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Designing an iPad app to engage very young children with autism spectrum disorder.

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Abstract

Individuals with autism spectrum disorders often benefit from technology-based intervention. Technologies being marketed to the autism community, and relevant published research, are proliferating. However, the process by which technologies are created is rarely reported. Understanding this process is necessary to facilitate recommendations about best practice in technology design and implementation and contextualise the findings of technology-based intervention. This report describes the development of an iPad app designed for very young children with autism. We describe methods for co-design with relevant stakeholders, expert evaluation and pilot testing of demo versions of the app, and their consequences for the finished game. In a final evaluation with 41 pre-schoolers with autism average game play over a 2 month period was 11 minutes per day, with no evidence of obsessive behaviour. We discuss how this approach permits individual studies to inform the design of multiple technologies, contributing to a new standard in how technologies for specific populations are designed, pilot-tested and reported.

Keywords: technology, autism spectrum disorder, iPad, design, social attention

Designing an iPad app to engage very young children with autism spectrum disorder.

Autism spectrum disorder (ASD) is a blanket term which describes a range of individuals having atypical behaviours in two diagnostic domains: social communication and restricted or repetitive behaviours (APA, 2013). ASD is also associated with language delays and intellectual disability in a large proportion of cases (Fombonne, 2005). There is a significant focus on early intervention in order to help young children with ASD overcome their difficulties (Rogers and Vismara, 2008; Woods and Wetherby, 2003).

Technology-based education and therapy has been employed to help people with ASD across the life span (Grynszpan, Weiss, Perez-Diaz and Gal, 2013; Pennington, 2010; Ramdoss et al., 2011a; Ramdoss, Machalicek, Rispoli, Lang and O'Reilly, 2012; Ramdoss et al., 2011b). Such approaches have been used successfully to teach literacy (Bosseler and Massaro, 2003; Heimann, Nelson, Tjus and Gillberg, 1995; Williams, Wright, Callaghan and Coughlan, 2002), emotion recognition (Bolte et al., 2002; Golan and Baron-Cohen, 2006) and social skills in general (Beaumont and Sofronoff, 2008; Hopkins et al., 2011). However few, if any, technological interventions have ever been applied to young children with autism. This is likely to be because, until recently, interaction with a computer required comprehension of the function and use of a mouse or keyboard, which is beyond the average pre-schooler. Certainly there is evidence from studies even with older children with ASD of the necessity of a learning phase in which the child develops their computer skills before they can begin to access the content of the intervention (e.g. Swettenham, 1996).

The rise of toddler-friendly touch screen technology, as embodied in the iPad, has begun to influence educational approaches to autism. Evidence suggests that children with ASD can access iPad and other touchscreen technologies (Kagohara et al., 2013), and have been observed to be more engaged and verbal during their use (Hourcade, Bullock-Rest and Hansen, 2012). As a result there are now hundreds of iPad apps being marketed specifically for use by children (and, to a lesser extent, adults) with ASD (see Figure 1). However this proliferation leaves very little room for quality control and many apps lack a foundation in research.

[insert figure 1 about here]

Moreover, the application of participatory design, which is thought to produce higher quality technologies as well as being a valuable process in and of itself (Frauenberger, Good, Alcorn and Pain, 2013; Frauenberger, Good and Keay-Bright, 2011; Guha, Druin and Fails, 2012), is rarely adopted in this field. This may be because developers believe that engaging with children with ASD as co-designers is not possible or because commercial app development proceeds at a pace which does not permit such elaborate processes. Commercial technologies including apps are rarely formally evaluated upon completion while academic-led new technologies do not always cross over to the open market for public use (Ramdoss et al., 2012). Furthermore, little is known about the design process which gives rise to the autism-specific education technologies, as this aspect is rarely acknowledged in published research papers (Fletcher-Watson, 2014).

In this research we aimed to harness the accessibility of touchscreens and the demonstrated advantages of technological interventions, and to apply these to targeting social communication skills in young children with ASD. These skills were selected because of their pivotal status in development (Charman, 2003) and because early interventions which focus on social communication have been demonstrated to have beneficial effects beyond the immediate intervention target (Kasari, Freeman and Paparella, 2006; Kasari, Connie, Gulsrud, Freeman, Paparella and Hellemann, 2012). We developed our new app-based, joint-attention intervention in a participatory design framework involving an array of experts and stakeholders. Our goal in the present paper is to share the app development process with an academic audience in order that future developers of technologies for this population might learn from our successes, and our mistakes.

The following sections of this paper will outline three phases of development of an iPad app, designed for the use of children with ASD under the age of 6 years. The goal of the app is to provide an opportunity to rehearse key social communication skills in a highly motivating environment. This approach permits an added practice 'dose' of therapeutic content to complement the interpersonal learning opportunities available to the child from trained therapists, parents, teachers and others around them. In this paper, Phase 1 explains the pre-development co-design phase which incorporated a number of data collection methods and participant groups. In Phase 2, we describe the initial app creation including writing the code, working in an interdisciplinary team, and creating graphics and animations. In Phase 3, we report on the app testing phase, again working with a range of methods and participant groups. The Discussion reports on the final 'result' which was the finished app, evaluates the benefits and pitfalls of the process, and describes next steps in evaluating and commercialising the app.

Phase 1: Co-Design Studies

The first research phase was a series of co-design activities created to gather ideas for the design of the game from a series of relevant stakeholders. The aim was to ascertain what sort of features children with ASD would most like to be incorporated into their games. Three separate participant groups, sets of materials, procedures and designs are described below and the results synthesised into a single set of design recommendations. For each component, the designs are exploratory, using mixed-methods, in which quantitative data from questionnaires or rating scales are combined with content analysis of discussion and images.

This research was reviewed and approved by the ethics committee of the School of Education at the University of [removed for blind peer review]. Each participant (or their parent) gave informed consent to be involved in the study. In the case of young children, researchers also gained verbal assent where possible, and monitored participants closely for signs of reluctance to participate.

Methods: Co-Design with Expert Adults

The first stage of the game development process involved direct consultation with advisors who included two parents of children with ASD, two pre-school visiting teachers from an autism support service, a speech and language therapist and an able adult with ASD. Each individual took part in interviews of one hour in which the researcher described the proposed project and asked for their commentary. These interviews informed the design process directly but also led to the selection of the participant groups described below, and the creation of appropriate materials for these co-design activities.

Subsequently, the researcher met with nine professional experts working for the Visiting Teacher Support Service (VTSS), an organisation which provides pre-school support to families with a child with additional support needs. All those consulted worked in the autism-specific VTSS team and reported that they had between three and twelve years of experience working with children with ASD.

Materials were a short questionnaire asking for professional background information and then moving on to questions about how children with ASD interact with computer games. The questionnaire ended with a series of open questions asking for suggestions for specific aspects of the game: setting, characters, music, rewards.

The procedure for this element was that participants took part in a group discussion chaired by the first author, and then completed their questionnaires. During the group discussion the participants all had a chance to look at an iPad and see some existing games for pre-schoolers.

Methods: Co-Design with Typically Developing Children

Participants in this co-design strand were thirteen typically-developing (TD) children aged from 2 – 10 years old, and their parents. Children were a convenience sample recruited from among friends and colleagues of the research team.

Materials were a short questionnaire asking for background information (age, gender, computer gaming experience and preferences) and then moving on to a series of open questions asking for suggestions for specific aspects of the game: setting, characters, music, rewards. In addition, there was a half-page space at the end of the questionnaire in which children were invited to "*draw me a picture of what you think our computer game should look like*".

The procedure for this element was that questionnaires were sent out to parents by post. They were accompanied by an information sheet and consent form for parents to complete. Parents were instructed to either allow their child to complete the questionnaire independently or, if they were unable to read, to complete the questionnaire with their child by reading items aloud and noting down their answers. Completed questionnaires were returned to the researcher in stamped addressed envelopes.

Methods: Co-Design with Children with ASD and related developmental disabilities

Participants in this co-design strand were children attending a local school for children with additional support needs. In total 20 children took part in these activities (which took place as whole-class activity) but consent forms were returned for a sample of nine and so only their data are reported and analysed here.

Children ranged in age 5 – 10 years and were drawn from two school classrooms. Most had an autism diagnosis with intellectual disability, though some were diagnosed with non-specific disabilities such as global developmental delay. We did not confirm diagnosis or measure severity of autistic characteristics in the sample. Because of these mixed profiles this group will be referred to as the DD (developmental delay) group.

Materials were a series of sheets of plain white paper and felt-tip pens and crayons. In addition, we provided laminated scenes of outdoor settings of a wide variety (e.g. the moon, American desert, UK countryside, modern urban streets, the beach, the jungle). These were accompanied by laminated cut-outs of characters and objects, again representing a wide variety. Characters included humans and animals, both familiar and exotic (e.g. businessman vs. cowboy, dog vs. dinosaur). There were multiple copies available of each setting and character, as well as various objects such as vehicles, toys and accessories for the characters. Participants could use supplies of putty adhesive to create a scene by sticking characters on to their chosen setting.

The procedure for this element was that participants were simply asked to make some pictures. They were not instructed that the goal was to design a computer game. Some children used pens and paper and some constructed scenes from the components provided. This took place during a 45 minute session in their classrooms (in two separate classes of ten children each).

Results

Interviews with Advisors

Interview data from the advisors were synthesised into a short document summarising the opinions of the group on the proposal. Opinions were categorised into: initial response to project topic; reward system ideas; music and sounds; generalisation; other comments. Initial responses were largely positive though concerns were raised about how use of the iPad might lead to confusion about appropriate touching of other people which is a common issue in autism (e.g. some children use other people's hands as if they were tools). The advisors recommended autism-specific rewards such as familiar phrases ("good looking!"), spinning shapes and vehicles. They were keen that verbal prompts and sound effects should be used throughout the game (e.g. character saying "Look at me!") but considered that music should be mute-able. There was concern about the ability of children to generalise from the game to real life and a recommendation that the game should therefore mimic real life as closely as possible. Nevertheless, advisors acknowledged that animations might be more appealing to young children.

Other comments were that parents enrolled in the research should be given advice on minimum and maximum use of the game and that they should be reassured that they should feel able to remove the game if they feel their child is becoming fixated. It was pointed out that some children can become fixated on repetitive elements such as the loading screen and this might cause them to turn the game on and off repeatedly instead of playing.

Questionnaire Responses and Analysis of Images

Expert adult informants (n=9) were initially asked to comment on whether they thought computer games were suitable for children with ASD. Their responses to the questionnaire items on this topic are provided in Table 1 below. It is clear that the opinion of these experts was that a computer game is an effective way to engage a child with ASD and may have potential to be used for learning.

[insert table 1 about here]

Another goal for this section of the design process was to identify appropriate content for the game. Table 2 illustrates the frequency counts for a number of common recommendations made explicitly (e.g. mentioned one or more times in an individual's response to questionnaire items) or implicitly (e.g.

appearing in one or more images produced by an individual child). Note that each participant was able to make as many recommendations as they wanted (questionnaire items were open) and so these counts do not sum to the group total. Repeated responses within a category by a single individual (e.g. a child creating a picture featuring 7 vehicles) were counted as only one instance of that category.

A common theme among the expert responses, not captured in these frequency counts, was a preference for personalisation within the game. All but one of the respondents in this group recommended that at least one element should be under the child's control. They should be able to choose a character, setting, reward and music for the game and they should be able to mute the music if wanted.

[insert table 2 about here]

Among the images created by the TD group in their questionnaires, there was a common theme of being on a quest or helping. Participants described their pictures using phrases such as *"you need to stop the evil queen"* and *"help someone fix the boat engine [then] drive the boat and collect things".*

Strikingly, the images constructed by the DD group often showed a highly regular layout. This is unsurprising given the preference for repetition and routine among people with ASD. Two examples of this kind of layout are shown in Figure 2.

[Insert Figure 2 about here]

Conclusions

There was a risk that the convenience sampling method used in recruitment would result in a highly biased sample who were more positive than most about the use of computer games as a therapeutic tool for children with ASD. However we found a healthy level of doubt in the group who were interviewed and among questionnaire respondents. In particular, concern among interviewees that the app could become an object of obsession, and that learning in a game may not generalise to the real world, are valuable warnings which can be taken into account in both the design of research studies but also in the way in which technology is used in homes and schools.

Drawing on the questionnaire data and participant images, it was possible for the study team to make some fairly clear decisions about the content of the game.

- Characters should be children, but the game could also feature animals, toys, plants and vehicles.
- Familiar background settings should be used.
- If music is used, nursery rhymes or classical music are preferred, though expert adults were keen that music should be optional.
- Children and adults alike recommend a reward token system for the game and most propose that the game should make no response when an incorrect answer is given.
- A regular on-screen layout would correspond with the spontaneous designs of the DD group.
- The loading screen should be simple and designed to minimise the possibility of a user becoming fixated on this – for example having no sound or animation.
- Where possible, personalisable features should be incorporated.

Phase 2: App Development

This section gives a narrative account of some of the key decisions which were made by the research team about the hardware and the platform used to deliver the game and about the game content. The principal goal was to create a game which would be accessible to children and highly motivating to play. The game had to deliver some meaningfully therapeutic content which we felt was appropriate to the developmental needs of the target population – pre-school aged children with a 'core' autism diagnosis. These things needed to be delivered within a strict time frame (one year for game development, including 6 months full-time equivalent for the lead computer programmer) and budget. Note that this Phase took place alongside and throughout the Design Phase described above and the Testing Phase described below.

Choosing the iPad

At the time that the research project began, in April 2010, the iPad had just been released by Apple. We were immediately drawn to the device because of its large touchscreen which we felt would be accessible to very young children. There were however some obstacles to using this as our chosen hardware. First, the original budget for the study was not sufficient to buy enough iPads for the planned clinical trial. Second, the computer programmer had no experience writing code for an app. Creating apps for Apple products entails a series of specific requirements including: creating the app on a Mac computer; creating an Apple developer account; downloading and using the X-Code system to build the app; working with one of a small set of computer languages. Nevertheless, we felt that the benefits of the iPad as a highly accessible user interface validated this choice.

Interdisciplinary Collaboration

The project was necessarily highly interdisciplinary involving close collaboration between psychologists and programmers, mediated by an expert in co-design and human computer interaction. One challenge was to convey the therapeutic goals of the app and formulate these into specific recommendations for its creation. The programmers then had to write code to produce the desired results. Here, we introduce a specific example of this process in action. Psychologists identified a need to ensure that each scene of the app looked different, to prevent players becoming either bored or fixated, and to prevent learning of correct responses through repetition.

To introduce the necessary degree of variation, each scene in the game is generated as the game is played rather than being pre-specified. This generation employs several randomised factors, while also meeting a number of fixed constraints. For example, for each scene in the first part of the game the app randomly selects a target character. Simple random selection would sometimes result in the same choices being made repeatedly, or in some available choices being made rarely or never. Therefore, randomised shuffling is used instead. Thus, the app takes the list of all available target characters, shuffles it into a random order, and then picks the first character in the list for the first scene, the second character for the next scene, and so on. Once each character has been used once, the list is re-shuffled and used again. This ensures that all the target characters are used equally often. At most, this may result in the same target character appearing in two consecutive scenes (at the end of one shuffled list and the start of the next). Similar shuffling mechanisms are used to make all of the app's randomised decisions when constructing a game scene.

The fixed constraints that the app must meet when generating a scene include:

- A fixed number of distractors must appear in each scene. This number increases as the player completes more scenes.
- Each distractor must be compatible with the setting. For example a lion may appear in a jungle setting, but not in a green grocer's.
- The character and each distractor must be placed in a compatible region within the setting. For example birds and clouds go in the sky, a person or a tree belongs on dry ground.

The app decides which target characters and distractors are compatible with which settings and regions using a simple tagging mechanism. A beach setting would be divided into a number of pre-defined rectangular regions, each tagged appropriately: e.g. “grass”, “sand”, “sky” and “water”. Distractors for potential inclusion in that setting would be similarly tagged: a boat would have the region tag "water", whereas a bird would have the region tag "sky". A ball would be tagged both “grass” and “sand”. The app looks for distractors, from a shuffled list as described above, with a region tag in common with one of the setting's regions. If there is more than one region in the setting that is compatible with the chosen character, one of them is chosen using the randomised shuffling method described above.

Working with students to get animations and graphics

It was a key feature of the game that it should have engaging graphics and animations. While advisors in the design phase had suggested that the app should be as close to real life as possible, they also acknowledged that animations would probably be more engaging to young children. In addition, we felt that even very young children now have computer gaming experiences and we wanted our finished product to live up to those standards. We had no dedicated budget to develop graphics for the game and so we worked with students on the BA Animation degree at the research institution to create stimuli for the game. As a result of this collaboration we were able to produce high quality graphics for the game.

Designing therapeutic content

Our goal at the outset of this project was to attempt to address the development of social communicative behaviours in a technological intervention. We identified two key components of social attention which develop in succession which are attending to other people and following social cues (pointing, looking) (Mundy and Newall, 2007).

[insert figure 3 about here]

The app was structured in a traditional game-like way, with ‘levels’ of increasing complexity, and also drew on traditions of experimental psychology in having a ‘target’ and ‘distractors’ in each scene. In Part One: Looking at People, a correct answer was to touch the character depicted on screen, when no other distractor items were present. Subsequently, distractor items appeared, but the correct answer was still to touch the character, or target. In Part Two: Following Social Cues, the on-screen character used head-turns, eye-gaze direction and pointing to indicate a target item, which could be touched by the player, with the result of moving on to the next screen. Note that these terms – e.g. Part One, Part Two, level, target – were used by the research and development team during creation of the game but were not apparent to players during any of the testing phases nor in the finished product. A fuller description of the completed app will be provided at the end of this paper

This phase was closely overseen by a team of experts from a range of disciplinary backgrounds including developmental psychology, clinical psychology, paediatric medicine and human-computer interaction. In addition the team consulted closely with groups involved in Phase 1 such as pre-school visiting teachers, speech and language therapists, and parents of children with ASD. All were supportive of the chosen focus of the app, which had obvious relevance to everyday concerns (e.g. language learning in pre-schoolers with autism) and of its evolving style.

The specifics of content design drew directly on the findings from Phase 1. As a result, the finished app (and interim ‘demo’ versions) featured children as the main characters, in familiar settings, with toys, animals and vehicles as distractor items. The loading screen was a static image without audio, designed to prevent obsessive and repetitive fixation on closing and re-loading the game. We added a simple soundtrack of environmental sounds (e.g. birdsong) in the scenes. This could be easily muted using the iPad controls. Sample graphics from the app were circulated by email to parents of children with ASD for comments on their suitability.

Three reward types were available for players to select from: a) abstract geometric rewards, designed to exploit the interest in geometric patterns common in autism; b) social rewards designed to provide reinforcement similar to that found within the natural environment, in this case acrobats performing with a soundtrack of applause; c) object of interest reward, designed to capture the attention of the user by exploiting topics of interest. In this case we used a train, one of the most prevalent special interests of children with ASD (DeLoache et al., 2007). Rewards were delivered by collecting visible tokens, building to a short animated reward sequence (see Figure 4). There was no negative feedback for an 'incorrect' response. In addition, particularly in the second part of the game, the layout of objects followed a regular pattern on screen. While we did not feel it was possible to implement a 'quest' narrative into this simple game, in Part Two we used an implicit template of helping another person to do their shopping as the narrative substrate.

[insert figure 4 about here]

In addition, further features were implemented drawing on expert advice. These included a number of aspects designed to facilitate access by even very young or less able players. The app includes no verbal or written instructions and starts with very simple screens in order to allow the player to work out what to do by trial and error. Selecting the app icon on the iPad home screen opens the game directly with no need to select a PLAY symbol or make any menu selections. The characters in the game were designed to have a low-impact eye-region which conveyed adequate information to signal gaze direction (for Part Two: Following Social Cues) but was not likely to overwhelm any users who might find direct gaze aversive (Kylliainen and Hietanen, 2006). In order to create an interactive and game-like feel to the app, we made distractor items produce sound effects (e.g. a lion roaring) or a verbal label (the word 'lion') when tapped. These were distinguished from the target character implicitly, by the fact that tapping these items did not result in collection of a reward token, nor progression to a new screen. Finally, we reduced sensitivity to repeated touch, to prevent players from tapping rapidly in a single spot to produce repetitive aural feedback.

Phase 3: User Testing & Expert Feedback

The third research phase was a series of user testing activities designed to evaluate different game features with a series of relevant groups. The overarching aim was to ascertain whether the app was appealing to children with ASD. In addition there were some specific questions of interest which were:

1. What is the minimum age at which a child can successfully engage with the app without adult help?
2. What is the preferred reward type among children with autism?
3. Is the level of repetition and the rate of learning progress appropriate for the target age group and developmental level?
4. Will children maintain interest in playing with the app repeatedly over an extended period of time?
5. How does having an iPad on loan and the app impact on family life?

Three separate participant groups and procedures are described below, and the results summarised in the same section. The overall findings are then synthesised into a single set of design recommendations. The participant groups and evaluation activities were selected following consultation with advisors including a community paediatrician, two parents of children with ASD, a speech and language therapist and an able adult with ASD. For each component, the designs are exploratory, using mixed-methods, in which quantitative data from rating scales or collected within the app are combined with verbal feedback and observation of game play.

Methods & Results: User Testing with TD Toddlers

This activity was set-up to explore the minimum age and developmental level at which a child could successfully, independently engage with the app. Participants were 12 typically-developing toddlers (5 male) aged from 15 months to 42 months. Testing took place during a mother and toddler playgroup, in the main play area. The researcher set up a small table with three iPads running the app, and simply waited for toddlers to come to have a look. For any engaged toddlers, parents were asked to complete a consent form and report directly to the researcher the age and gender of their child.

The youngest children, aged 15-19 months (n=3) were able to access the game but showed a tendency to be distracted by the single iPad button. However, on leaving the game, they often immediately resumed play, by tapping the icon on the screen. Children aged around 2 years old (n=3) showed an immediate, definite, focussed interest in the game and a rapid understanding of how to progress. Some played for an extended period (e.g. 20 minutes) and shared their enjoyment by laughing, nodding, commenting and so on. This age group found it challenging when the game progressed from Part One: Looking at People to Part Two: Following Social Cues as this transition happened without warning and required learnt responses (tapping the person to collect a token) to be re-configured (tapping a target object to collect a token). However ultimately none were put off by this transition and all quickly adapted to the new circumstances.

Older children from 2.5 years upwards also enjoyed the game but some showed an unexpected reluctance to touch the screen – perhaps associating the iPad with the television at home which they are not normally allowed to touch. These older children were bored by the more abstract reward setting (Figure 4a) and preferred the acrobats (4b) or train (4c).

Methods & Results: User Testing with Young Children with ASD in Nursery and School

The goal of this investigation was to explore the reward preferences of children with developmental disabilities including autism (Humphry, 2011). Ten children (6 males) aged 4 or 5 years old, from three nurseries and primary schools participated. Four had a confirmed ASD diagnosis and the other 6 were all receiving additional support for social and communication difficulties, pending formal diagnosis. Participants simply viewed the reward animations in a random order, either in small groups (with an iPad each) or individually. The investigator noted their reactions and then asked them to rate each reward type using a simple visual voting system (Figure 5). For some children, this system was too complex and so the investigator would instead present the reward types side-by-side on three iPad screens and ask the child to indicate their preference.

[insert figure 5 about here]

Most participants spent a lot of time tapping the screens during the animations, especially the moving objects, evidently expecting them to be interactive. Verbal responses were common, including naming objects on screen, or making a ‘choo-choo’ sound effect for the train. The abstract reward was least popular, with only one child selecting it as their favourite. The other two rewards – acrobats and train – appeared equally popular (n=5 and n=4 respectively). However, no girls indicated that the train was their favourite reward.

Another finding from this stage of the evaluation was that the participants’ tolerance for repeated scenes without progression in complexity was very high. For this pilot, the development team set up the app to produce different-looking scenes at the same complexity level (i.e. with the same number and type of distractors on screen) for 20 repetitions before progression. This means that although the reward was introduced more often (every five scenes) it took a long time for the children to progress to a level of increased difficulty. Perhaps because of the known preference for routine and repetition, we found that the players in this group were unperturbed by the repetitive structure and played for extended periods of time – in each case the session was terminated by the investigator, rather than because the child became bored.

Methods & Results: User Testing with Children with ASD and their Parents at Home

This phase involved 10 children with an established diagnosis of an ASD working with the iPad at home for between four days and two weeks. Participants were aged four to six years old and two were female. We recorded the amount of time children spent playing the game and also interviewed parents to gather their observations on their child’s interaction with the app, and the experience of having an iPad at home. Children played the game for between 28 minutes and 3 hours, 59 minutes. Taking into account the differences in length of time with the iPad, and after removing one participant whose mother limited her access to five minutes every other day, this equates to a range of approximately 6 minutes – 37 minutes per day.

Data collected during parent interviews indicated high levels of satisfaction with the app, particularly the visual reward system and accessible, simple style. No faults with the iPad or other technological breakdowns were reported. All parents found a positive impact of the iPad, with one stating that it was the only way she could leave her son safely alone in a room at home. Parents of children who were at the older and more able end of the range represented, especially those with extensive gaming experience, did report that their child became bored with the app after an initial enthusiastic period of play.

One interesting finding was that the use of a heavy protective case had a positive effect from a parent perspective, encouraging one child to sit down and play in a focussed way rather than moving around the house with the iPad. The parent felt that carrying the iPad around would have prevented extended play (and thus access to learning) and also risked damage to the iPad. Another comment was that although the transition from Part One to Part Two posed challenges for players, this then encouraged them to seek help from their parents. Parents enjoyed the balance between independent play and occasional help-seeking inspired by the app.

For three of these participants, it was possible to extract data recorded within the iPad and relate it to preferences (see Figure 6). Each of these participants had a period of time playing the app using each of the available reward settings, and also with an ablated reward consisting of no visual tokens in the game, and a simple message every five trials which read *“You completed 5 trials!”*. In each case the reward type identified by the parents as being the child’s favourite resulted not only in longer periods of play but also in more accurate play (represented by fewer touches per screen to the background or to distractors) (see Humphry 2011 for more detail).

[insert figure 6 about here]

Results Summary

Evaluation with typically-developing toddlers revealed that children as young as 15 months could successfully, independently access the game, though immediate understanding was only evident from about 2 years old.

Our initial intention was to evaluate whether one of the three evaluated reward systems was more effective than the others. However we found that children had differing reward preferences and so decided to retain all reward options as a personalisable feature within the app. The impact of rewards on play is indicated by preliminary evidence from three participants of a relationship between reward preference and duration and pattern of game play.

Another goal of these studies was to explore whether the rate of learning progress was appropriate for the target age group and ability level. We found that young children with ASD were very tolerant of repetition at a particular level of the game, continuing to play even when difficulty and complexity did not increase. Furthermore, extended periods with the iPad and app at home also indicated that children would continue to play the game over a period of days or weeks. The exception to this was more able children, especially those with extensive gaming experience.

Finally, we were able to find evidence among parents of a positive influence of having the iPad on family life. Parents experienced no technical faults, breakages or other problems using the hardware or the app. They reported positive attitudes, including welcoming the opportunity to allow their child to play independently, using a game they felt was appropriate for their child's needs.

Conclusions

As a result of these formative evaluations of the game, a number of modifications were introduced. For example, we retained all three reward screens and, through the materials included with the app, encouraged parents to help their child find and use their favourite reward. We set a lower ability limit for the app of approximately 15-months equivalent in visual reception and fine motor skills. In a subsequent trial (reported in Fletcher-Watson et al., 2014) we included an opportunity during the baseline data collection visit for children to have some experience with an iPad in order to get used to the touchscreen.

Two findings presented something of a conundrum: on one hand, younger children in nurseries and schools showed a high tolerance for repetition at a single level of difficulty, while on the other hand, older and more able children involved in user testing at home wanted a bigger challenge. We decided, in consultation with pre-school visiting teachers, that it was a priority to ensure that the finished app was accessible to very young children and those with significant developmental delays, even if this meant failing to capture the interest of older and more able children. This is because the target skills being rehearsed in the app (looking at people, following social cues) are associated with a very early developmental level and/or severe autism presentation. Therefore it was most appropriate to ensure that the opportunity to rehearse these skills was available to those children most likely to lack them.

Another pair of findings was somewhat contradictory. Parents were positive about the opportunity for independent play afforded by the app and iPad. However we were also struck by the possibilities for social communication afforded by including challenges where the child would have to seek adult assistance. In the end, the decision was taken to retain the abrupt transition between Part One and Part Two for this reason. Scaffolding real world social communication was not integrated in to the app in any other way, though we do consider this a valuable principle which could be incorporated into future learning games. For example, in a subsequent student project which built on development of the FindMe app, a new reward system was built which instructed the player, through audio cues, to *"Go and show your Mum"* in order to promote sharing of achievement and social interactive opportunities (Dragomir, 2013).

The Finished Game

The finished game has two parts; Part One: Looking at People, and Part Two: Following Social Cues. The first part of the game aims to teach children with autism to prioritise people in a scene. Their job is to touch the person on the screen. The screen gets increasingly crowded with distracting items as they progress through the game, making the job of pointing at the person more challenging (see Figure 7). In Part One, Level 1 only a person is visible, with no distractors. This is designed to make the player's job of working out what to do very easy – there is really only one thing which can be touched. Subsequently, distractors start to appear, first of all unmoving and then moving around the screen. All scenes in Part One are set outdoors in both familiar (e.g. rolling green hills, sandy beach) and exotic (e.g. jungle, savannah) countryside. The whole of Part One is completed in 80 trials and the player moves on seamlessly to Part Two.

[Insert figure 7 about here]

In Part Two the character is re-located to a series of shop interiors. This visual transition is intended to help indicate to the player that the desired responses has changed. Target objects appear in one of six locations around the screen and are indicated by the character using head-turn, eye-gaze direction and a point (all depicted statically, without motion cues, see Figure 7). Once more, in the first levels only one target appears on screen. Subsequently, more of the six possible object locations are filled with distractor objects until all six locations are filled. After 30 correct trials at this highest level of complexity, Part Two repeats from the beginning but this time the character provides only head-turn and eye-gaze direction cues without a manual point.

The program randomly selects a background, character and set of distractors for each scene from a menu of available options, with the restriction that there should be no direct repetition in adjacent scenes. The game uses eight different characters representing both genders and a range of ethnic groups. Distractors are interactive: when touched they produce either a sound effect (e.g. a realistic miaow) or a verbal label (e.g. “cat”).

Throughout the game, the player collects tokens for each correct answer (touching the person or target object) and after five tokens are collected they are rewarded with a short animation. Reward systems can be selected in the parent menu and include spinning shapes on a black background with music; jumping acrobats to the sound of applause; and a train going across the screen and in and out of a tunnel (with suitable sound effects). There are no specific instructions but the character does issue verbal cues (e.g. “Look at me!” for Part One, “Can you help me?” for Part Two) and encouragement (e.g. “Well done!” or “Good looking!”). The character’s voice is child-like and distinct from that used for verbal labelling of distractors, which is an adult female.

The research version of the game (but not the commercial release) collects in-app data in the form of time-stamped recordings of every screen onset, item of content and touch. These can be downloaded and synthesised into a summary of learning for subsequent analysis of learning processes, not just outcomes. In a subsequent trial of the therapeutic potential of the completed app (reported in Fletcher-Watson et al., 2014), 41 children with autism (aged under 6 years) had access to the app for an average period of 58 days. Children played on average for 11 hours in total, or about 11 minutes per day. 74% of children were able to reach the highest level of the game. There was no relationship between game play and ability level of the children measured by the Mullen Scales of Early Learning (Mullen, 1995).

[insert table 3 about here]

Overall Discussion

This paper has reported on the development of an iPad app, in a game format, designed to help children with ASD rehearse key social communication skills in a motivating and rewarding environment. Our goal has been to describe clearly the many processes in design, expert consultation and user testing which we believe are essential for development of good technologies for this unique population. We worked with a range of relevant stakeholder groups including potential players, their parents and practitioners who work with them. These groups were involved in the earliest design decisions as well as in testing prototype version of the game. In addition, we used expert consultation to ground the game in theoretical and evidence-based knowledge of features of autism and suitable targets for intervention. This process was essential to ensure that the app was not only appealing and fun but also directly addressed a relevant learning goal. Results show high levels of interest in the app in a sample of children with autism. As a result of our experiences we have synthesised a short set of guiding principles for technology design which may provide the basis for a more developed framework for best practice (Table 3).

Limitations

Each individual activity reports on small samples and some data have been evaluated subjectively by the first author alone. Potential questions of significance were not all able to be addressed. For example, clearly delineating the stage at which a child becomes too old or too able to engage with our simple app was not achieved. Nevertheless, collectively the findings provide concrete support for both design features in the final game and for aspects of management of the subsequent randomised controlled trial to evaluate therapeutic potential.

The final game did not include as many personalised features as consultation indicated were desirable. While players could select a preferred reward type, there was no opportunity to vary learning rate, appearance of characters and distractors, and audio content. Some of these features were improved in the commercial version, which included not only a range of languages but also the option for parents to record their own audio content using any language or include preferred vocabulary (e.g. "well done *Sarah*")

It is not possible to draw firm conclusions about whether a game developed in this collaborative and iterative manner will produce more effective results (in terms of impact on learning and behaviour) without making a direct comparison with a game intended for the same population created without co-design, consultation and testing. Although this comparison has not been made, the latter is not regarded, in general, to be good or effective design practice. We do have preliminary evidence that design features such as the reward system directly inspire more, and more focussed, play. Moreover, when moving on to evaluate the game in a trial, we can be relatively confident that any lack of learning is not attributable to a lack of engagement with the technology.

Future Directions

This app has now been evaluated in a randomised controlled trial reported elsewhere (Fletcher-Watson et al., 2014). Moreover, the app has been licensed by a commercial app development company and released for download via iTunes. The commercial partner modified the app superficially to increase relevance to an international audience (e.g. replacing Scottish voices with English voices, adding additional languages, reformatting parent menus). In addition, they created a version for iPhone. Part One: Looking at People is available as a free download. Consumers can also buy the full app or unlock additional content by making an in-app purchase. Our goal was to make the full app available to users in a way which was commercially viable for our business partner, while also giving consumers a chance to try out the app for free initially. We had also hoped to garner feedback from the user community, but despite downloads in excess of 90,000, only 14 respondents have completed the online feedback survey for the app.

On the basis of this fruitful relationship, our research team continue to work with our commercial partner to develop additional evidence-based apps for pre-schoolers with ASD. Our experience in the design process has also given us a significant insight into commercially available technologies for people with ASD, and a framework in which to evaluate their design and applicability. This is being translated into a number of public engagement activities, such as online app reviews and talks to parent and practitioner groups. In this way, the complex design process which led to the creation of a single app is impacting more widely in ways which directly benefit the autism community.

Final Conclusions

Technology is a method of delivery of educational and therapeutic content, communication supports and entertainment, which particularly appeals to a large proportion of people with ASD. Touchscreens such as the iPad are now bringing these technological solutions to even very young or developmentally delayed individuals. The rate of development of new commercial technologies far outstrips academic research progress and individual attempts to evaluate and recommend technologies to the community. In this context, it is essential to use evidence-based research to provide a framework for best practice in technology design, implementation and evaluation. Children with neurodevelopmental difficulties who require help with learning do not have time to waste. Reporting on this development process provides a way to extend the relevance of our work beyond this single app and have an impact on understanding of technology for autism in both research and practice.

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Conflict of interest declaration

The iPad app described in this paper has been licensed by a commercial developer and is now available as a free version on the Apple App Store, and also as a priced “Pro” version. Some of the authors on this paper (SFW, HM, HP) may receive royalty payments in future if downloads of the Pro version exceed a certain threshold.

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Table 1: Expert questionnaire response frequencies on game use by children with ASD

Item	A Lot	Somewhat	A Little	Not at all
How much do children with autism like computer games?	8	0	1	0
How much do children with autism play computer games?	8	1	0	0
To what extent is playing computer games a positive experience for a child with autism?	3	6	0	0
To what extent can children with autism learn new things from a computer game?	5	4	0	0

Table 2: Showing frequency counts for game elements recommended by different participant groups: the most consistently popular categories are highlighted

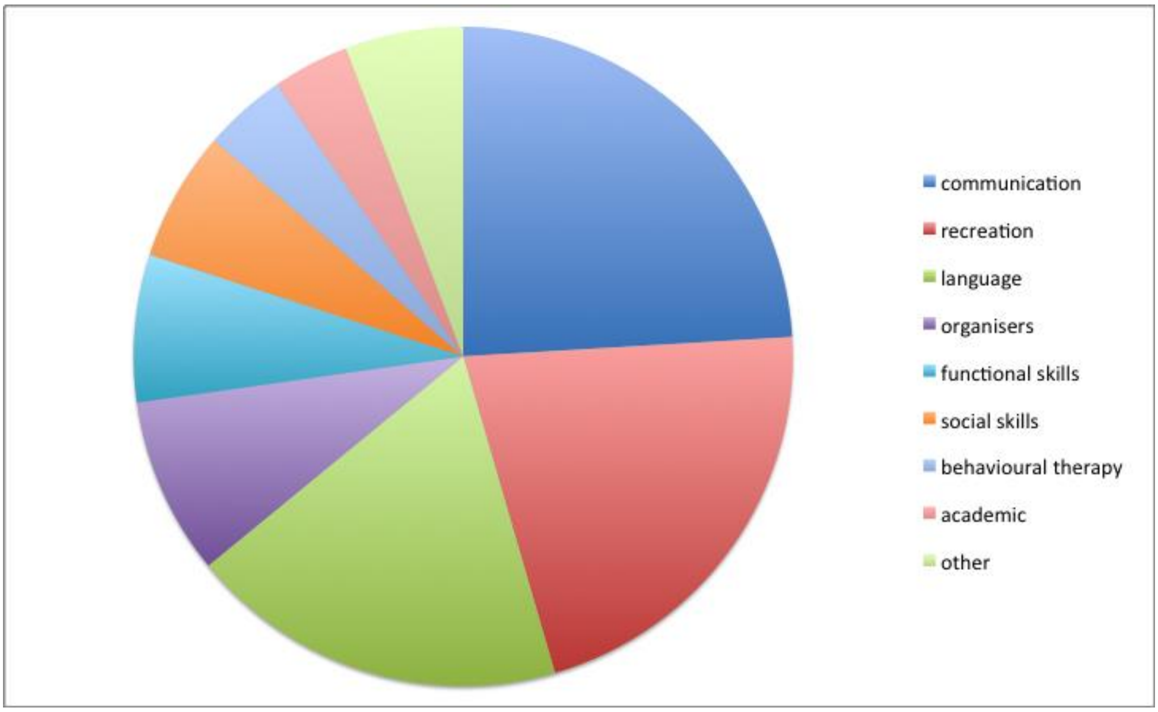
Item		**Experts n=9**	**TD Group n=13**	**DD Group n=9**
Characters	Children	5	6	6
	Animals	5	5	2
	Vehicles	2	2	3
	Adults	4	4	7
	Fantasy characters	0	7	7
	Famous characters	1	0	0
Settings	Familiar	5	7	9
	Exotic	0	6	2
Other objects	Vehicles	6	4	-
	Animals	6	7	-
	Toys	3	2	5
	Flowers / plants	2	2	3
	Food	0	3	2
	Letters / Numbers	0	1	0
	Buildings	0	1	0
Music*	Nursery rhymes	2	3	-
	Classical	1	4	-
	Pop music	0	3	-
	Cartoon theme tunes	0	1	-
Game's response to a correct answer	Smiley face	4	0	-
	Gold star / token	4	8	-
	Music	4	0	-
	Numbers / points	1	3	-
	Cheering	0	2	-
Game's response to an incorrect answer	Nothing	4	3	-
	Sound effect	2	3	-
	Remove points / tokens	1	3	-
	Sad face	2	0	-
	"Try again"	3	1	-
	Thumbs down	0	2	-

**Most adult respondents suggested that music should be optional and made no recommendation for the type of music*

Table 3: Suggested guiding principles for best practice in technology design for users with ASD

Principle	Example	Impact
Theoretical foundation	Review of existing literature and expert consultation. Group brainstorming to consider how to encapsulate a learning or therapeutic outcome in technology.	Identification of appropriate learning goal.
Interdisciplinary working	Collaboration between academics and practitioners with backgrounds in education, psychology, computer science, and art and design. Sub-disciplines of interest could include human-computer interaction, learning analytics and participatory design	End product draws on multiple expertise, realising learning goals within real-world parameters.
Co-design	Drawing and other creative activities with children. Interviews and questionnaires to gather suggestions in specific domains (e.g. audio content). Joint exploration of similar, existing technologies (both hardware and software). This could include technologies selected to appraise their 'look and feel', their suitability for an intended user group, or for their learning goals.	Visual, audio and other design features of the product fit the preferences of the user group. Product builds on existing examples of good practice.
Pilot-testing	Repeated, iterative process in which demo versions of the technology (including components such as sample graphics) are given to users and stakeholders for testing or commentary. Should include opportunities for extended use, use in relevant settings (e.g. classroom, home), and testing by users at the limits of the proposed age / ability range.	Appropriate interface and sensitivity of controls. Clearly defined target user group and setting. Understanding of the link between features of the technology and motivation.
Personalisation	Final product involves multiple options for users (and facilitators such as parents and teachers) to select from menus of components.	Design team do not presume to know preferences of users. Final product is highly motivating and enjoyable.

Figure 1: Apps available for people with autism, organised by primary function



NB: *Data downloaded from the Autism Speaks website on 02.01.2013 Includes apps for iPad, iPhone and other (Android) touchscreen devices*

Figure 2: Examples of images created by children in the DD group

Figure 3: Images from demo versions of the app showing Part One: Attention to People [left] and Part Two: Following Social Cues [right]

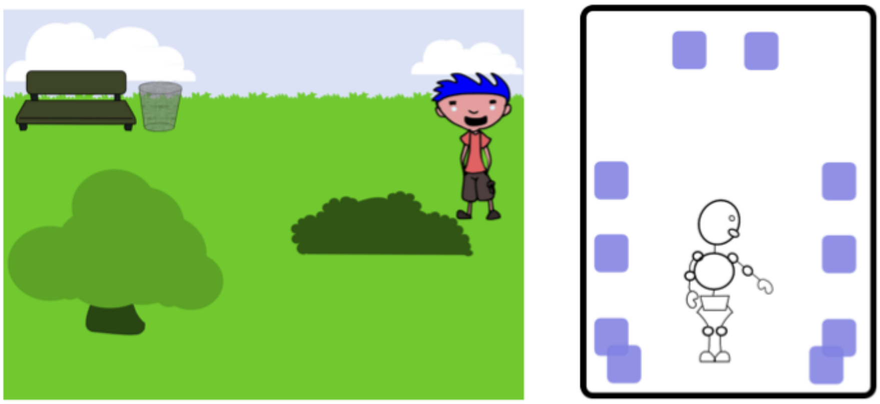


Figure 4: Examples of reward tokens and screenshots of periodic reward animations

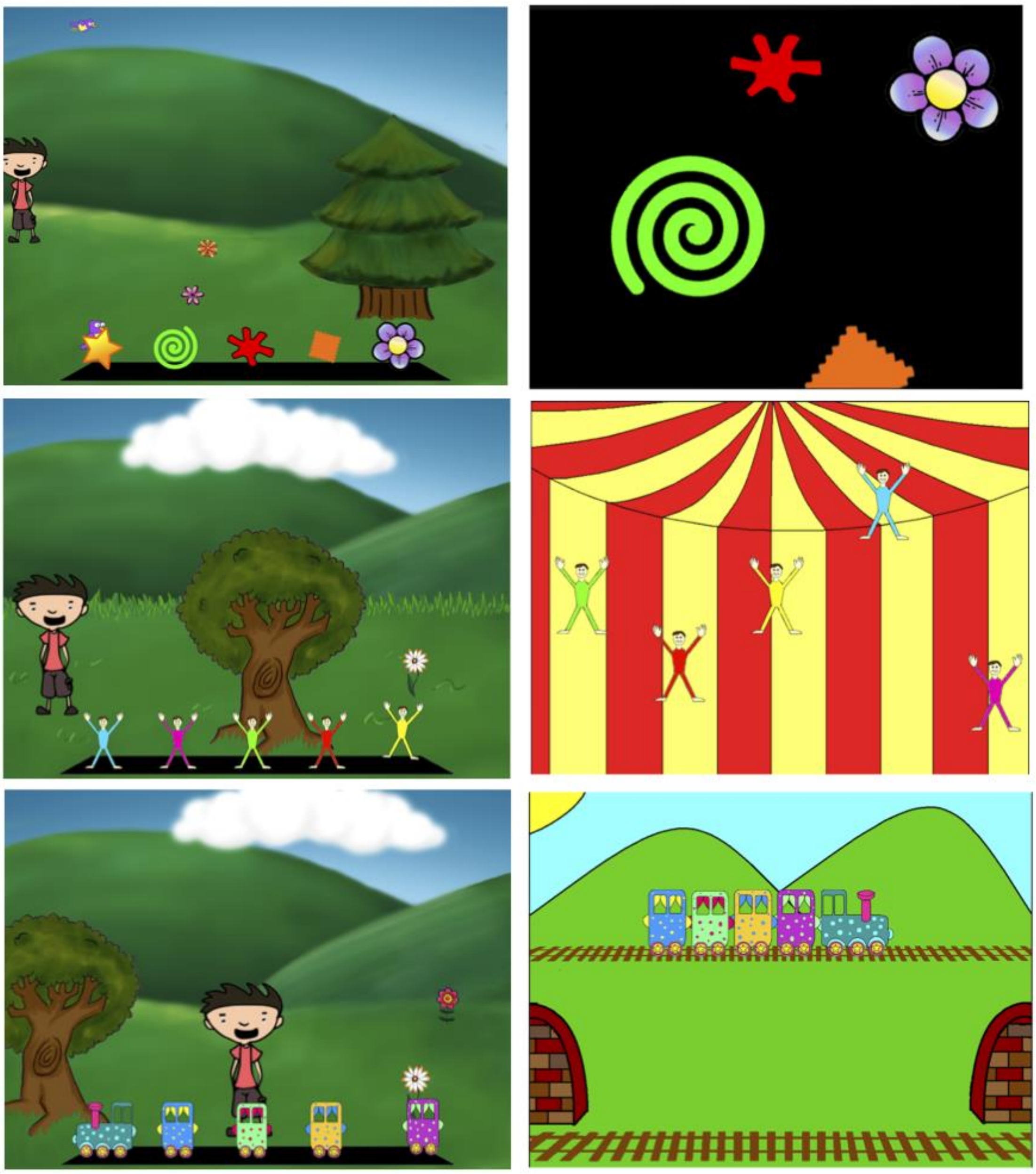


Figure 5: The visual voting system

Figure 6a: Time played (minutes) in favourite and ablated reward conditions

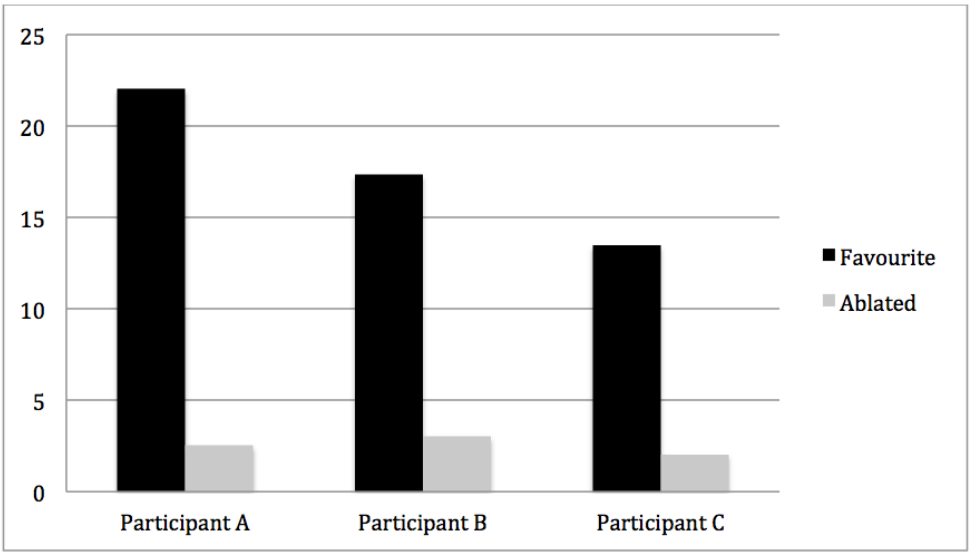
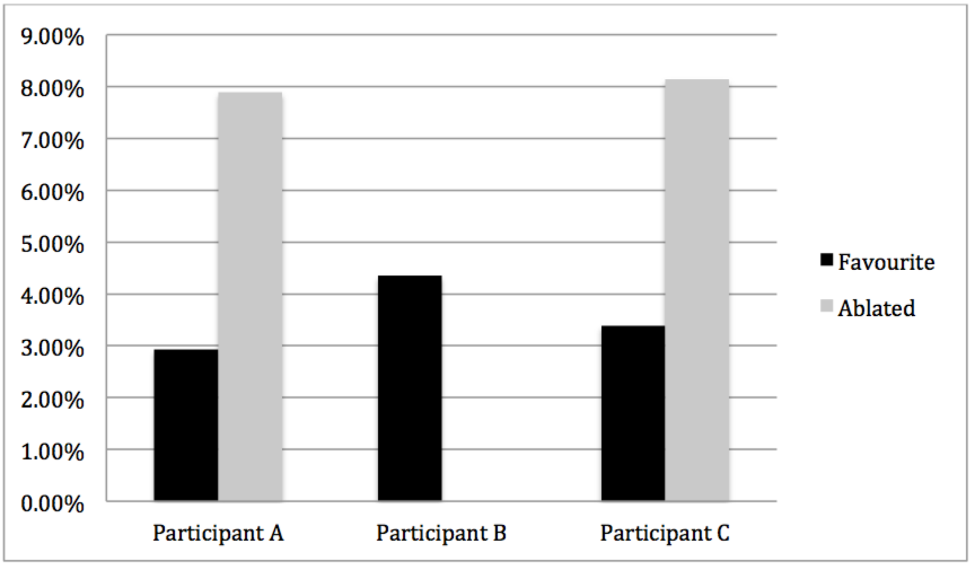
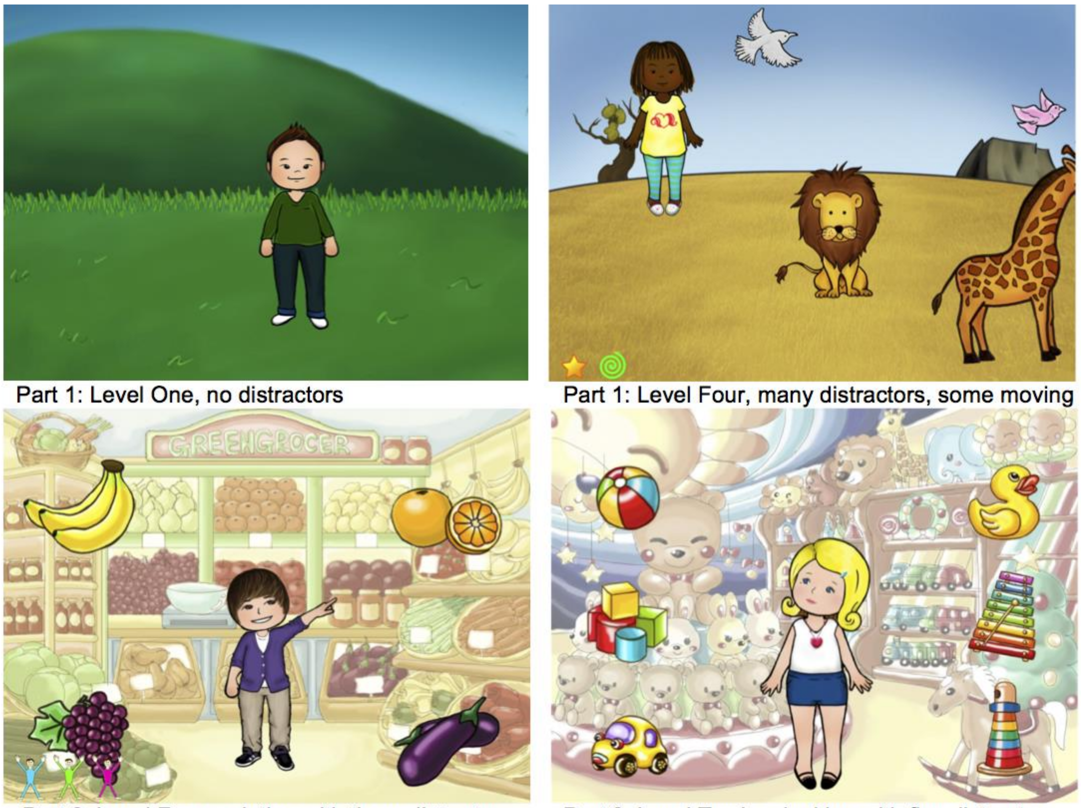


Figure 6b: Percentage of touches to distractors in favourite and ablated reward conditions.



NB: Participant B played so little in the ablated reward condition that he did not reach a level in which distractors appeared on screen.

Figure 7: Screenshots from the final, completed app



Part 1: Level One, no distractors

Part 1: Level Four, many distractors, some moving

Part 2: Level Four, pointing with three distractors

Part 2: Level Twelve, looking with five distractors