping, as well as giving the adult an option to create one for the player. E4 echoed this thought, saying that the game should *"give them the option to make their own coping as each child will have their own, and try to think about incentivising some variation in coping"*.

Reward System. The reward system of earning currency to unlock new customisation options for the player's character and room was regarded as a good incentivisation system. Improvements around the reward system generally regarded user experience, as most experts were keen to integrate the rewards together in the main game. The quests were designed to reward the player with unique items and complement the achievement system that rewarded the player with coins. Some experts said they would rather the quests were integrated outside of the tutorial, as E3 stated *"the quests should be added into the main game rather than the tutorial"*. Others thought all rewards could be combined to reduce complexity. E1 was a proponent of this: *"you could move quests and achievements together, you can show the rewards you've got and have a section for more [rewards]"*. E5 and E6 both liked how the achievements were incremental, stating it was important not to give the user access to all customisation options from the start.

Adult Portal. The adult portal was as an idea that all experts thought could bring greater utility and adaptability to the game. E5 and E6 both enjoyed using the 'Create Situation' feature in the adult portal, with E5 mentioning that *"creating a story was easy"* and E6 stating that *"it's easy to manage the stories you create"*. The adult portal was seen as an opportunity to ensure content could be tailored to each child's needs. E3 recommended adding a capability to edit the current example situations, while E4 thought that being able to change the difficulty of each situation depending on the player's ability would be appropriate.

Usability. The participants liked the overall visual appeal of the UI, with E2 calling it an *"intuitive and simple design"*, E4 stating that they *"like the avatars and the visuals are good - simple but appealing, it's really nicely designed. I think the interactions are appealing for kids"* and E6 enjoyed the use of icons on the buttons and calming options. Most feedback came in the form of minor improvements in the positioning of certain buttons, such as the 'Save and Exit' button from the Edit Room panel. Including a 'back' button whenever a 'next' button was present in tutorials and situations was also mentioned by E2 and E5. The use of the dog graphic as an assistant was positively remarked on by E1, E2, E5 and E6, with the ability to choose its name mentioned as *"good customisation"* by E5 and that its presence *"would make the child feel at home"*; however, both E2 and E6 asked the dog be kept in place rather than move around the room during the tutorial.

4.2.6 Impact on Development

The experts generally believed the initial prototype was suitable for the project's goal, particularly liking the potential customisation afforded to players. A set of development decisions could be prioritised depending on the feedback from the experts, HCI and ASD design principles and evidence from previous literature. These decisions and their justifications are summarised in Table 4.2.

Development Decision	**Priority**	**Justification**
Keep the calm bar and make it more noticeable	High	E3, E5 from the formative evaluation
Make text in tutorials and situations less ambiguous	High	All experts from the formative evaluation, ASD-4
Increase options and decrease complexity in situations	High	E1, E4, E6 from the formative evaluation, ASD-1, ASD-6
Add visual aids to help with breathing and counting coping strategies	High	E2, E5 from the formative evaluation
Capability for users to upload songs	Low	E1, E6 from the formative evaluation. However, very difficult to seamlessly integrate third-party music applications.
Addition of a text-to-speech option for dialogue	Medium	Encouraged by E1 from the formative evaluation. However, might be too time-consuming to incorporate a text-to-speech model into the development environment.
Incremental achievements system	High	E5, E6 from the formative evaluation, ASD-2, Literature Review [41]
Quests system. If time allows, integrate it into the achievements system	Low	Not well-received by E3 and E5 from the formative evaluation.
Addition of a 'back' button to replay dialogue	High	E2, E5 from the formative evaluation, ASD-6
Adult Portal for creating and managing custom stories and calming options	Low	A large feature almost completely separate from the main game that requires a larger timescale to develop fully.

Table 4.2: Initial design decisions for low-fidelity prototype

Chapter 5

High-Fidelity Prototype

This chapter details the technical decisions made for the game's development and their justifications, followed by a description of the game's features and flow of events.

5.1 Technical Decisions

Development Environment. The environment used for development was the game engine Unity [62]. Unity is a versatile and powerful game engine commonly used to develop 2D and 3D games across mobile devices, PCs, consoles and other platforms. By combining interactive UI assets with scripts written in C#, game mechanics and other reactive components can be created to suit project requirements. Unity was chosen as the researcher had previous experience using Unity and it facilitates rapid prototyping, iterative development and deployment of high-quality games, which suited the purposes of the project.

Target Platform. The target platform for development was iOS due to choosing to develop for a tablet in Chapter 3, and iOS platforms have substantial build support in Unity. However, the researcher was aware that some of the final evaluations were taking place online and participants may not have a tablet to play the game on. Therefore, the game was also developed to be playable on Windows, MacOS and Linux operating systems so that all future participants could easily install the game onto their computers. Unity has rigorous support developing for multiple platforms, so the approach was considered feasible.

Game assets. Icons, sprites and images were used across the game to display graphics to the user. The researcher designed the buttons and other interface elements using the Figma [59] editor, where designs were improved from the low-fidelity prototype or created based on the feedback and research gathered from chapters 2, 3 and 4. Icons on buttons and elsewhere in the game were gathered from open-source Figma icon asset packs and adapted for the game requirements. Background images, character sprites and decoration sprites were free assets from Freepik [63], a website where artists can create and share high-quality photos and vectors for personal project use. Attribution is required when using free assets from Freepik and was included in the game's credits.

5.2 Prototype Description

Tutorial Start. The game was named 'Calm and Collect' to reflect the main objectives of staying calm and collecting resources and items. The major flow of events in the game is similar to the Figma prototype, encompassing a tutorial presenting: character creation, completing the player's first situation and how to decorate the player's room. The player starts in their empty bedroom with the assistant, shown in Figure 5.1, and is given information about how to play the game and its overall objective, using the next and back buttons to navigate through each tutorial stage. The player then can choose a name for their character (Appendix A.1.a) and the assistant (Appendix A.1.b), adhering to the customisation design guideline in ASD-1. The player was also given the choice of playing as themself or as someone else (Appendix A.1.c), a suggestion from E1 in the formative evaluation in case the child would be more comfortable not directly putting themselves into situations. This decision does not majorly impact the game and only changes certain dialogue word choices to match their decision. Relaxing background music is also played throughout the game, helping to comply with ASD-10.

Features are gradually introduced to the player by displaying buttons with a helpful arrow to point the feature out (Appendix A.1.d). The arrow had a blinking animation in the low-fidelity prototype, but this was removed due to feedback from E2 and E6 in the formative evaluation and to comply better with ASD-8. Each new button was given an expanding and contracting animation to indicate that the player could push this button to explore the new feature. The first is the settings button, which allows the player to change the player and assistant name. The player then navigates to the 'Dress up!' button to choose their character.

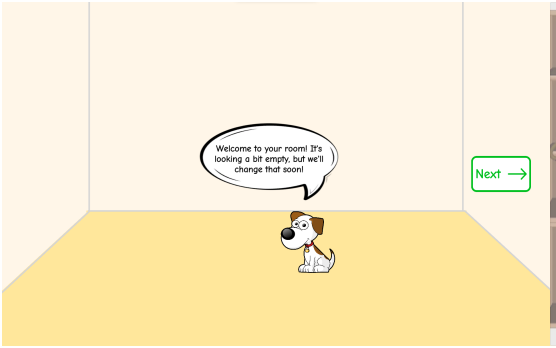


Figure 5.1: Opening screen

Figure 5.2: Character selection screen

Character Selection. The character selection screen is shown in Figure 5.2. The player is presented with 6 free characters and 6 characters with coin icons that can be paid for using coins. The character options attempted to be diverse for maximum character customisation and were only limited by the assets available to the researcher. The player is prompted to scroll across the selection screen to view all available options and cannot progress until they have selected their first character. While coins have been mentioned in previous dialogue in the tutorial, this scene is the first display of the player's coin total, starting at 0.

Attempting to choose a paid character allows the player to discover that they must

pay 200 coins to unlock this option (Appendix A.1.e), thereby familiarising the player with the game's unlock system mechanics. Having selected a character the player's first achievement pops up (Appendix A.1.f), rewarding them with 200 coins and 20 experience points (or XP for short). The player can return to the character selection panel to buy a new character if they wish to play with a paid option.

Achievements. As mentioned, choosing their first character rewards the player with an achievement. Achievements are given for completing a certain task and are a mark of the player's progression. The achievements award the player coins and XP and are given incrementally throughout the tutorial. The three achievements added were to: choose the player's first character, complete their first situation and finish the tutorial.

Completing their first achievement allowed the player to view the available achievements in the game, which are shown in (Appendix A.2.a). The player's level and coin total are now also displayed on the screen to the player, with a clearer label stating 'Level: 1' and a progress bar added to give a better indication of XP progress as per E6's recommendation.

Situation Home. The player is then told to try completing their first situation to earn more coins. The situation home screen asks the player to choose between a school or home situation by tapping the school or house button (Appendix A.2.b). The home option is faded so the player can test the same example situation designed in the low-fidelity prototype: 'School Lunch'.

A more concise explanation is given on how the situations work, with the language focusing on giving clear instructions on the overall objective of completing situations. The researcher removed the other situations from this scene (Appendix A.2.c) to declutter the UI and focus attention on the 'School Lunch' situation. The player is encouraged to try the situation and, as requested by E3 in the formative evaluation, an arrow points to the situation to indicate it is a button to be pushed.

'School Lunch' Situation. The 'School Lunch' situation inserts the player into a scenario in a school cafeteria where there is a conflict with one of their peers, as shown in Figure 5.3. The player's friend would rather sit with a new student than the player at lunch. Negative interactions such as this decrease the player's calm bar and require the completion of a calming option to restore it to maximum capacity. The calm bar is also more prominently pointed out to the player as being important to keep full, following feedback from E3 and E5 (Appendix A.2.d). The completed situation awards the player 500 coins, 100 XP and redirects them back to their home bedroom, unlocking the game's second achievement: 'First Situation'.

The situation attempted to give greater freedom than initially afforded in the low-fidelity prototype. First, the player can return to previous options to change their decisions using the back button. Second, the game's dialogue is less directive of the player's actions and does not dictate how they should feel in certain situations, as children's reactions are heterogeneous. The player instead can choose if a certain action, like a calming option, made them feel better, the same or worse. The player can also choose to try the calming method again or a different one, or continue with the situation, helping to meet ASD-7.

Figure 5.3: School Lunch situation

Figure 5.4: Calming options

Calming Options. There were three calming options presented in the situations. Though other decisions in situations can affect the calm bar, only counting, breathing and speaking to a trusted person are labelled as explicit calming options (Figure 5.4). As per feedback from the formative evaluation, breathing and counting contained greater visual aids, adhering to ASD-10, and allowed the player to advance early by displaying the 'Next' button before the activity finished.

The counting option displays a visual animation of the numbers 1 through 10 appearing sequentially on the screen (Appendix A.2.e), followed by a congratulatory message. For deep breathing, an animation of the text 'Breathe In' and 'Breathe Out' are shown sequentially three times (Appendix A.2.f), followed by a congratulatory message. The breathe-in text expands for 3 seconds and turns into the breathe-out text, which contracts for three seconds. Speaking to someone trusted allows the player to speak to a close teacher, parent or friend who tries to help them understand the situation and provide general support through reassuring dialogue (Appendix A.2.g).

Edit Room. After completing their first situation, the player is returned to their room where they are directed to the 'Edit Room' button. This scene, shown in Figure 5.5, allows the player to customise their room by changing the wall and floor colour and placing decorations. All wall and floor colours are free and use colours with soft tones, adhering to ASD-1 and ASD-12. The player could place decorations by selecting a different part of the room and choosing an option from the scroll bar. Each part of the room had at least one free decoration and others available for coins (Appendix A.2.h). Paid options were made affordable to ensure players were not priced out of options with a purchase they might regret. After decorating, they save and exit to complete the tutorial. An example of a completed room can be seen in Figure 5.6.

Completing the Tutorial. The end of the tutorial awards the player with a final achievement of 200 coins and the ability to tap the assistant if they need a suggestion. The player can now use the game freely, though the suggestion from the assistant is to try their first home situation. Doing so discovers that the home situations are now available, including the 'Moving House' situation (Appendix A.3.a), which was modelled on P2 and P4's comments in the design workshop.

Starting in the player's newly designed room, the situation is centred around the scenario of the child moving house (Appendix A.3.b). In a similar manner to the 'School Lunch'

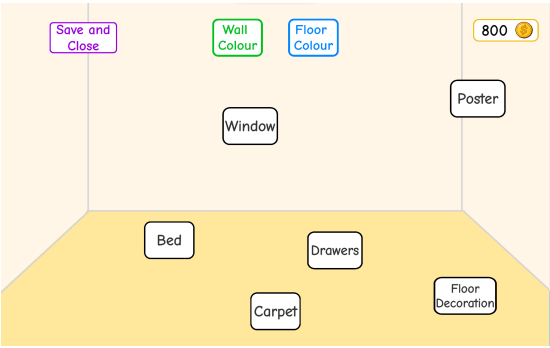


Figure 5.5: Room editing screen

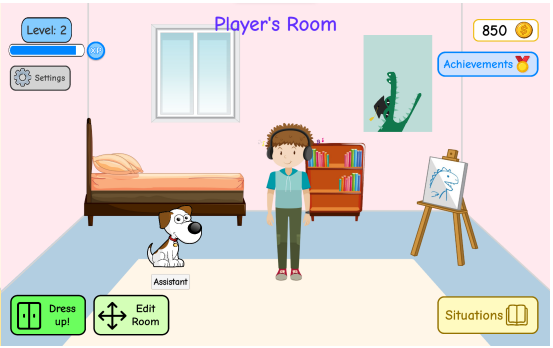


Figure 5.6: Example of a decorated room

situation, the player's calm bar is reduced dealing with potentially anxious feelings about moving house. Calming options are presented to help restore the player's calm and more non-calming story options than in the 'School Lunch' situation are included to keep the situation engaging (Appendix A.3.c). The situation spans across the player's old room, driving to the new house and their new room, and the situation ends with the player decorating their new room with their old decorations (Appendix A.3.d).

Chapter 6

High-Fidelity Prototype Evaluation

This chapter presents the evaluations of the high-fidelity prototype with peers, experts and children. This chapter helps to answer **RQ3:** *To what extent does the game help children with autism cope with anxiety in daily situations?* Section 6.1 outlines a usability study conducted with undergraduate Informatics students and academic staff members. Following this, Section 6.2 details the evaluation study involving experts in Human-Computer Interaction (HCI), Accessible Design, Computing Education, and Software Engineering. Subsequently, Section 6.3 details the evaluation conducted with children. Finally, the findings are analysed and discussed in Section 6.4.

6.1 Usability Study

The first evaluation to take place was a usability study with University of Edinburgh Informatics students and Informatics staff at a Project Event day.

Aims: This study aimed to gather quantitative data on the usability of the high-fidelity prototype and qualitative data on possible improvements before the evaluations with children and experts took place.

Participants: Though a larger number played through the game, eleven University of Edinburgh Informatics staff and Informatics students completed the form.

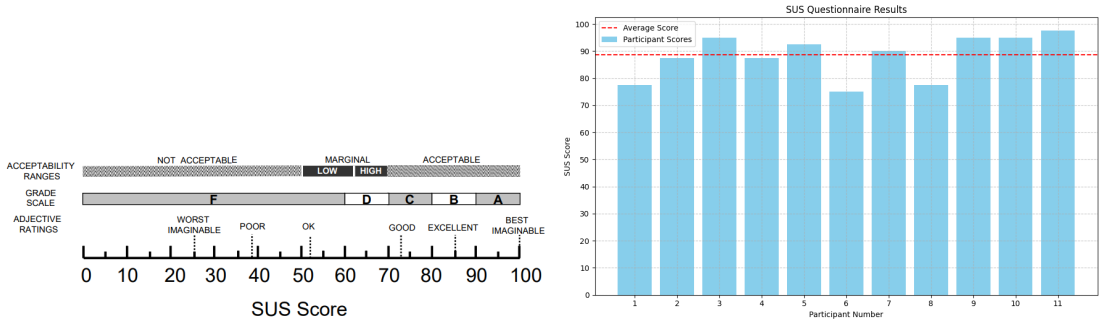
Procedure: The materials used were: the researcher's laptop with 'Calm and Collect' ready to play; the project poster (Appendix D.1); the Microsoft Form (Appendix D.2); and the usability study PIS (Appendix D.3).

Participants were offered the chance to play through the prototype at the event. If interest was shown, the researcher gave an overview of the project, its objectives and the high-fidelity prototype. Participants who elected to play through the game were invited to vocalise their thoughts and comment on usability aspects they enjoyed and others they felt needed improvement. The researcher noted down any relevant comments and then requested the participants to follow a QR code to complete the form [64].

Data Collection and Analysis: The data was collected through the SUS questionnaire [65], a widely used tool in usability studies to assess the perceived usability of a product,

follow-up questions that identified specific feedback and the researcher's notes. The SUS questionnaire consists of 10 statements where users can rate their agreement using a five-point Likert scale [66]. SUS scores were calculated using the formula in Appendix D.4. The results can be evaluated using an acceptability rating scale developed by Bangor et al. (2016) [67], as shown in Figure 6.1.a, with each SUS score corresponding to an adjective. Question answers were analysed to find any improvements that could be made before the evaluations with children and experts and the researcher's notes were analysed using open coding [68].

Results: The SUS scores were calculated and plotted, with the dotted line in Figure 6.1.b indicating the average score. The SUS scores ranged from 75 to 97.5, meaning that all results fell between the "Good" and "Best Imaginable" adjectives. The average score was 88.6, so using the adjective rating scale the participants on average found the usability of the high-fidelity prototype to be "Excellent".



(a) SUS Scale (b) SUS Results

Figure 6.1: SUS Acceptability ranges, adjective ratings and results.

Feedback from the optional questions was mostly positive, with P1 and P9 enjoying the *"friendly tone"*, P4 appreciating the *"frequent messages of encouragement"* and P8 recognising the *"incentive system with the amount of customisation settings available"*. Aspects that participants liked the least were largely based around some visual asset choices, with P4 remarking there was a *"watermarked background"* the researcher had not noticed in the 'School Lunch' situation, and P5 commenting that *"some of the visual assets were mismatched... though still suiting the calm pastel-y visual style"* when decorating the room. Other improvements were suggested, with P2 recommending *"more choices for decision making other than calming down"*, and P6 and P10 advocating for *"more options for outfits and places"* and *"the option to add custom furnishings"* respectively, as a lot of the final room decorations and non-calming options had not been added at this point.

The researcher also noted that participants looked to skip the breathing and counting animations early and at times were not certain which part of the tutorial they needed to navigate to. The improvements of fixing some visual asset errors, adding more non-calming options, skipping calming options early, clearer arrow and button animations in the tutorial and adding a wider range of room decoration options were therefore made before the following evaluations with children and experts.

6.2 Evaluation with Experts

6.2.1 Aims

This evaluation had the following key goals:

- Establish whether the game is appropriate for the target audience.
- Determine the suitability of the game to help children cope with anxiety in difficult situations.
- Determine whether the game is engaging, intuitive and easy to play for the target audience.
- Identify any usability challenges and frustrations.
- Gather feedback and suggestions for future improvements.

6.2.2 Participants

Experts E2 through to E6 from the formative evaluation all participated in the final evaluation. Three other experts joined them for a total of eight experts, as summarised in Table 6.1.

Participant Number	**Occupation**	**Area of Expertise**
E1	PhD Student at the University of Edinburgh	HCI
E2	Software Engineer	HCI and Accessible Design
E3	Reader in Design Informatics at the University of Edinburgh	HCI, Sociology of Technology and Accessible Design
E4	Reader in Computer Science Education at the University of Edinburgh	Computing Education and Access to Computing Education
E5	Software Engineer	HCI
E6	Lecturer at the University of Edinburgh	Software Engineering and HCI in Usability Contexts
E7	PhD Student at the University of Edinburgh	HCI
E8	Product Manager	UX, UI and accessible design

Table 6.1: Expert participants for the final evaluation

6.2.3 Methods and Procedure

Evaluations with E1 and E3 took place in person and the others were conducted over Microsoft Teams. The materials used for the evaluations were: a Consent Form (Appendix E.6) and a PIS (Appendix E.5), a computer with 'Calm and Collect' installed and a backup mobile phone to record sessions.

Evaluations took place individually, with each expert signing and returning the Consent Form before the session. Sessions in person were conducted by allowing the expert to play through 'Calm and Collect' on the researcher's laptop and online sessions used an installer sent by the researcher to install the game onto the expert's computer. Each session used the same cooperative evaluation methodology [60] used in the formative evaluation to allow open dialogue between the researcher and experts, including clarifying questions on user behaviour.

However, issues regarding application and security permissions on devices running macOS meant the installer was unable to open 'Calm and Collect'. In these cases, the researcher shared their screen to demonstrate the game, where the researcher stepped through and the expert made decisions as if they were playing. After finishing, the researcher asked each expert several questions in a semi-structured interview. The questions (Appendix E.8) referred to: the game's suitability for the target audience; its engagement, intuitiveness and ease of use from a child's perspective; complicated aspects that could frustrate users; its effectiveness in helping children cope with difficult situations; other suggestions and improvements for the game.

6.2.4 Data Collection and Analysis

The data was collected through recordings of the sessions and notes from the researcher. Thematic Analysis [55] was used on the data and highlighted the following themes: **1)** Appropriateness for the target audience; **2)** Effectiveness as a tool; **3)** Engagement; **4)** Ease of use; **5)** Usability challenges and frustrations; **6)** Improvements and suggestions.

6.2.5 Results

Appropriateness for the target audience. All experts thought that the game, in general, was suitable for the target audience. E2 stated that: *"The vocabulary seems easy to understand for the target group, the situations seem relatable too"*. E5 noted the appealing design, stating: *"It's suitable, the looks of the assets are great... nice cartoonish characters and objects"*. E8 noted the impact the music could have: *"I think so, it's very calming throughout. The music kept me calm, I think for a user with autism that's a great thing"*.

Some experts believed that varying some game aspects based on the player's age could further enhance suitability. E3 stated that: *"It's a great baseline. 7-year-olds might not be as fluent in reading, but it is applicable in general"*. Slightly contrary to E3, E4 said: *"I think it is [suitable], maybe for the younger ones, but could be the full range depending on development"*. E7 suggested it could take time for the younger age group to adapt, stating: *"9 to 11 [year-olds] would be fine, but clicking some buttons for 7 and 8-year-olds could be challenging, though the touch screen aspect will help with that"*.

Effectiveness as a tool. The experts were all positive about the tool's potential to help children with autism cope with anxiety. E1, E2, E3, E6 and E7 all mentioned that the coping strategies were presented in a way that could help children in real life. E1 stated it could be a good way *"to practice calming techniques"* and E3 commented that it could be used for *"teaching kids strategies"*. E7 was similarly optimistic, stating: *"I*

think they will start intuitively counting and breathing along with the game, and they'll start feeling calm inside".

Two of the experts, E1 and E4, pointed out that close collaboration with parents and educators could maximise the tool's use. E1 commented that children using the calming options *"would do well with parents explaining why it's important"*. As the situations were set by the researcher and not customised for each player, E4 believed that these perspectives would be best when designing situation resolutions: *"The role-playing idea is useful, though it is an artificial situation where you have to predict responses. There's a lot of ways the situation could be resolved, so you'll need a lot of good advice from experts about that"*.

Engagement. The reward system helped contribute to this positive user experience, with E2 stating: *"You've made it engaging by giving them rewards and a corresponding certificate"* and E7 expressing that *"the reward is very good... it incentivises children to complete situations"*. E6 agreed that the engagement of the game had taken a step forward, saying that aspect *"was much better than the low-fidelity"*. E4 thought further incentive could be given, suggesting that *"fewer free options might increase motivation, though if they're working with parents and teachers that will motivate them"*.

Ease of use. The experts were in unanimous agreement about the game's appealing and intuitive design. E1, E2, E6 and E8 commented on the appropriate colour scheme and all experts liked the visual assets used for the customisation options, making the game easier to play through. E2 stated: *"It would be easy to play through... you have the character who gives instructions... I like you have an arrow to signal which step is next"*.

Usability challenges and frustrations. E3 and E6 both mentioned that the tutorial's length could be frustrating, with E3 stating: *"The duration of the tutorial is long... integrate it more... anytime a game aspect is too drawn out could be a weakness."* E6 similarly said: *"The only thing that is frustrating is too many steps in the tutorial, I would have an intermediate setting for users wanting to move faster"*. E1 pointed out that greater clarity on how the calm bar functioned could help aid usability, as *"the calm level going down could be frustrating, you could have an even more basic example showing the calm bar"*. E8 similarly mentioned that *"the child might not know the end goal, especially when they see the calm bar going down and they don't know how to help it"*.

Suggestions and improvements. The most common suggestion made for future work regarded finding more ways to vary the experience for each user. E3 stated: *"You could set their age and adjust their stories... they don't want another thing that sounds like their parents"*. E5 mentioned the importance of providing repeatability, suggesting the benefit of *"the admin adding custom situations to stop the child getting bored of default ones"*. E6 also favoured a wider range of options, stating: *"It would be great for parents to set up other strategies for kids... they could choose from a library of games or songs and play through their favourites"*.

Adding more animations across the game was recommended by some experts, with E1 and E3 both mentioning the potential benefit of an extra animation showing the calm bar

decreasing. E5 added that other small interactive animations for the rewards, such as *"the coins and XP could move to the bar and coin total when you get them"* and objects in the bedroom, such as *"when you tap your assistant or a decoration, think about it moving or playing a sound"*, could help to further improve the game's experience for children.

6.3 Evaluation with Children

6.3.1 Aims

This evaluation had the following key goals:

- Determine if the tool is suitable for the target audience.
- Establish whether the target audience finds the game enjoyable, engaging and easy to use.
- Determine whether the tool could help children overcome anxiety in difficult situations
- Gather feedback for improvements in future work.

6.3.2 Participants

The same four children from the design workshop participated in the final evaluation, as summarised in Table 6.2.

Participant Number	Age	Gender
P1	12	Female
P2	12	Female
P3	7	Female
P4	10	Male

Table 6.2: Child participants for the final evaluation

6.3.3 Methods and Procedure

Evaluations with participants P1, P2 and P3 were in person and P4's session took place on Microsoft Teams. The materials used for the evaluations were: PIS (Appendix E.1) and Consent Form (Appendix E.2) for parents; PIS (Appendix E.3) and Consent Form (Appendix E.4) for children; a computer with 'Calm and Collect' installed; a certificate of attendance (Appendix E.7) and a backup mobile phone to record sessions.

The parents were contacted through email, and upon agreement for their child to participate, Consent Forms were signed and returned before the session. P1 and P2 evaluated the tool together and P3 and P4 evaluated the tool individually. Before each session, the researcher explained the prototype's pertinent details to the participant(s) and the purpose of the evaluation. The session with P3 was conducted by allowing the

participant to play through the prototype on the researcher's laptop while the researcher took note of the participant's behaviour and comments. Due to English not being the participant's first language, the researcher assisted by reading some dialogue aloud to the participant. The researcher assisted P4 in setting up the prototype's installer on his computer and similarly allowed the participant to play through the game freely while noting the participant's experience.

As P1 and P2 undertook the evaluation together and were familiar with each other, the researcher opted to use the constructive interaction [69] method for their evaluation. Constructive interaction is a version of think aloud where two participants collaborate on the same task and verbalise their thoughts. This method often appears more natural than think aloud and can often be more productive, especially when the individuals know each other. After completing the game, the researcher asked each participant three 5-point Likert scale questions to rate the game's fun, engagement and ease of play and if they thought they could use anything from the game in real-life situations. Additionally, participants were asked to give two stars (two features they liked) and a wish (a feature they wished to see improved or changed), followed by any other suggestions for improvements. The full questions are listed in Appendix E.9.

6.3.4 Data Analysis

The data was collected through recordings of the sessions and notes from the researcher. Thematic Analysis [55] was used on the data and highlighted the following themes: **1)** Fun; **2)** Engagement; **3)** Ease of use; **4)** Favourite features; **5)** Applicability of calming strategies; **6)** Improvements and Suggestions.

6.3.5 Results

Fun. P1 and P2 mutually agreed on all their ratings, rating the fun of the game as a 3 out of 5. However, both participants recognised they were older than the target age group, as mentioned by P1: *"I would actually play this if I was younger... it would be a 4 to 5"*. P3 gave it a 5 and P4 rated it as 4.

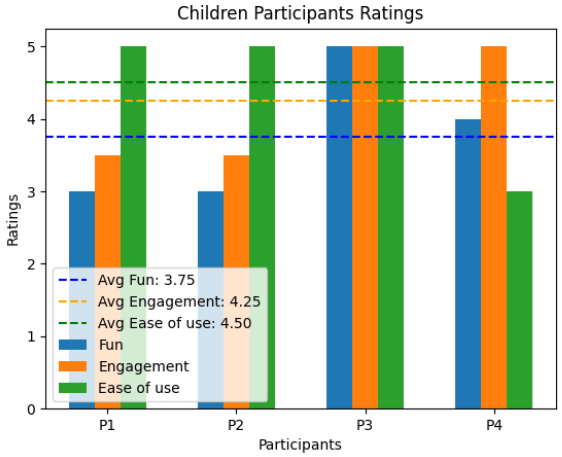


Figure 6.2: Children ratings of fun, engagement and ease of use

Engagement. P1 and P2 gave the engagement a 3.5, with P2 stating: *"I agree [with P1]. I remember how I was, I would find this game perfect"*. P3 and P4 both rated the game's engagement as 5.

Ease of use. P1 and P2 agreed that the game was a 5 for ease of play. P3 was insistent the game was "1000" for ease of play, so this was taken to mean a 5. P4 rated the game as a 3, stating: *"It's quite easy but there are some challenging bits. You could make some decisions that could be costly"*. The full ratings are compared in Figure 6.2.

Favourite features. The choice of situations was highlighted by most of the participants as a favourite feature of theirs. P1 thought they were relevant, stating: *"I liked the situations, I think they were quite realistic"*. P4 agreed, mentioning that they were *"very good situations and they're very realistic and that's why I like them"*. P3 enjoyed both situations, mentioning: *"At school, I liked talking with my friend"* and *"I liked when we moved houses because I got my tank of fishies"*.

The participants also enjoyed the visual asset choices in the game, particularly customisation options. When editing their room, P2 remarked: *"I love these posters, I would want one of these posters... they're so beautiful... I love that zebra... I love that one let's get that one, that fits our room"*. P1 enjoyed picking out room options with P2, mentioning that *"fish tanks are very relaxing"* and that *"if you get that [guitar decoration] then that makes you feel calm"*. Choosing the wall, floor and carpet colours was a highlight for P4, remarking *"Ooh a carpet!"* and, having selected his colours, said *"I think that looks good"*.

Applicability of calming strategies. All four participants were positive the calming strategies could be applied to real-life situations. P1 thought that *"the coping things were great and you could do it in real-life"* and P2 stated that *"it was good to step away for a second, you could definitely use that"*. P3 and P4 enjoyed using the strategies in situations, with both noticeably counting and breathing with the animations. When asked if they would use any strategies in real life, P3 answered *"calming and breathing"*. P4 similarly said: *"Yeah definitely. The options to count to 10, breathing and talking to the teacher, all of these are good"*.

Improvements and suggestions. Having enjoyed the game's customisation aspects, the participants all requested additional options to be included. P1 would have liked to *"choose what the music was"* and P2 sought more *"customisation on the character... it would be nice to change the hair and clothes"*. P3 would have liked to see *"a bunk bed... more books [in the drawers]... a cat [assistant option]"* and *"the whole rainbow!"* for room colours. P4 stated that they *"like the room idea"* but wanted more options, mentioning that *"the drawers look the same... more colours... add a back garden to do stuff and customise in"*.

Extending and having situations cross over was seen as a potential improvement by some participants. P4 suggested having *"different levels... every different level you have different options"*. P2 mentioned the possibility of seeing an earlier situation's character again: *"You could meet up with Jake again later!"*. P1 proposed extending the 'Moving House' situation: *"Maybe the parents have an argument after moving house, which makes the character uncomfortable and needs to calm down"*.

6.4 Discussion

Enjoyability. The data from the evaluation with children gave some indications to the tool's enjoyability from the target audience's perspective. As seen in Figure 6.2, the tool was rated 3.75 on average, however, the two participants who were aged 12 acknowledged that had they been younger their rating would be 1 to 2 points higher. This data answers **RQ3.1:** *Is the game enjoyable for the target population?* positively, suggesting it is.

Engagement. Both evaluations with experts and children gave some insight into the game's engagement. The experts in general believed the game to be engaging, citing the incentivising reward system and realistic situations as key drivers for this measurement. The evaluation with children provided empirical quantitative data to support the experts' comments, as the game's engagement was rated as 4.25 out of 5 on average, with the same children stating a higher rating would have been awarded had they been within the target age group. The data gathered from these studies therefore positively answers **RQ3.2:** *Is the game engaging for the target population?*.

Usability. All three studies provided data for this metric. The study from Informatics students and staff gave very positive initial indications of the tool's usability. The average score from the SUS questionnaire was 88.6, signifying the game's usability was "Excellent", and even the lowest calculated scores were still above the threshold for "Good" usability. Qualitative data from the experts supported this assessment by commenting positively on the game's ease of use, with the game's colour scheme, visual choices and intuitive design as the main contributors. Both quantitative and qualitative data from the evaluations with children also suggest high usability, as the average ease of use rating was 4.5 and children often expressed positive comments about the game's design choices, styles and options. The positive results from all three studies suggest that **RQ3.3:** *Is the game easy to use for the target population?* is answered positively.

Suitability for the target population. The tool and its activities were regarded as suitable for the target population through the qualitative data expressed in the experts' evaluation. The vocabulary, situations, visual assets and music were all considered appropriate for children with autism, and even experts who recommended more variation for different ages within this range believed it was a good baseline for this audience. The data from this study therefore suggests that the game, even as a baseline, positively answers **RQ3.4:** *Are the activities in the game suitable for the target population?*.

Potential effectiveness of the tool. The data gathered from both evaluations with experts and children indicated that the tool had the potential to be effective in helping children with autism cope with anxiety. The comments from the experts suggest they thought the calming strategies were simple, easy to practice and applicable in real life. The children's assessment of the game supported this, as all four believed the coping strategies used in the tool could be applied in difficult situations. The data gathered from both evaluations therefore affirm **RQ3.5:** *To what extent could the game be a success in presenting strategies to help cope with anxiety for the target population?*.

Chapter 7

Conclusions and Future Work

This chapter answers the project's research questions and discusses its limitations, future work and conclusions.

7.1 Research Questions

RQ1: *What are the most common challenges that might elicit anxiety in children with autism?*

This research question was split into the following sub-questions:

RQ1.1: *What challenges commonly arise at home?*

This sub-question was answered by conducting a workshop with children. The results indicated that participants often felt stressed when moving to a new place, such as a new home, or encountering unfamiliar people. Participants often found that scenarios encountering information imbalances with adults can also cause anxiety. These results informed the researcher's design and development of the 'Moving House' situation.

RQ1.2: *What challenges commonly arise at school?*

This sub-question was also answered in the workshop with children. The results were similar to challenges at home but focused on the difficulty social situations could bring. New classmates and teachers, meals and moving schools all place children in unfamiliar situations and can cause anxiety. These results informed the researcher's design and development of the 'School Lunch' situation.

RQ2: *How can a technology-based game be designed to present strategies to help children with autism cope with anxiety?*

This research question was split into the following sub-questions:

RQ2.1: *What requirements are needed to effectively design the game?*

This sub-question was answered by reviewing previous literature on the subject and analysing the design workshop's results. The researcher gathered ideas on game components from participants, successful designs in previous work from the literature

and well-established HCI and ASD design principles to create requirements for the tool's design. This generated the design decisions summarised in Section 3.3 Table 3.2, which were used for the low-fidelity prototype's design. The low-fidelity prototype's evaluation with experts allowed the requirements to be further refined to effectively design the game.

RQ2.2: *How can we involve stakeholders in creating the game?*

Stakeholders were involved at every stage of the project as their input and feedback were critical components for project decisions and evaluations. Children in or close to the target audience were involved initially to gather high-level requirements and design implications for the game. The same children then evaluated the game to see if the tool was fun, engaging and easy to play. Experts in relevant fields were consulted on both prototypes, and their feedback was fundamental when evaluating whether the tool and its components were appropriate for the project goal. Though most children were TD, they were able to give feedback on their preferences for the app's age range. When combined with experts evaluating certain game components' suitability for children with autism, TD children formed a good approximation of the target population.

RQ3: *To what extent does the game help children with autism cope with anxiety in daily situations?*

This research question was split into the following sub-questions:

RQ3.1: *Is the game enjoyable for the target population?*

This sub-question was answered through the summative evaluation with children, who were asked to rate the game based on how much fun they had. **RQ3.1** is therefore answered positively, as the game's enjoyability was rated 3.75 out of 5 on average, with two participants acknowledging the rating would have been higher had they been within the target age range.

RQ3.2: *Is the game engaging for the target population?*

Evaluations with children and experts answered this sub-question. The study with children indicated that all found the game engaging to play and the experts were largely in agreement that it was a good baseline for engagement with the population, though some wanted added customizability to solidify this. As its engagement was rated 4.25 out of 5 on average by the children, and comments from experts indicated the game would be engaging for the target population, the answer to **RQ3.2** is therefore positive.

RQ3.3 *Is the game easy to use for the target population?*

Positive results from the summative evaluation with Informatics students and academic staff, experts and children indicated the game was easy to use. The usability study reported positive results, suggesting that the game's usability was 'Excellent', while the experts agreed that the game's design and visuals made it easy to use. Finally, the children all found the game easy to play, though one found a couple of aspects challenging. Due to the 'Excellent' usability rating, an average ease of use rating of 4.5 out of 5 from the children and positive comments from experts, the answer to **RQ3.3** is positive.

RQ3.4: *Are the activities in the game suitable for the target population?*

The summative evaluation with experts answered this sub-question. The experts agreed that the game's tasks were appropriate and the reward system was suitable for the target audience, with only minor usability issues pointed out. Since the experts deemed the game's activities were suitable for the target population, **RQ3.4** is answered positively.

RQ3.5: *To what extent could the game be a success in presenting strategies to help cope with anxiety for the target population?*

The experts from the summative evaluation agreed that the game, using a blend of simple but practical coping strategies, realistic situations and appealing rewards, was an appropriate solution for the project's goal. Though there were suggestions from experts about adding more customisation in the presented situations and coping strategies, the game was overall deemed to have the potential to be a success in helping the target population overcome anxiety, thus positively answering **RQ3.5**.

7.2 Limitations

One limitation regards the participants the project was able to recruit. The vulnerability of the target population made it difficult to identify participants who were diagnosed with ASD, within the age range and willing to participate in multiple studies. Two participating children were outside the age range and had to act as proxies for children within the age range, so recruiting a larger number of participants firmly within the target audience could give more weight to the results of this study.

A further limitation of the project lies in its nature as a proof of concept. While the project showed promising results from preliminary evaluation sessions with experts and children, it is limited to a controlled setting. The game's real-world applicability could vary depending on the differences in children with autism and other factors outside the project's scope. It is, therefore, necessary to use a longer-term study with more iterations of the technology to assess its suitability before considering widespread adoption.

7.3 Future Work

Addressing challenging features, such as the tutorial and the calm bar, noted by the experts in the summative evaluation would be the initial future work undertaken. Integrating the tutorial could explain the game's key objectives and components less intrusively and would help improve user experience and enjoyability. A further improvement to user experience could be implemented by providing greater clarity on how the calm bar functions. Rather than introducing the calm bar in the first situation, a shorter and simpler example would better illustrate the importance of keeping it full and ensure users understand how to play through situations effectively.

Accounting for the heterogeneous nature of children with ASD is crucial when developing technology for this population. The tool's long-term development would therefore focus on enhancing its adaptability to the population's diverse needs through more

extensive customisation options and a platform for caregivers to set them. Integrating a tool that could let caregivers easily implement situations with tailored resolutions and coping strategies could allow children to better simulate real-life scenarios and practice staying calm. Adding further options to customise room themes, characters and music would also help promote a friendly and incentivising environment for children to play through.

After incorporating these improvements into the tool, the next step would be to involve more stakeholders, especially children diagnosed with ASD, in further design and testing studies. Children, either individually or as caregiver-child dyads, could use the tool for several weeks in an extended study. By comparing self-reported anxiety levels and other metrics from before and after the tool's use, the game's impact on the target population could then be thoroughly measured for real-life situations.

7.4 Conclusions

This project explored how a technology-based intervention could be developed to help children with ASD overcome anxiety in stressful situations at home and school. Using a participatory approach that involved children and experts in HCI, ASD and education throughout the project, a tablet-based game has been designed, implemented and evaluated iteratively. Evaluating the tool highlighted its potential to support children when encountering difficult situations by providing strategies to stay calm in a fun, engaging and accessible game. The project's contributions are as follows:

1. The identification of the common challenges between situations at home and school that might cause anxiety in children with autism.
2. A design concept and implementation of a tablet-based game that presents coping strategies to children with autism in difficult situations, based on the previous literature and empirical data collected from studies with children and experts.
3. The provision of empirical evidence through evaluations with Informatics students and academic staff, children and experts indicating that the game has the potential to support children with ASD overcome anxiety in challenging daily situations.

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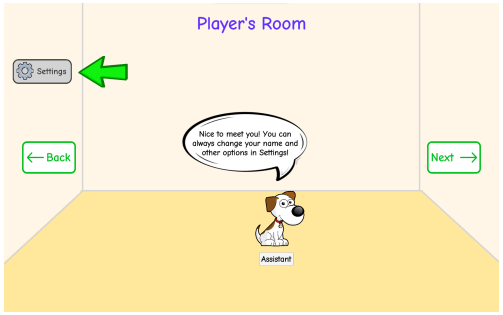
Appendix A

High-Fidelity Prototype Screenshots

(a) Choose Player's Name

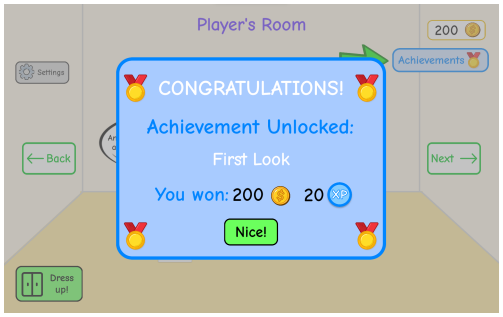
(b) Choose Assistant's Name

(c) Play As Me or Someone Else Choice



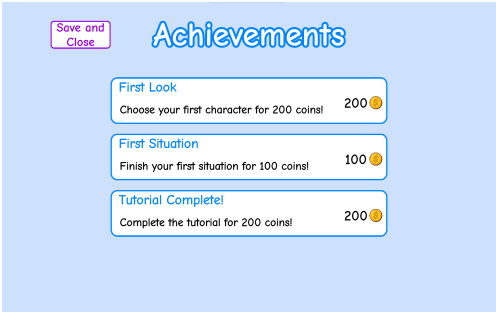
(d) Introducing a new button

(e) Trying to unlock a character



(f) First Achievement Unlocked

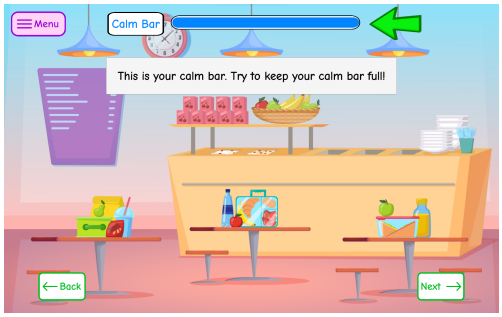
Figure A.1: High-fidelity prototype screenshots



(a) Achievements Screen

(b) Choose Home or School Situation

(c) Choose School Lunch



(d) Calm Bar Introduction

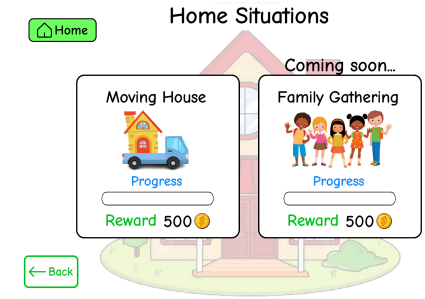
(e) Counting Calming Option

(f) Breathing Calming Option

(g) Speaking to Someone You Trust

(h) Decoration Options

Figure A.2: High-fidelity prototype screenshots 2



(a) Home Situations

(b) Moving House Situation Start

(c) Non-Calming Options

(d) Moving House Ending

Figure A.3: High-fidelity prototype screenshots 3

Appendix B

Design Study Materials

B.1 Participation Information Sheet - Parent/Guardian

Participant Information Sheet – for parents and guardians

Project title:	Toward a Technology to Overcome Anxiety in Children with Autism
Principal investigator:	Dr Aurora Constantin
Researcher collecting data:	Benjamin Norman
Funder (if applicable):	

This information sheet is for parents and guardians. It explains the 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.

This study was certified according to the Informatics Research Ethics Process, reference number 818448. Please take time to read the following information carefully. A shortened version of this information will be read aloud to your child should you agree to their participating in the project. You should keep this page for your records.

Who are the researchers?

Lead Researcher: Benjamin Norman (s2022343@ed.ac.uk)

Supervisor: Dr Aurora Constantin (aurora.constantin@ed.ac.uk)

What is the purpose of the study?

Many different circumstances can cause children with autism to suffer with anxiety. These include social situations, changes to their routines, and disruptive events such as the COVID-19 pandemic. The goal of my project is to design a technology-based tool to help children with autism cope with and manage their anxiety in different situations.

How can my child help?

Your child will take part in one to maximum three workshops. The workshops will comprise a variety of activities which will help to inform the design of my prototype and provide potential ideas to enhance fun and engagement with the technology designed.

Does my child have to take part?

No – participation in this study is entirely up to you and your child. You can withdraw your child from the study at any time, without giving a reason. Your child may also withdraw at any time by saying that s/he does not want to take part any more. Your rights will not be affected. If you wish to withdraw, contact the PI. We will stop using your child's data in any publications or presentations submitted after you have withdrawn consent. However, we will keep copies of your and your child's original consent, unless your child is too young to reasonably give written consent, in which case we will only keep parent consent forms, and of your withdrawal request.

What will happen if my child takes part?

The workshop will take place in person or online (depending on your preference) with the researcher Benjamin Norman and the supervisor Dr. Aurora Constantin present. Your child will be able to participate and engage in numerous requirement and design gathering activities, such as group discussions and drawing designs, and provide feedback and ideas to help inform the next steps. Each workshop will last about 30 minutes. We would like to video record this session to provide record for later analysis and allow us to freely interact with your child during the session without having to take notes. The video will only be used to transcribe the audio and then deleted, and not shown to any other parties during analysis. If you are not comfortable with your child being video recorded, then your child should not participate in this particular study.

Are there any risks associated with taking part?

There are no significant risks associated with participation.

Are there any benefits associated with taking part?

There are no benefits/forms of compensation for taking part in this study.

What will happen to the results of this study?

The results of this study may be summarised in published articles, reports and presentations. Quotes or key findings will be anonymized: We will remove any information that could, in our assessment, allow anyone to identify your child. With your consent, information can also be used for future research. Your child's data may be archived for a minimum of two years.

How will personal information be protected?

Your child's data will be processed in accordance with Data Protection Law. All information collected about your child will be kept strictly confidential. Your child's data will be referred to by a unique participant number rather than by name, for example 'Participant 1', 'Participant 2' etc. Your child's data will only be viewed by the researcher/research team of lead researcher Benjamin Norman and his supervisor Dr. Aurora Constantin.

All electronic data will be stored on a password-protected encrypted computer, on the School of Informatics' secure file servers, or on the University's secure encrypted cloud storage services (DataShare, ownCloud, or Sharepoint) and all paper records will be stored in a locked filing cabinet in the PI's office. Your and your child's consent information will be kept separately from your / your child's responses in order to minimise risk.

What are my and my child's data protection rights?

The University of Edinburgh is a Data Controller for the information you and your child provide. You have the right to access information held about your child. Your right of access can be exercised in accordance Data Protection Law. You also have other rights including rights of correction, erasure and objection. For more details, including the right to lodge a complaint with the Information Commissioner's Office, please visit www.ico.org.uk. Questions, comments and requests about your personal data can also be sent to the University Data Protection Officer at dpo@ed.ac.uk.

Who can I contact?

If you have any further questions about the study, please contact the lead researcher, Benjamin Norman (s2022343@ed.ac.uk).
If you wish to make a complaint about the study, please contact inf-ethics@inf.ed.ac.uk. When you contact us, please provide the study title and detail the nature of your complaint.

Updated information.
If the research project changes in any way, an updated Participant Information Sheet will be made available on http://web.inf.ed.ac.uk/infweb/research/study-updates.

Alternative formats.
To request this document in an alternative format, such as large print or on coloured paper, please contact Benjamin Norman (s2022343@ed.ac.uk).

General information.
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 say that s/he does not want to take part anymore.

For general information about how we use your child's data, go to: edin.ac/privacy-research

Thank you for taking the time to read this.

B.2 Consent Form - Parent/Guardian

Design Workshop Permission 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 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 developer.

If you **give permission** for this study, please fill out the sections below and **return this form to the researchers.**
If you **DO NOT** wish to give permission, **you do not need to do this**. 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: _____

Signature: _____

Date: _____ /_____/_____

THE UNIVERSITY of EDINBURGH
informatics

October 2023

B.3 Participation Information Sheet - Child

Participant Information Sheet

Project title:	Toward a Technology to Overcome Anxiety in Children with Autism
Principal investigator:	Dr. Aurora Constantin
Researcher collecting data:	Benjamin Norman
Funder (if applicable):	
RT number:	818448

Designing and Testing Technology to Help Children

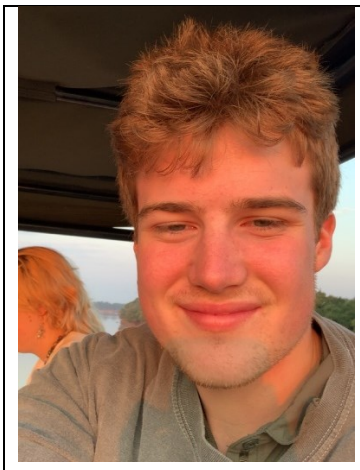
(may be read aloud to the child)

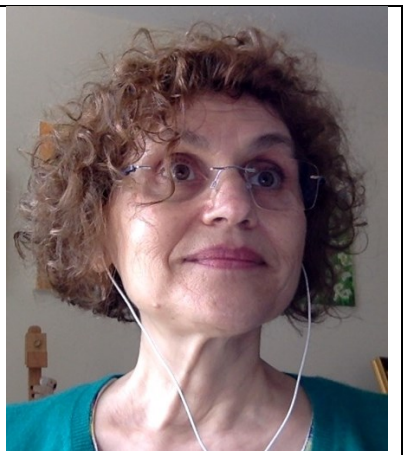
This page is for children. Some researchers are organising a study **at the University of Edinburgh**. It says who they are, and what they will do **during the study.**

They will ask you to help with making and testing new games/apps, take part in different activities, and answer a few questions. You can decide if you want to say "yes" or "no" to helping and can **change your mind at any time**.

Who is organising the study?

This is Ben, who is a student in the School of Informatics. Their job is to make a new app or game that can help children. They will ask you to help them by giving some ideas, taking part in different activities, help test the app/game, and answer some questions. Aurora is a lecturer, and she is guiding Ben in creating the app or game.





Ben	Aurora

How can I help?

Some children with autism find that lots of different things can make them worried. They might find simple activities like talking to other people and changes to their usual activities harder than most children. Sometimes they find it hard to understand and manage what they are feeling. We would like to design some kind of fun app or game to help these children with their worries, and we would like you to help us! We would like to hear your ideas for ways to make some of these situations less scary and we would like you to help us to make our games fun.

What will happen if I help?

You will get to take part in workshops to create and test a game app. During these workshops you will participate to various activities. You will get to talk with other children about your ideas, and we might ask you to do some drawings to work out your ideas.

You can tell us if you want to stop doing any of the activities. You do not have to tell us why. Please tell us if you need the toilet, or if you want to take a break. You can also say you do not want to help any more, and that is OK. We will always listen to you.

The researchers will ask if it is OK to make an audio or video recording of you helping design the game, doing activities and answering questions. This is because it is too hard for them to write down everything that happens. They will listen to or watch the recording later to help them understand what your ideas and thoughts were.

What will happen after I have finished helping?

The researchers will learn a lot about children and designing games and apps from the ideas and feedback that you give when you take part in the experiment. They will

write about what they have learned and use it to help to create designs and then evaluate how good they are.

Do you want to ask a question?

It is OK to have more questions. You can ask the researchers as many questions as you want about the experiment. Ask your mum or dad to help you call them on the phone or write an email with your question.

B.4 Consent Form - Child

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 game/app 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 game/app
developer anymore.

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

There are no wrong answers to questions.

Anything I can do is very helpful.

Do you want to be a game developer? YES / NO

Aurora and Ben will listen to/watch the recordings later.
They will not show them to other people.

Is it okay to take video recordings? YES / NO

Write your name:

_____

THANK YOU 😊!!

October 2023

B.5 Certificate of Attendance

Figure B.1: Certificate of Participation

B.6 Persona Slides

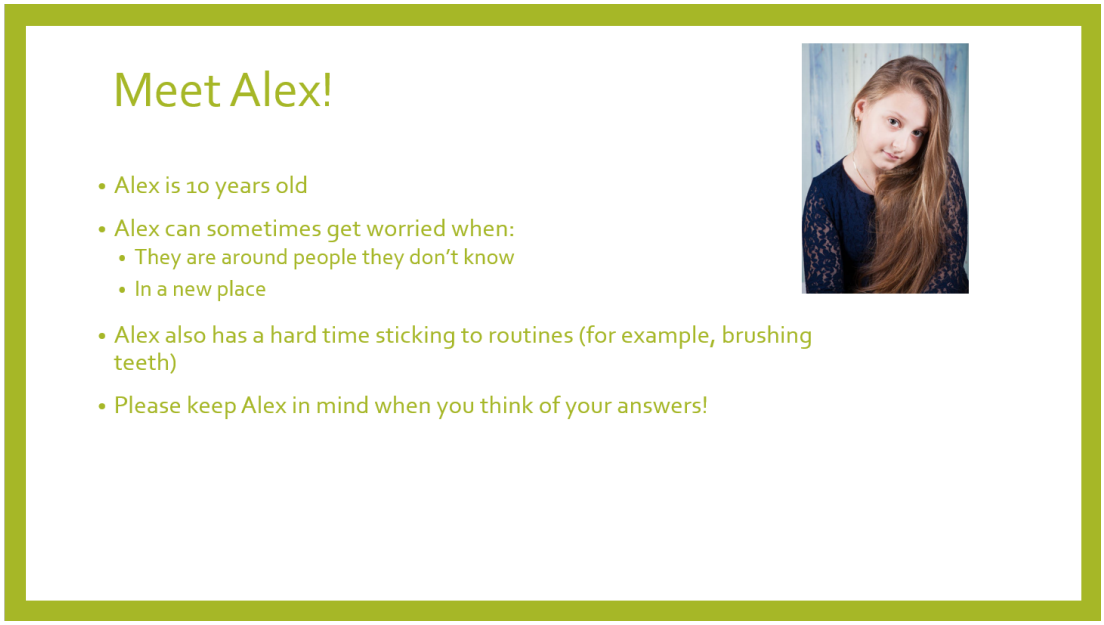


Figure B.2: Persona - Female

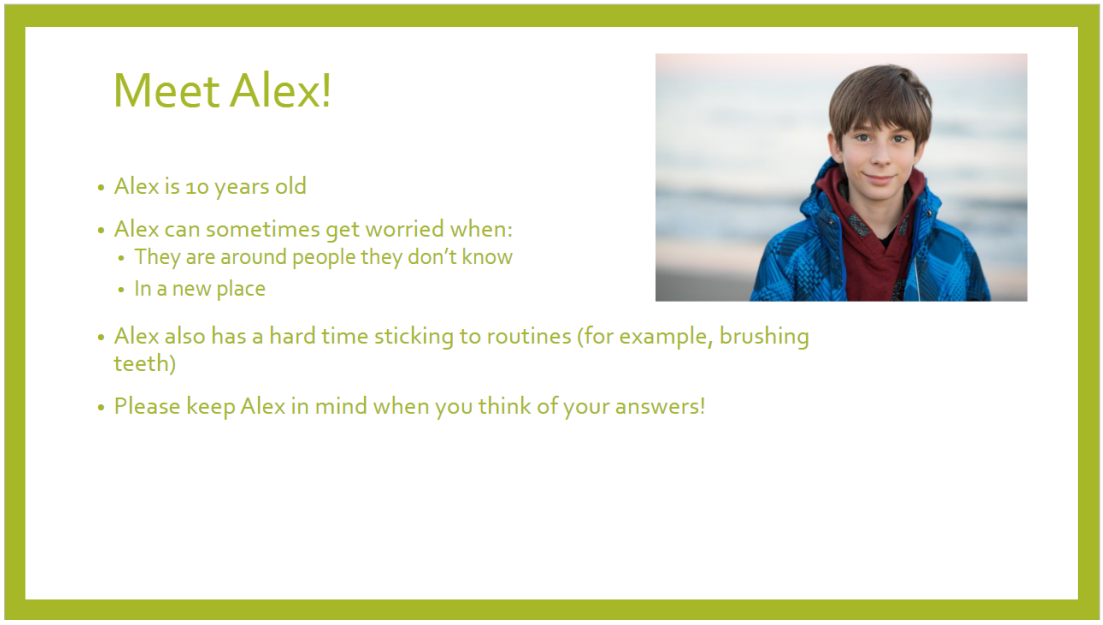


Figure B.3: Persona - Male

Appendix C

Formative Evaluation Materials

C.1 Formative Evaluation Consent Form

Formative Evaluation Permission Form

	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 you 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 recording.

If you **give permission** for this study, please fill out the sections below and **return this form to the researchers.**

Full name: _____

Contact telephone number: _____

E-mail address: _____

Signature: _____

Date: _____ /_____/_____

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October 2023

C.2 Formative Evaluation Participation Information Sheet

Participant Information Sheet

Project title:	Toward a Technology to Overcome Anxiety in Children with Autism
Principal investigator:	Dr Aurora Constantin
Researcher collecting data:	Benjamin Norman
Funder (if applicable):	

This information sheet is for experts in the formative evaluation. It explains the research project at the University of Edinburgh. 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.

This study was certified according to the Informatics Research Ethics Process, reference number 818448. Please take time to read the following information carefully. You should keep this page for your records.

Who are the researchers?

Lead Researcher: Benjamin Norman (s2022343@ed.ac.uk)

Supervisor: Dr Aurora Constantin (aurora.constantin@ed.ac.uk)

What is the purpose of the project?

Many different circumstances can cause children with autism to suffer with anxiety. These include social situations, changes to their routines, and disruptive events such as the COVID-19 pandemic. The goal of my project is to design a technology-based game to help children with autism cope with and manage their anxiety in different situations.

What is the formative evaluation?

The formative evaluation seeks to gain feedback on the low-fidelity prototype for the high-fidelity prototype I will create for the game. The prototype has been created in Figma and simulates the main actions that will be undertaken in the high-fidelity

prototype. This is a very important stage of the design process, as getting feedback from experts in relevant fields will help to improve my final design.

What will the formative evaluation look like?

The formative evaluation will begin with an overview of the prototype and the key mechanics behind it. You will then be given time to explore the prototype freely while thinking aloud. The researcher may direct you to certain parts of the prototype to get further feedback or clarification on certain parts. The evaluation will conclude with a semi-structured interview to discuss certain key points on its suitability and other feedback.

Are there any risks associated with taking part?

There are no significant risks associated with participation.

Are there any benefits associated with taking part?

There are no benefits/forms of compensation for taking part in this study.

What will happen to the results of this study?

The results of this study may be summarised in published articles, reports and presentations. Quotes or key findings will be anonymized: We will remove any information that could, in our assessment, allow anyone to identify you. With your consent, information can also be used for future research. Your data may be archived for a minimum of two years.

How will personal information be protected?

Your data will be processed in accordance with Data Protection Law. All information collected about you will be kept strictly confidential. Your data will be referred to by a unique number rather than by name, for example ‘Expert 1’, ‘Expert 2’ etc. Your data will only be viewed by the researcher/research team of lead researcher Benjamin Norman and his supervisor Dr. Aurora Constantin.

All electronic data will be stored on a password-protected encrypted computer, on the School of Informatics’ secure file servers, or on the University’s secure encrypted cloud storage services (DataShare, ownCloud, or Sharepoint) and all paper records

will be stored in a locked filing cabinet in the PI's office. Your consent information will be kept separately from your responses in order to minimise risk.

What are my data protection rights?

The University of Edinburgh is a Data Controller for the information you provide. You have the right to access information held about you. Your right of access can be exercised in accordance Data Protection Law. You also have other rights including rights of correction, erasure and objection. For more details, including the right to lodge a complaint with the Information Commissioner's Office, please visit www.ico.org.uk. Questions, comments and requests about your personal data can also be sent to the University Data Protection Officer at dpo@ed.ac.uk.

Who can I contact?

If you have any further questions about the study, please contact the lead researcher, Benjamin Norman (s2022343@ed.ac.uk).

If you wish to make a complaint about the study, please contact inf-ethics@inf.ed.ac.uk. When you contact us, please provide the study title and detail the nature of your complaint.

Updated information.

If the research project changes in any way, an updated Participant Information Sheet will be made available on http://web.inf.ed.ac.uk/infweb/research/study-updates.

Alternative formats.

To request this document in an alternative format, such as large print or on coloured paper, please contact Benjamin Norman (s2022343@ed.ac.uk).

General information.

Once again, **this study is completely voluntary and you are under no obligation to take part.** Even if you say yes now, you may withdraw from the study at any time and for any reason by contacting us.

For general information about how we use your data, go to: edin.ac/privacy-research

Thank you for taking the time to read this.

C.3 Questions for experts in formative evaluation

- Do you think the game design is suitable for children with autism aged 7-11?
- Do you think the example situations outlined are appropriate?
- Does the flow of events make sense?
- Are the coping strategies presented suitable?
- Do you think the current reward system is engaging for the target audience?

Appendix D

Usability Study Materials

D.1 Project day poster

Ben Norman Dr. Aurora Constantin

TOWARD A TECHNOLOGY TO HELP CHILDREN WITH AUTISM OVERCOME ANXIETY

The Research

- Anxiety is often a comorbidity of autism
- Children with autism can find unexpected and social situations challenging
- Digital interventions can help reduce anxiety by presenting coping strategies in a gamified manner

The Goal

This project aims to:

- Create a game that lets these children play through difficult situations while using these strategies to stay calm.
- Use varied and progressive rewards that customise their room and character to incentivise play.
- Give the option for teachers and parents to create custom situations for the child.

RESEARCH QUESTIONS

1. What are the most common challenges that might elicit anxiety in children with autism?
2. How can a technology-based game be designed to present strategies to help children with autism cope with anxiety?
3. To what extent does the game help children with autism cope with anxiety in daily situations?

FEEDBACK FROM YOU!

Feedback is crucial for my project! Please come say hi and give the game a try!

D.2 SUS Questionnaire

1. Please answer each question honestly and read each question very carefully. *

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I think that I would like to use this system frequently.	◯	◯	◯	◯	◯
I found the system unnecessarily complex.	◯	◯	◯	◯	◯
I thought the system was easy to use.	◯	◯	◯	◯	◯
I think that I would need the support of a technical person to be able to use this system.	◯	◯	◯	◯	◯
I found the various functions in this system were well integrated.	◯	◯	◯	◯	◯
I thought there was too much inconsistency in this system.	◯	◯	◯	◯	◯
I would imagine that most people would learn to use this system very quickly.	◯	◯	◯	◯	◯
I found the system very cumbersome to use.	◯	◯	◯	◯	◯
I felt very confident using the system.	◯	◯	◯	◯	◯
I needed to learn a lot of things before I could get going with this system.	◯	◯	◯	◯	◯

2. What did you like most about the game?

3. What did you like least about the game?

4. What suggestions do you have to improve the game?

5. Are there any visual/design choices you didn't like?

6. Any other comments:

D.3 Usability Participation Information Sheet

Participant Information Sheet

Project title:	Toward a Technology to Overcome Anxiety in Children with Autism
Principal investigator:	Dr Aurora Constantin
Researcher collecting data:	Benjamin Norman
Funder (if applicable):	

This information sheet is for experts in the final evaluation. It explains the research project at the University of Edinburgh. 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.

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Who are the researchers?

Lead Researcher: Benjamin Norman (s2022343@ed.ac.uk)

Supervisor: Dr Aurora Constantin (aurora.constantin@ed.ac.uk)

What is the purpose of the project?

Many different circumstances can cause children with autism to suffer with anxiety. These include social situations, changes to their routines, and disruptive events such as the COVID-19 pandemic. The goal of my project is to design a technology-based game to help children with autism cope with and manage their anxiety in different situations.

What is the usability study?

The usability study seeks to gain feedback on the high-fidelity prototype I have created for the game. The prototype has been created in Unity and takes the potential child through the game and how to complete the situations. This is a very

important stage of the process, as getting feedback from users on usability and the UI is very important.

What will the usability study look like?

I will give you an overview of the game and what it is trying to accomplish. I will ask you to then view and play through the prototype freely, and can comment on anything you find interesting or noteworthy. I will then ask you to fill in a short questionnaire going through the usability of the system, as well as what you liked and what improvements you would suggest.

Are there any risks associated with taking part?

There are no significant risks associated with participation.

Are there any benefits associated with taking part?

There are no benefits/forms of compensation for taking part in this study.

What will happen to the results of this study?

The results of this study may be summarised in published articles, reports and presentations. Quotes or key findings will be anonymized: We will remove any information that could, in our assessment, allow anyone to identify you. With your consent, information can also be used for future research. Your data may be archived for a minimum of two years.

How will personal information be protected?

Your data will be processed in accordance with Data Protection Law. All information collected about you will be kept strictly confidential. Your data will be referred to by a unique number rather than by name, for example ‘Expert 1’, ‘Expert 2’ etc. Your data will only be viewed by the researcher/research team of lead researcher Benjamin Norman and his supervisor Dr. Aurora Constantin.

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What are my data protection rights?

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Updated information.

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Alternative formats.

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General information.

Once again, **this study is completely voluntary and you are under no obligation to take part.** Even if you say yes now, you may withdraw from the study at any time and for any reason by contacting us.

For general information about how we use your data, go to: edin.ac/privacy-research

Thank you for taking the time to read this.

D.4 SUS Calculation Formula

- For each of the odd numbered questions, subtract 1 from the score.
- For each of the even numbered questions, subtract their value from 5.
- Take these new values which you have found, and add up the total score. Then multiply this by 2.5.

Figure D.1: SUS Calculation Formula

Appendix E

Summative Evaluation Materials

E.1 Evaluation Participation Information Sheet - Parent/Guardian

Participant Information Sheet – for parents and guardians

Project title:	Toward a Technology to Overcome Anxiety in Children with Autism
Principal investigator:	Dr Aurora Constantin
Researcher collecting data:	Benjamin Norman
Funder (if applicable):	

This information sheet is for parents and guardians. It explains the 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.

This study was certified according to the Informatics Research Ethics Process, reference number 818448. Please take time to read the following information carefully. A shortened version of this information will be read aloud to your child should you agree to their participating in the project. You should keep this page for your records.

Who are the researchers?

Lead Researcher: Benjamin Norman (s2022343@ed.ac.uk)

Supervisor: Dr Aurora Constantin (aurora.constantin@ed.ac.uk)

What is the purpose of the study?

Many different circumstances can cause children with autism to suffer with anxiety. These include social situations, changes to their routines, and disruptive events such as the COVID-19 pandemic. The goal of my project is to design a technology-based tool to help children with autism cope with and manage their anxiety in different situations.

How can my child help?

Your child will take part in one to maximum three workshops. The workshops will comprise a variety of activities which will help to inform the design of my prototype and provide potential ideas to enhance fun and engagement with the technology designed.

Does my child have to take part?

No – participation in this study is entirely up to you and your child. You can withdraw your child from the study at any time, without giving a reason. Your child may also withdraw at any time by saying that s/he does not want to take part any more. Your rights will not be affected. If you wish to withdraw, contact the PI. We will stop using your child's data in any publications or presentations submitted after you have withdrawn consent. However, we will keep copies of your and your child's original consent, unless your child is too young to reasonably give written consent, in which case we will only keep parent consent forms, and of your withdrawal request.

What will happen if my child takes part?

The workshop will take place in person or online (depending on your preference) with the researcher Benjamin Norman and the supervisor Dr. Aurora Constantin present. Your child will be able to participate and engage in numerous requirement and design gathering activities, such as group discussions and drawing designs, game testing, and provide feedback and ideas to help inform the next steps. Each workshop will last about 30 minutes. We would like to video record this session to provide record for later analysis and allow us to freely interact with your child during the session without having to take notes. The video will only be used to transcribe the audio and then deleted, and not shown to any other parties during analysis. If you are not comfortable with your child being video recorded, then your child should not participate in this particular study.

Are there any risks associated with taking part?

There are no significant risks associated with participation.

Are there any benefits associated with taking part?

There are no benefits/forms of compensation for taking part in this study.

What will happen to the results of this study?

The results of this study may be summarised in published articles, reports and presentations. Quotes or key findings will be anonymized: We will remove any information that could, in our assessment, allow anyone to identify your child. With your consent, information can also be used for future research. Your child's data may be archived for a minimum of two years.

How will personal information be protected?

Your child's data will be processed in accordance with Data Protection Law. All information collected about your child will be kept strictly confidential. Your child's data will be referred to by a unique participant number rather than by name, for example 'Participant 1', 'Participant 2' etc. Your child's data will only be viewed by the researcher/research team of lead researcher Benjamin Norman and his supervisor Dr. Aurora Constantin.

All electronic data will be stored on a password-protected encrypted computer, on the School of Informatics' secure file servers, or on the University's secure encrypted cloud storage services (DataShare, ownCloud, or Sharepoint) and all paper records will be stored in a locked filing cabinet in the PI's office. Your and your child's consent information will be kept separately from your / your child's responses in order to minimise risk.

What are my and my child's data protection rights?

The University of Edinburgh is a Data Controller for the information you and your child provide. You have the right to access information held about your child. Your right of access can be exercised in accordance Data Protection Law. You also have other rights including rights of correction, erasure and objection. For more details, including the right to lodge a complaint with the Information Commissioner's Office, please visit www.ico.org.uk. Questions, comments and requests about your personal data can also be sent to the University Data Protection Officer at dpo@ed.ac.uk.

Who can I contact?

If you have any further questions about the study, please contact the lead researcher, Benjamin Norman (s2022343@ed.ac.uk).
If you wish to make a complaint about the study, please contact inf-ethics@inf.ed.ac.uk. When you contact us, please provide the study title and detail the nature of your complaint.

Updated information.
If the research project changes in any way, an updated Participant Information Sheet will be made available on http://web.inf.ed.ac.uk/infweb/research/study-updates.

Alternative formats.
To request this document in an alternative format, such as large print or on coloured paper, please contact Benjamin Norman (s2022343@ed.ac.uk).

General information.
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 say that s/he does not want to take part anymore.

For general information about how we use your child's data, go to: edin.ac/privacy-research

Thank you for taking the time to read this.

E.2 Evaluation Consent Form - Parent/Guardian

Evaluation Permission 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 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 tester.

If you **give permission** for this study, please fill out the sections below and **return this form to the researchers.**
If you **DO NOT** wish to give permission, **you do not need to do this**. 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: _____

Signature: _____

Date: _____ /_____/_____

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October 2023

E.3 Evaluation Participation Information Sheet - Child

Participant Information Sheet

Project title:	Toward a Technology to Overcome Anxiety in Children with Autism
Principal investigator:	Dr. Aurora Constantin
Researcher collecting data:	Benjamin Norman
Funder (if applicable):	
RT number:	818448

Testing Technology to Help Children

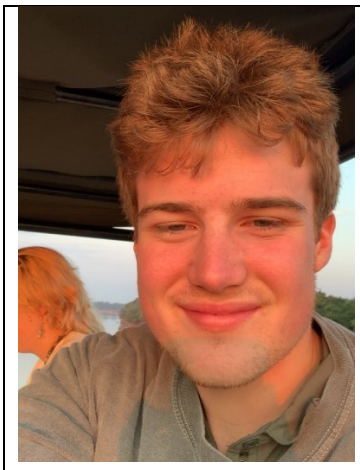
(may be read aloud to the child)

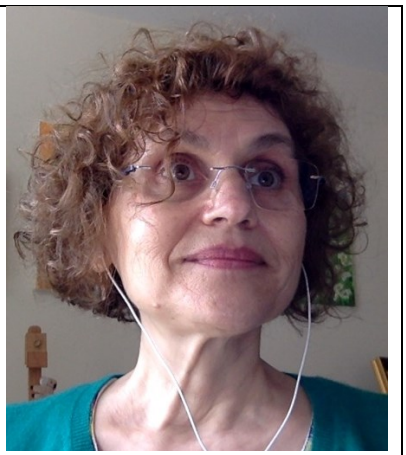
This page is for children. Some researchers are organising a study **at the University of Edinburgh**. It says who they are, and what they will do **during the study.**

They will ask you to help with making and testing new games/apps, take part in different activities, and answer a few questions. You can decide if you want to say "yes" or "no" to helping and can **change your mind at any time**.

Who is organising the study?

This is Ben, who is a student in the School of Informatics. Their job is to make a new game that can help children. They will ask you to help them by helping to test the game and answer some questions. Aurora is a lecturer, and she is guiding Ben in creating the game.





Ben	Aurora

How can I help?

Some children with autism find that lots of different things can make them worried. They might find simple activities like talking to other people and changes to their usual activities harder than most children. Sometimes they find it hard to understand and manage what they are feeling. We have designed a fun game to help these children with their worries, and we would like you to help us to test it! We would like to hear your ideas for ways to make some of these situations less scary and we would like you to help us to make our games fun.

What will happen if I help?

You will get to take part in a workshop to test the game. During this workshop you will participate in various activities, including playing through the game. You will get to talk with other children about your ideas, and we might ask you to do some drawings to work out your ideas.

You can tell us if you want to stop doing any of the activities. You do not have to tell us why. Please tell us if you need the toilet, or if you want to take a break. You can also say you do not want to help any more, and that is OK. We will always listen to you.

The researchers will ask if it is OK to make an audio or video recording of you helping design the game, doing activities and answering questions. This is because it is too hard for them to write down everything that happens. They will listen to or watch the recording later to help them understand what your ideas and thoughts were.

What will happen after I have finished helping?

The researchers will learn a lot about children and designing games from the ideas and feedback that you give when you take part in the experiment. They will write about what they have learned and use it to evaluate how good the game is.

Do you want to ask a question?

It is OK to have more questions. You can ask the researchers as many questions as you want about the experiment. Ask your mum or dad to help you call them on the phone or write an email with your question.

E.4 Evaluation Consent Form - Child

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 game tester.

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 game tester 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 very helpful.

Do you want to be a game developer? YES / NO

Aurora and Ben will listen to/watch the recordings later.
They will not show them to other people.

Is it okay to take video recordings? YES / NO

Write your name:

_____

THANK YOU 😊!!

October 2023

E.5 Evaluation Participation Information Sheet - Expert

Participant Information Sheet

Project title:	Toward a Technology to Overcome Anxiety in Children with Autism
Principal investigator:	Dr Aurora Constantin
Researcher collecting data:	Benjamin Norman
Funder (if applicable):	

This information sheet is for experts in the summative evaluation. It explains the research project at the University of Edinburgh. 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.

This study was certified according to the Informatics Research Ethics Process, reference number 818448. Please take time to read the following information carefully. You should keep this page for your records.

Who are the researchers?

Lead Researcher: Benjamin Norman (s2022343@ed.ac.uk)

Supervisor: Dr Aurora Constantin (aurora.constantin@ed.ac.uk)

What is the purpose of the project?

Many different circumstances can cause children with autism to suffer with anxiety. These include social situations, changes to their routines, and disruptive events such as the COVID-19 pandemic. The goal of my project is to design a technology-based game to help children with autism cope with and manage their anxiety in different situations.

What is the summative evaluation?

The summative evaluation seeks to gain feedback on the high-fidelity prototype I have created in Unity. This is a very important stage of the project process, as

getting feedback from experts in relevant fields will help evaluate the final design and feed into future work.

What will the summative evaluation look like?

The formative evaluation will begin with an overview of the prototype and the key mechanics behind it. You will then be given time to explore the prototype freely while thinking aloud. The researcher may direct you to certain parts of the prototype to get further feedback or clarification on certain parts. The evaluation will conclude with a semi-structured interview to discuss certain key points on its suitability and other feedback.

Are there any risks associated with taking part?

There are no significant risks associated with participation.

Are there any benefits associated with taking part?

There are no benefits/forms of compensation for taking part in this study.

What will happen to the results of this study?

The results of this study may be summarised in published articles, reports and presentations. Quotes or key findings will be anonymized: We will remove any information that could, in our assessment, allow anyone to identify you. With your consent, information can also be used for future research. Your data may be archived for a minimum of two years.

How will personal information be protected?

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Thank you for taking the time to read this.

E.6 Evaluation Consent Form - Expert

Summative Evaluation Permission Form

	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 you 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 recording.

If you **give permission** for this study, please fill out the sections below and **return this form to the researchers.**

Full name: _____

Contact telephone number: _____

E-mail address: _____

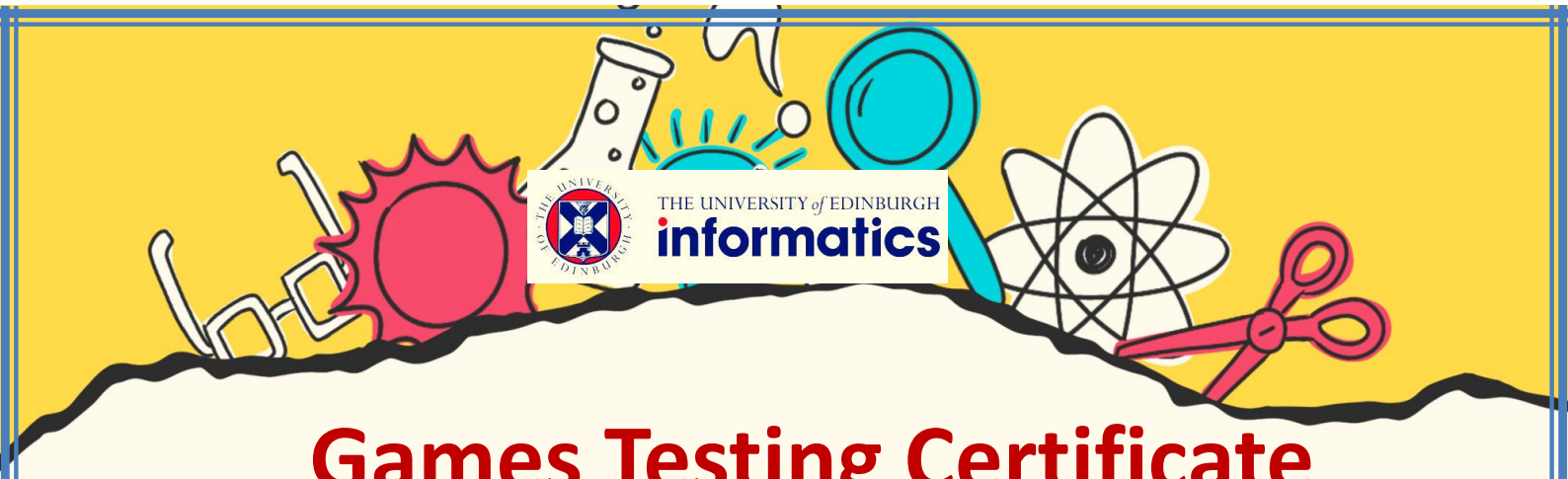
Signature: _____

Date: _____ /_____/_____

THE UNIVERSITY *of* EDINBURGH
informatics

February 2024

E.7 Certificate of Attendance



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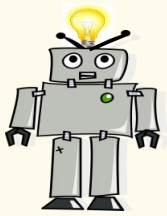
Games Testing Certificate

presented to

in grateful appreciation for sharing their knowledge and experience testing a game, March 2024.

Dr Aurora Constantin



Benjamin Norman

E.8 Questions for experts in the summative evaluation

- Is the game appropriate for the target audience?
- From a child's perspective, do you think the game is engaging, intuitive and easy to play?
- Did you identify any aspects that could frustrate users, be too complicated or cause other problems?
- Do you think the game could be effective in helping children cope with difficult and stressful situations?
- Do you have any other feedback, suggestions or improvements for the game?

E.9 Questions for children in the summative evaluation

- Can you give the game two stars (two features you liked) and a wish (a feature you would like to be changed or improved)?
- On a scale of one to five, can you rate the game on how: fun it was, engaging it was and easy it was to play?
- Do you think you could use anything from the game in real-life situations?
- Do you have any other improvements to suggest?