# Deep-Sea Disco Mat: Developing an Inclusive Social Play Technology for Autistic and Neurotypical Children

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# Executive Summary

Social play is important for the development of all children and yet children with autism experience social play far less than their neurotypical peers. In this project I researched the importance of social play for autistic and neurotypical children and the technologies used to assist social play. I designed and built my own play technology: a musical mat that allows children to create music by placing toys in different combinations on the mat. I ran a study to test the mat and analysed the footage of the study using ELAN a video annotation software. My results suggest that playing with the mat did increase social play behaviours in all the children. I propose ways in which the design could be improved and taken further and reflect on my work and its limitations throughout.

- I extracted design principles from literature to design an inclusive social play technology aimed at mixed groups of neurotypical and autistic children. (p1-14)
- I ran an expanded proxy design session using toys as proxies for autistic and neurotypical children in order to include children in the design process. (p14-20)
- I used RFID readers wired to a Raspberry Pi and programmed in Python to read from RFID tags and play different musical tracks that I composed using Ableton. (p21-26)
- I built a structure for the mat using laser-cut wood to house the electronics and keep them safe (p26-33)
- I recruited for a study and ran a session where I observed play behaviours with and without the mat for a group of neurotypical and autistic children. (p34-36)
- I analysed footage from the study using ELAN to show that the mat did increase social play behaviours in all the children. (p36-45)

# Acknowledgements

I want to thank the Bristol Autism and Social Play group who helped and supported me throughout my project. In particular I would like to thank Brooke Morris, Hayati Havlucu and my supervisor Oussama Metatla.

# Ethics Statement

This study did not require blanket ethics, but was covered by an independent ethics application. **Reference number: 15664**

# Author's Declaration

I declare that the work in this dissertation was carried out in accordance with the requirements of the University's Regulations and Code of Practice for Taught Programmes and that it has not been submitted for any other academic award. Except where indicated by specific reference in the text, this work is my own work. Work done in collaboration with, or with the assistance of others, is indicated as such. I have identified all material in this dissertation which is not my own work through appropriate referencing and acknowledgement. Where I have quoted or otherwise incorporated material which is the work of others, I have included the source in the references. Any views expressed in the dissertation, other than referenced material, are those of the author.

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# 1 Introduction

## 1.1 Aims and Objectives

Social play is a key factor in healthy child development. We learn the building blocks of many skills through our early interactions with peers [7], [28]. Children with autism benefit from social play, as any other child does, and yet they engage in social play less than their neurotypical peers [3], [11]. I am interested in how we can design play technologies to reduce this disparity. Many play technologies aimed at autistic children focus on curating neurotypical traits in the child and place the burden of change on them, rather than designing for inclusion on both sides.

In this project I researched the history of autism and social play and play technologies, taking design principles from the literature and weighing them up, so that I could design a successful inclusive play technology. After drawing out three key design criteria, I knew my technology should be: tangible, musical, and modular. I then began an iterative design and implementation process, working on developing a musical mat, which I called the Deep-Sea Disco (DSD) mat. I used expanded proxy design techniques and ran a study with children in order to test and evaluate both my design and implementation. I used video annotation software to analyse the footage from the study and extracted the data to assess the ways in which the children interacted without the mat and then while playing with the DSD mat. The analysis showed that playing with the DSD mat did increase social play characteristics in all the children. However, the analysis also revealed many ways in which my design could be further improved.

My aim was to encourage social play behaviours from which all the children would benefit. I also hoped to design a technology that would not place the burden solely on the autistic children to change their behaviours. Instead, I hoped to encourage all the children to work together and adapt in small ways to contribute to the play.

## 1.2 Motivation and Positionality Statement

My motivation is in part due to my own experience and I want to be open about this. I have autism myself and this plays a role in my decision to undertake this research. My autism was diagnosed fairly late, when I was 19, but the effects have been felt throughout my life. I felt motivated to take on this study as I wanted to contribute to our understanding of autism. I also hoped to ease some of the discomfort in being misunderstood or misinterpreted as a child with autism in your interactions with peers. I recognise that my analysis and evaluation of the work I carried out will be through the lens of someone with autism.

## 1.3 Research Question

I have two research questions that I hope to ask and answer through this report. The first and main question is “What makes an effective inclusive social play technology (within the scope of autistic and neurotypical mixed groups)?” This question is something I considered carefully throughout the research and design phases of the project and returned to when evaluating my own design. This question is at the heart of the project and remained in my mind throughout.

The second question focuses specifically on my design and build for the project: “What behaviours does the DSD mat encourage or dissuade?” This question should help me evaluate the success of my design and also provide useful information for further designs with the goal of facilitating inclusive social play. If my design dissuades certain behaviours and encourages others this could play a helpful role for further researchers hoping to design within this field.

# 2 Background

## 2.1 Models of Disability

Before I explain the history of research into autism and social play it is important to understand the differences in models of disability and the ways we understand autism. The medical model of disability, which took over from the historical religious view that disabilities were punishments for sins committed in this life or a past [1], suggests that a person is disabled if they are limited in their function by a medical issue to the extent that they are considered *deficient* to a "healthy" person [8]. According to this model a disability is akin to an illness and in many cases a terminal illness - an amputee cannot "recover" from the loss of a limb. Any limitations a disabled person experiences under the medical model can be attributed to the disabled person and their "deficiencies" [8]. This medical model has been heavily criticised in recent years. It blames the disabled person for any hardships they face by suggesting that no matter what they do in life there will always be something deficient about them when compared to a non-disabled person.

The social model of disability was proposed as an alternative view of disability in the 1980's [23]. According to the social model the terms "impairment" and "disability" should be separated. The social model suggests that an impairment is a kind of medical abnormality such as the loss of a limb, a chromosomal difference, or a neurological difference, an impairment is a mere description of the physical body with no judgement or value attached [18]. A disability, meanwhile, is the result of society not taking different impairments into consideration when designing public spaces [8]. For example, a person who uses a wheelchair, according to the medical model is considered disabled by virtue of whatever medical factor causes them to use a wheelchair, whereas, the social model of disability states that this person has an impairment of some kind but they only *become* disabled in situations where society has not taken this impairment into consideration with its design. In a building with stairs and no elevator someone in a wheelchair is disabled, if there is an elevator they are a person with an impairment (a mere description of the way their physical body functions) but they are able to participate in the use of the building just like anyone else meaning they are not disabled.

Autism seems to be well described by the social model of disability. The impairment found in autism would be certain nebulous neurological differences that are as yet not well described or defined. However, the *disability* present in autism can only be seen when an autistic person interacts with other people or an environment that does not suit their needs.

In a world where all the ceilings in every building are five foot high, a six foot person might seriously struggle to operate. They might try their best to find ways to adapt, but after years of doing their best constantly ducking or crouching in order to get-by they find themselves burned out and exhausted. It may seem clear reading this example that it is not the six foot person's *fault* for feeling this way. If they are expected to live in this world it does not seem unreasonable to ask for certain accommodations to be made. Even just raising the ceilings in a few buildings might improve their overall quality of life significantly. Being autistic is often like being six foot in a five foot world. The disability appears only at the interaction between the autistic person and the outside world. There is nothing inherently disabled about an autistic person just as there is nothing inherently disabled about a six foot tall person - but when you are expected to fit through five foot doors every day of your life it can look and feel like there is something wrong with you.

According to the social model, social changes and design accommodations would remedy disabilities in contrast to the medical model where medical intervention is the only suggested way to alleviate discomfort [18]. This sets the stage for the rest of this thesis as I try to design and build an inclusive play technology - aiming to ease the disability barriers of social play. Autism is simply a neurological difference that does not need to be disabling if we take an inclusive approach to design.

## 2.2 Social Play

Social play is defined in many ways, the common features of these definitions suggest that it is an enjoyable, intrinsically motivated activity, which serves no external purpose and involves some level of social interaction [10], [15]. Social play amongst young children is essential for healthy development [7], [28]. There a four main characteristics of child development: "physical, intellectual, emotional and social" [20]. Play can benefit each of these areas in numerous ways [28]. To give a few examples: playing games which involve tangible objects such as balls, sticks, hoops, or figurines will encourage both fine and gross motor skills and coordination. Often games, whether invented or followed, involve a strategic element which develops decision making and other intellectual pursuits. The cooperative element of most games along with the reactions and feelings expressed by other children involved, encourages both social and emotional development as they have the opportunity to instigate and react to the emotions of other children. These skills play a key role in a child's ability to create lasting bonds and relationships [28].

Play is generally purposeless other than for its developmental benefits, this means that the process is the desired goal rather than the outcome [28]. In other words, whether a game is won or lost, led or followed, structured or free does not matter. In fact varied play should encourage the growth of different development characteristics which should be beneficial to a child's overall development.

## 2.3 Autism Spectrum Disorder (ASD) and Social Play

Generally research suggests that children with ASD engage in social play less than their neurotypical peers [3], [11]. In some studies the non-autistic children engaged socially in play over 56% more of the time than the ASD children [11]. Children with ASD have a harder time interacting and engaging with peers in social play [5]. Given the known benefits of social play, researchers have tried different methods to increase the social engagement of children with autism. One area of focus has been on individually trying to address social "deficits" through skills sessions, however these have been minimally effective [3]. Some techniques which do seem to encourage "prosocial" behaviours of ASD children within groups are: smaller group sizes, child-directed play and limited adult interaction [3]. Many of the interactions initiated by autistic children were started through the use of a tangible object [3], it is possible that the use of an object relieves some of the pressures or regular stressors of a social interaction.

Christopher Frauenberger emphasises that the social exclusion ASD children experience can lead to a spiral where their social skills — underused — deteriorate which makes it harder to join in with peers, leading to falling further behind socially [7]. Often ASD children might prefer repetitive solitary activities over group play, perhaps because they have already experienced miscommunications amongst peers which left them feeling misunderstood [7]. The results of some studies show that ASD children who were enrolled in inclusive schools or programs (where they engaged socially with neurotypical children) showed more social behaviours (initiating and responding), than children who were only enrolled in special education schools or programs [3]. This could contribute to the suggestion that early positive social experiences can lead to an upwards spiral of further positive interactions.

Much of the research in this area revolves around changing the behaviours of autistic children in order to better meet the needs of the neurotypical children in a group. It is noted by researchers that children with ASD are "not accepted as well by their peers" [3]. Many assistive technologies are intended for "intervention or therapy" [25]. That is, they view autism as characterised by its percieved "deficits" that should be corrected [15]. Katta Spiel puts this simply:

> "The implicit assumption is that there is an increase in quality of life for autistic individuals if they function in a more neurotypical way and technologies are designed towards this goal." [25]

Perhaps this should not be the goal. The autistic way of experiencing the world has many beautiful and beneficial elements on both individual and societal levels. In order to address this, it seems we should also focus on encouraging neurotypical children to be more accepting and open within their social play and ways of thinking so that we don't force the burden of change onto the autistic children alone. I worked as part of the Autism and Social Play research group here at Bristol. Their research has lately focused on the double empathy problem which highlights "interpersonal issues rather than problems of one group" [15]. They work on the design principal that barriers to social play arise from the interaction of neurotypical and autistic children and are not inherent to either group individually. I intend to adopt this view throughout my design.

Many studies which do include mixed groups within social play have revolved around ASD children playing with children who have other disabilities and so the results are not necessarily applicable to the case of ASD and neurotypical children playing together [7], [11], [15]. However, mixed groups of autistic and neurotypical children have been identified as beneficial to all participants, more than non-mixed groups [15]. This may link back to the developmental benefits of social play, differences in the participants may encourage the use of different skill-sets and further develop previously unused social tactics. The goal of this project is to gain a better understanding of social play within mixed (neurotypical and autistic) groups.

## 2.4 Social Play Technologies and Autism

The use of technology in assisting social play, historically, has a fairly negative reputation. One damning article reads: "playing is interacting and cooperating with others, discovering likes and dislikes, and developing in all areas of development. Using technology does not allow for these opportunities" [28]. I disagree with this claim, though I acknowledge that one cause of this response is that many papers do not seem to distinguish between kinds of technology [24]. Ruslan Slutzky does not distinguish between technologies including: TV, tablets, Skype, or electronic toys, when putting together the overall analysis of results in his study [24]. Clearly some of these technologies provide greater space for social interaction than others. I think social play technologies include more than simply electrical devices with screens. I take a social play technology to mean a device used to enhance social play [22].

Technology interactions can be more predictable than human responses and may be favoured by ASD children for this reason [5]. Computer interactions can provide a way in to social interactions for ASD children by providing predictability and regulation [5]. One of the main criticisms of this approach suggests that computer interactions may become the sole method of interaction preferred by autistic children over human-human interactions. TUIs (tangible user interfaces), which allows users to interact with a digital environment through physical space, are seen as a helpful medium between the two sides of this argument [5], [17]. Using technology within play, especially in the format of tangible play technologies, has had positive results in encouraging social play behaviours for children with autism [2], [16], [17]

## 2.5 Key Factors to Influence Design

To conclude the background section I highlight three areas of technology assisted social play between mixed groups noted by the literature, that will go on to influence my design. These ideas are heavily influenced by the design considerations in the Double Empathy paper by Brooke Morris et. al. [15].

1. I aim to **reduce ambiguity**. There is evidence that situations with no predefined rules may lead to misunderstandings in mixed social play groups, a solution might involve a technology with a clear use that the children can interact with independently in order to show willingness to play without having to communicate that verbally [15].

2. I aim to provide the opportunity for **sensory regulation**. Children with ASD are more likely to be hyper-reactive to sensory stimulation which can lead to increased anxiety and overwhelm, which are not conducive to constructive social play [21].

In order to regulate this children may need to withdraw from a group setting and be able to control their sensory input - whether that is noise, touch or smell. Regulation could come in the form of calming music, repetitive behaviours or physical distance [15], [25].

3. I aim to prioritise the opportunity for **control within social play**. Linking the two previous points, autistic children often prefer to do things a certain way which may not be shared by others (even other children with ASD) [15], [21], [25]. This feature could take the form of control of the game or play technology itself or the ability to control their own individual actions and environment. Allowing the children control within the situation should help them with sensory regulation as well.

# 3 Design

## 3.1 Design Ideas Based on Background Research

To begin the design process I thoroughly researched design approaches previously taken within this space and also looked to the interviews and recordings taken at schools by the Bristol Autism and Social Play project. I used this research to come up with three key factors, discussed at the end of the previous chapter, which I thought should influence my design. All of this led me to prioritise three key things within my design each focusing on a different design factor. I will expand on each and give the evidence and reasoning behind them.

### 3.1.1 Tangible Object

The majority of research suggested that a tangible user interface is best suited to encourage social collaboration [6], [16], [17], [27]. This seems intuitive, if you want to encourage children to come together and have meaningful shared experiences in a space this seems most easily achieved using a substantial physical object. A tangible object need not imply there is only one goal to the play [17]. Instead, it gently guides play so that children can share a common focus even if they arrive at the object with different ideas. This also links to my first design factor of **reducing ambiguity**. Entirely free play or intangible games may lead to confusion and misunderstandings between neurotypical and ASD children. A tangible object should reduce this by making the focus of play clear.

### 3.1.2 Musical Object

In other studies developing play technologies for children (neurotypical or ASD), music features heavily and seems to have positive results [7], [27]. It seems important that no unpleasant sound can be created by the technology as this could cause sensory distress to any child but particularly ASD children with hyper-sensitivities [27]. Adding music to my design provides a kind of **sensory regulation** within play, my second design factore.

### 3.1.3 Modular Object

One idea which arose throughout my research was that of using a modular object to allow for more freedom and control within play. Christopher Frauenberger talks about children creating their own "play spaces" where they can use a technology within a familiar environment [7]. This could be achieved by modularising the technology so that each child has a degree of control within the group play [15]. They can then choose to play with the group or to take themselves away. They can also control their play experience. A modular toy allows for individual play or group play. This reflects my third design factor to provide the **opportunity for control** with a social play setting.

## 3.2 Design Plan

Bringing these ideas together I started to brainstorm ideas that combined tangible, modular objects with music. I became interested in using Radio Frequency Identification (RFID) tags to build something which would allow the children to each have an item which could interact with a map object which would respond in different ways depending on the item the child had. A simple example might be if one child had a small toy pig while another had a toy cow, when they hover over the same place on the map one would oink while the other mooed. I thought if I could also integrate music into the map response it would cover all the key design features I hoped to use. The design would be modular in that each child could have an individual item that they could move around and take into their own space and individually interact with the map. However, they

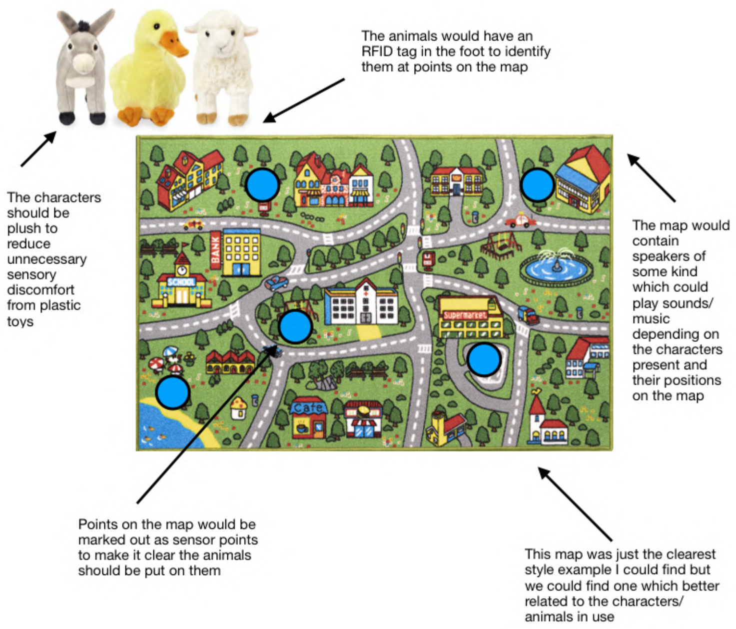


Figure 3.1: First Design

could also all partake in group play which would illicit different responses from the map - encouraging them to collaborate.

## 3.3 Designs

The design process was one of the most significant in my project. It was an iterative process where I constantly reflected on and evaluated the design at each stage, with the help of the Autism and Social Play research group. I also wanted to include children in the design process. This is a helpful tool that is important within the field of Human-Computer interaction (HCI) for developing more inclusive technologies that represent the people they claim or aim to be designed for [13]. I discuss this process in greater detail towards the end of the chapter in 3.4.

My first design, shown in figure 3.1, was the result of my design plan and design ideas, discussed at the beginning of this chapter. I took this to an initial meeting with the


Figure 3.2: Second Design

rest of the Autism and Social Play group to get feedback and ideas. Their ideas and criticisms influenced the next stage of my design. They suggested that, based on the observational data they had already collected within schools, children liked to split up amongst multiple areas and had quite defined categories of play based on these locations. They mentioned a "stage" area in the playground which the children seemed to enjoy dancing on but that not all the children wanted to get involved in this. The children also formed an audience to the stage where they were clapping and making music for whoever was on the stage. They suggested that I should consider multiple mats or areas which performed distinct functions but that cohere to one overall goal and "communicate" with each other.

After this meeting I went away and put together my second design, shown in figure 3.2. This incorporated the key ideas from our design meeting including multiple areas and different methods of play. In this design children could choose what to get involved with music, lights or dancing and each would interact with the others. I presented this design at our meeting the following week. I noted in the meeting that I thought given the time constraints on my project I would only be able to complete the music and stage sections. Depending on the success of my project in the evaluation study the group could then decide to expand my design to include another section if they thought this would be beneficial. This design was given the preliminary go-ahead. Our plan was to gather together some of the physical materials I would use and run a design session with the children using the plush toys and the rug to observe any design feedback from the children. This would then inform any changes that needed to be made before I went ahead with the final implementation.

## 3.4 Co-Designing with Children

Including children in the design process of technologies that are created for their use is one of the goals of HCI [7], [13], [14], [26]. However, there are a number of barriers to doing this effectively especially amongst children with additional needs, who may find it difficult to verbalise their feelings. They may also be more likely to be led to conclusions by whoever is conducting the study [13].

Children's responses to a design might not take the same form as an adult's review but lots of their comments or actions can be incredibly insightful [14]. Asking questions like "What is this for?" might show that a design feature is not clear enough in its purpose. "That's silly!" might show that there is a mismatch in design and function or could show engagement and enjoyment, depending on the child's other reactions or behaviours. Co-designing with children may involve extra effort on the part of the researcher to interpret the responses of the children but I believe they can and should be involved in the process.

### 3.4.1 Expanded Proxy Design

One way to include children in the design process is through expanded proxy design. Proxy design allows people close to the intended user of a technology to assist with the design process in order to help researchers understand the needs of the user when the user might find it hard to describe what they might need. Metatla et al describe the idea of expanding this notion of proxy design to use objects or toys as proxies for children to design “through” [13]. In expanded proxy design some of the needs or traits of the end-goal user are bestowed on a toy, this is explained to the children who then come up with design ideas to help the toy with whatever they might need. In their paper, they use the example of a toy hippo who can only speak “hippo”. The children were tasked with the goal of designing a game that they could explain and play with the hippo despite the language barrier. The undercover aim was to include children in the design process of designing games for inclusive play between children who do not speak the same first language.

### 3.4.2 Running My Own Expanded Proxy Session

As part of my study I ran an expanded proxy design session. I had hoped to run this before I implemented my final design so that I could make changes based on the suggestions raised. However, as I go on to explain in Chapter 5.2, unfortunately this was not possible. I ran the expanded proxy design session directly before evaluating my design. My expanded proxies were plush toys that would go on to interact with the mat to make music. Each toy was given a one-line personality trait which was a trait of either a neurotypical or autistic child (or both!), these can be seen in figure 3.3. The personality tags were tied with ribbon to each toy so that the children could remind themselves. I talked through each toy and then asked the children if they could come up with a game or a way to let all the toys play together while helping them all feel comfortable. The children were encouraged to use paper, pens and stickers to draw their designs. The session was filmed so it was easy to go back and hear the children’s explanations of their designs which are described below.

The children all engaged with the expanded proxy design task to different extents. I will talk through each child’s response and include an image of their design before I draw out a few themes that appeared most apparent. I will refer to the children by their anonymised pseudonyms created for my analysis of the study: A1, N1, and N2 (A refers to the diagnosed autistic child and N for neurotypical).


Figure 3.3: Expanded Proxies: Fish with Personalities

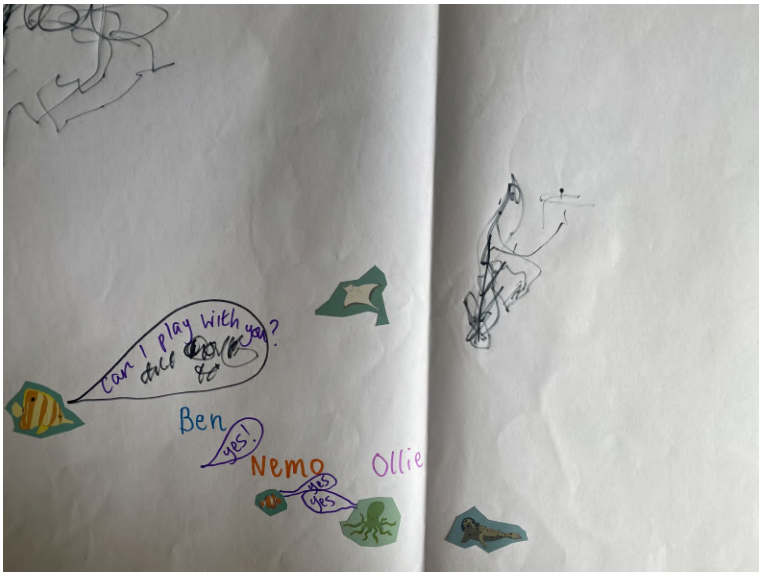


Figure 3.4: A1's Expanded Proxy Design

Figure 3.5: N1's Expanded Proxy Design

A1 appeared to struggle slightly with the task, they seemed distracted throughout which may have been their own interests in other things in the room or possibly that the task was confusing. They were prompted a lot by their parent throughout the task. It was clear A1 somewhat understood the task as they gave coherent answers to my questions about what each toy might need based on their personality tag. Hence, they did not seem keen to draw or use stickers on the paper so their parent did most of the compilation of their proxy design but through the medium of a conversation with A1 about the needs of each toy. Their design, shown in figure 3.4, shows Ollie, Ben, Sally and another fish playing when Amy the Angel Fish whose tag says that she finds it hard to ask to join in coming over and asking to play. A1's parent prompted that if someone does not know how to join in with a game they should ask and this is what they wrote on the design. However, I had hoped to show or encourage other methods of asking or understanding when someone wants to join in. A1 throughout the session held on to Ben the Blue Tang and would take this fish away from the design group understanding and appearing to empathise with the idea that Ben liked space.

N1 seemed the most eager to complete the design task and they put together a clear

Figure 3.6: N2's Expanded Proxy Design

vision for how the toys might play together. In figure 3.5, N1 has drawn a game of cricket played with the Tom the turtle at the centre as his personality tag requires, N1 described Tom as being the wicket keeper. N1 described Ollie the octopus as controlling the game directing the players in what to do, as his personality tag requires. Sally the seal is pictured near the upper centre of the page with headphones on listening to her own music so she does not feel overwhelmed by too many noises, just as her tag suggests. When asked about Suzie the starfish who likes to copy Tom, N1 explains that cricket requires two wicket keepers so Suzie can copy what Tom is doing in her own way. They placed Ben the Blue Tang in a game of Frisbee with another fish because "you need to have space to play Frisbee". N1 did not have all the fish playing together in the sense of the same game, instead, all the fish were together on the playground but involved in different games or behaviours based on their tags. N1 was very quick to pick up on all the animals' needs and to remember them throughout the design process.

N2 took the design in a very different direction, drawing an underwater "tornado" of sea creatures seen in figure 3.6. The toys are squeezed very tightly together. When asked about the reasoning later by their parent they said that they had put Ben in the middle to make him cross because he liked his own space. This feedback was given to me by the parent after the session when they spoke to their child about the events of the session. This shows how valuable insight from parents can be when designing with children as they might be able to ask more detailed questions and feedback after the session ends. In this case it shows that N2 understood the intent of the task and purposefully chose to design against it.

### 3.4.3 Evaluating My Expanded Proxy Design Session

To be critical of the session I think that perhaps the children were slightly too young for the way this task was structured. I will explain the recruitment process and why this ended up happening in chapter 5.2. The children all struggled at times to read the personality tags for themselves, requiring help from me or their parents to read them out. In addition to this, the task did not grip the attention of N2 or A1 for very long and they perhaps would have benefited from a more focused, shorter task. However, as shown in the descriptions above, all the children engaged to a degree and all of them incorporated ideas from the personality tags into their designs. They all picked out the element of space and played with this in their drawings. I think that with a slightly older age group this task would have yielded even more insights.

I am also aware that positive and negative feedback to situations and tasks presents differently in neurotypical children compared to autistic children [13]. I mentioned above that there were several times throughout the design task where A1 appeared to be distracted but there were also times which showed they had been listening during periods of apparent distraction. It is highly possible that they were focused for more of the task than is visually obvious. A1 at one point during the design task put Ben the fish inside the plastic box that was originally holding the pens. I commented that Ben was trapped and A1 let him out of the box again. I initially saw this behaviour as "off-task" as it did not seem to directly connect to the design, but it might be possible to interpret this as another exploration of space and design. I bring this up to highlight the challenges of co-design with children and the limitations of using observations and reported data. I hope that at least through my awareness of the challenges I have been able to keep an open mind to what I observed and the conclusions I draw.

It was difficult only being able to run one session which contained both a proxy design study and an analysis of the design and implementation of the mat. I learned a lot through the proxy design and free play that would have gone on to influence further design work if I had had the time. I think it would be worth taking a few different ideas and running further design sessions to get more feedback and design insights from the children.

# 4 Implementation

I hoped to test my implemented design in a school before the end of July which placed a tight time restraint on my build. For this reason, I had to begin the basic implementation early in June before I had finished the final design.

I implemented my design in stages. I started small, using one RFID reader and tag in order to learn about the processes involved and test what would be possible within my time constraints. This method of building in stages allowed more time to consider the holistic design as I built. I knew that I would be using RFID tags so I started the build with those while I simultaneously researched and discussed the design with my supervisor to hone in on the final product.

## 4.1 First Stage: One RFID Reader

I began the implementation by acquiring some of the equipment. I knew that I would need RFID tags and readers and some way of running software that could take information from these readers and perform actions. There were two options for this: an Arduino or a Raspberry Pi. I had a small amount of experience working with a Raspberry Pi to run basic ARM code and I felt more comfortable about my ability to set up software on the Pi, so I went with this option. I also bought all of the connecting pieces necessary (power cables, HDMI cables, jumper wires and a breadboard). I began by installing an operating system on the Raspberry Pi. I used an SD card to download the OS through the Raspberry Pi website which I could then insert into the Pi. I could then write and run code on the Pi.

Once the Pi was set up I turned my attention to the RFID readers. When they arrived the readers did not have attached pins, the pins needed to be soldered into position before the readers could be used. I had no experience with soldering but after watching some introductory videos and reading some beginners' guides I made my first attempt at soldering on the pins. Unfortunately, it did not go to plan, at the time I did not understand why, though I now know my iron was not hot enough and I did not have a way to properly clean the iron before soldering. When I attempted to wire my first soldered reader to the Pi, the connection was not good so the RFID reader power light would cut in and out intermittently flashing red. At this point I sought help from the Hackspace lab in the Merchant Venturers Building. I was given a brief demonstration of soldering and then I was allowed to use the equipment in the lab. Using the lab's soldering irons and brass sponges to clean the iron helped significantly and I was able to solder (or re-solder) all of my readers, this is pictured in 4.1. When I wired up the reader to the Pi, as described in the next paragraph I could see a constant red light, indicating power on, rather than the flickering light I had seen before due to a poor connection.

I knew that eventually I wanted to connect multiple RFID readers which would mean using a breadboard to split the input from the Pi to multiple readers. I used a schematic for wiring up multiple RFID readers to a Raspberry Pi through a breadboard to check that all of my inputs and outputs were in the correct locations [12]. Although, at this stage I only had one reader wired to the board as shown in 4.1.

I used the PyPi Python libraries for the Raspberry Pi to access a mfrc522 library for using RFID readers. I used the basic example code to check that things were working and read my first tags. Initially, when I printed the tag data the text stored in the tags was a long string of numbers. For my purposes I needed to be able to reference tags easily and distinguish between up to five tags so a long string of numbers was not the best way to do this. I wrote a small script which could write data to the text part in each tag and changed my tags so that each had a number from one to five. This helped me throughout the project as I could easily refer to each tag and write code to behave differently for each one.

The next challenge was using music within my code. There a many options for playing

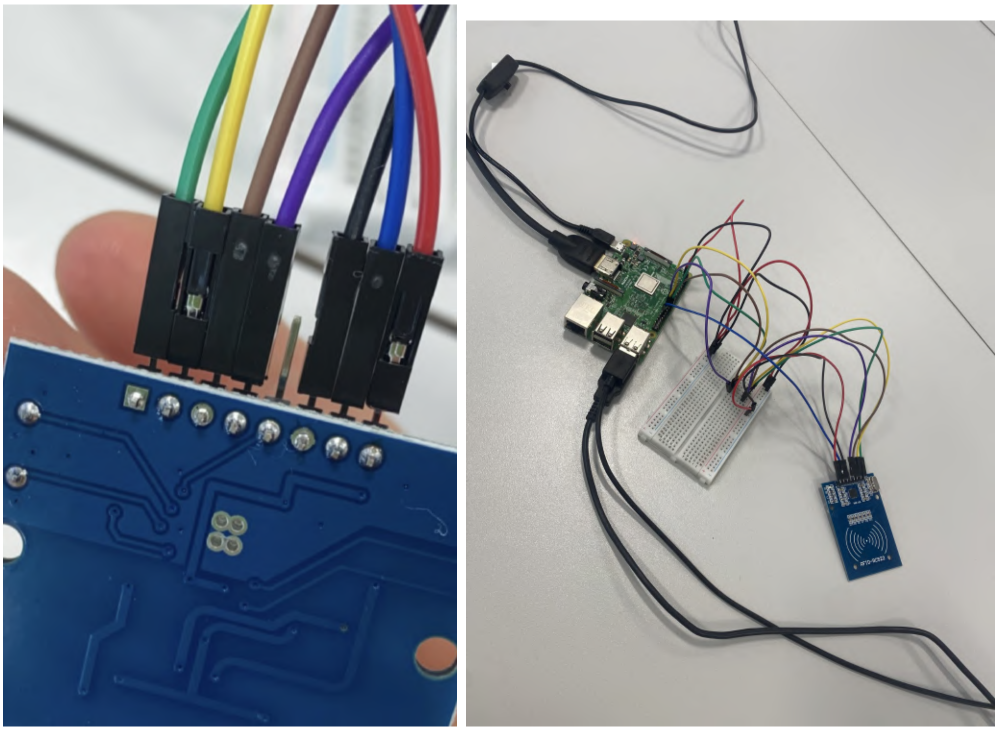

Figure 4.1: Second Attempt at Soldering (left) One Reader Wired to Pi (right)

music in Python, I tried both the playsound and pydub libraries before settling on pygame. Pygame allowed me to play the music in the background while the rest of the code still ran which would allow me to check whether a tag had been removed from the reader and stop the music if this was the case. Using the other libraries I would need to set up multiprocessing or multiple Python threads in order to play music while running code. I experimented with all of the options but pygame allowed for the simplest and cleanest implementation. I downloaded some free music samples to test whether pygame worked, ahead of implementing the final music.

## 4.2 Second Stage: Multiple RFID Readers and Music

My research into using RFID readers with a Raspberry Pi suggested that setting up one reader would be straight forward but that attempting to use multiple readers simultaneously was less so. The Raspberry Pi accesses data from the readers using the Serial Peripheral Interface (SPI). However, the Pi only has one set of pins to connect an SPI device, so reading from multiple RFID readers simultaneously is impossible. However, you can use free GPIO (General Purpose Input/Output) pins to connect to an SPI device (in this case the readers) and then by setting the output of those pins to low or high you can cycle through them using the SPI to access each reader in turn, you can read from different readers in the same second which would make my project possible. I wired up my readers to the Pi as shown in the circuit diagram 4.3.

I used the RPi.GPIO library to control the GPIO pin output from the Pi, setting all of the pins connected to readers to low initially and then rotating through which pin I set to high and reading the output from the RFID reader connected to that pin, you can see how I do this in figure 7.1. This allowed me to cycle through the readers and get data from multiple tags on different readers in near real-time.

At this stage I had made more design choices. I had decided on the "under the sea" theme and ordered the plush toys and rug. I sewed the RFID tags into the small plush toys as pictured in 4.2.

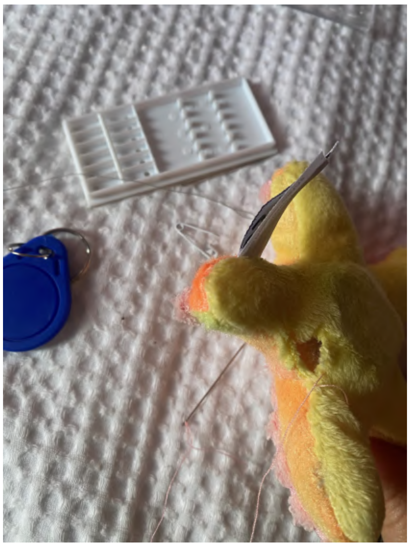

Figure 4.2: Sewing Tags into Plush Toys

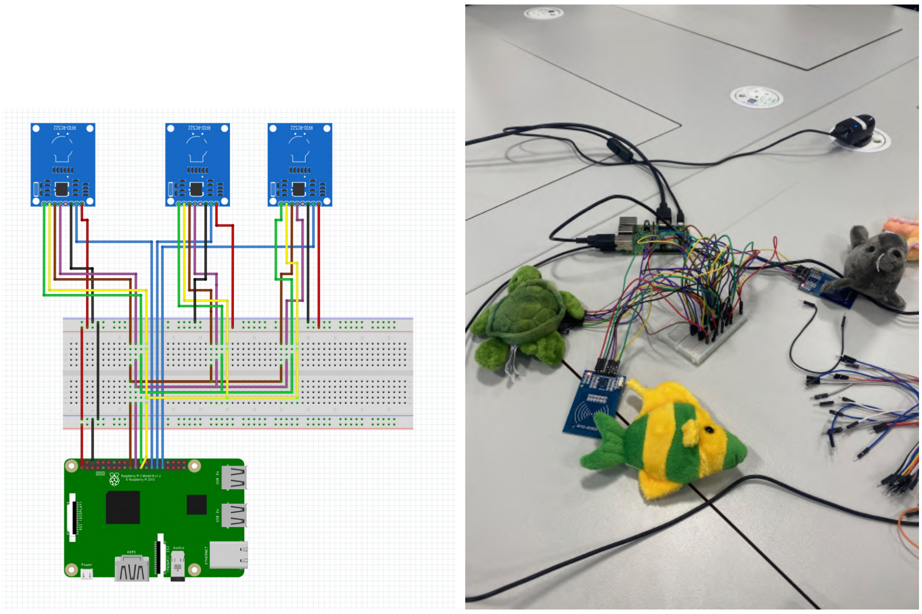

Figure 4.3: Circuit Diagram Made Using Fritzing (left) Three Readers Working (right)

Now that I could read data from multiple tags, as seen in 4.3, I could think about the music that I wanted to use. I wanted each tag to contribute something unique to the song that was being created so that it was noticeable what each child was adding or removing from the music. I met with lecturer Pete Bennett, who specialises in TUIs involving music, to discuss the music element to my project and he suggested that I use a software called Ableton Live. This way I could make my own music and save each variant of the song to play in my code. I created a basic song composed of individual elements: bass guitar, piano chords, drums, and flute. I then recorded each variation and combination of these component parts resulting in 15 different music options that could be played over the three readers.

## 4.3 Third Stage: Hardware

The electronic and programmed components of the project were nearly complete at this stage so I began to focus on the physical hardware that would house them. I first needed to create a frame so that the electronics would sit below the rug and be safe from damage. The frame needed to be strong enough to withstand children climbing or walking over it. I wanted to spread the readers across the space of the rug but the laser cutter in the lab can only cut material up to 800x500mm and the rug is 1500x1000mm so my laser cut design was split into three pieces so that it would span the length of the rug. I used Inkscape to draw my designs before importing them to CorelDraw to cut, pictured in 4.4. The three pieces fit together to create channels for the wires to run through, though at this stage the wires were still far too short for the end design this can be seen in 4.4.

I used a larger piece of chipboard which I sourced from the General Engineering lab scrap to go behind my laser cut design so that I could tape the wires to the back board set within the laser cut board. I securely screwed the three laser cut boards to the chipboard. There were slight differences in the sizes of the chip board and the lasercut boards as the height of the chipboard was correct for the size of the rug but the width was too narrow whereas the laser cut board summed to the correct width but were slightly too short

Figure 4.4: Cutting Middle Section (left) Laser-Cutting and Current Wiring Set-Up (right)

for the height of the rug, this is visible in 4.5. I fixed this discrepancy using small laser cut support blocks of wood to go under the edge of the laser cut boards on either side where the chipboard came up short. The small difference in height of the laser cut boards compared to the chipboard did not matter as the rug was thick enough to cover this.

My original plan had been to place the Raspberry Pi and the connected breadboard inside the channels of the laser cut wood so that the mat could be self contained. However, although I used the thickest plywood available to laser cut (12mm) which was just enough to house the Pi, in the end I decided that it might be best to house the Pi and breadboard in a separate box attached to the side so that if children wanted to jump or lie on the mat this wouldn't damage the Pi or the connected wires which would be pressed fairly close to the surface of the mat. I used MakerCase to create a laser cut design for a box that I could attach to the side of the mat [9]. I added a small hole for the wires to run from the Pi in the box out into the channels of the laser cut boards 4.5. I used hot glue to put the laser cut box pieces together. I attached this box to the outside of the chipboard.

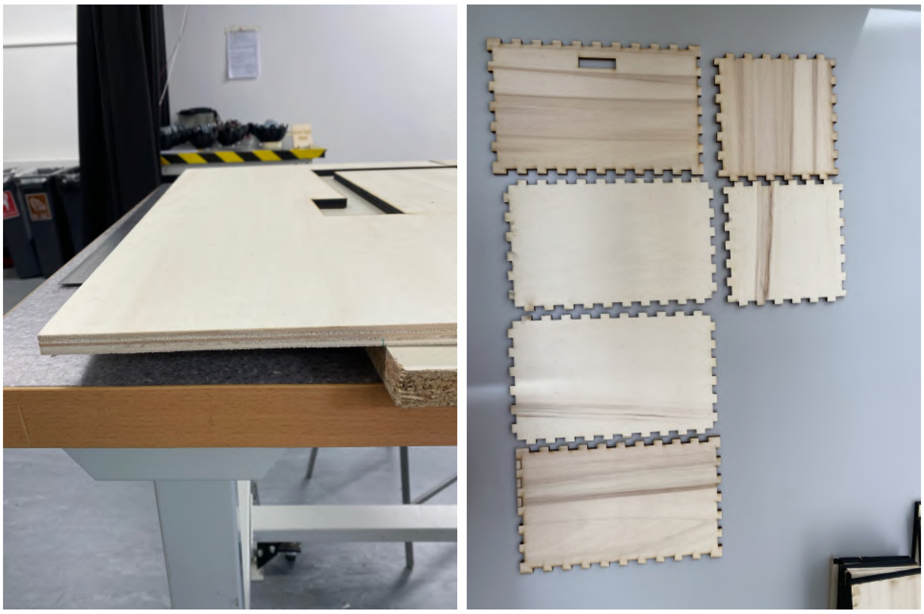

Figure 4.5: Visible Gap Under Plywood (left) and Laser-Cut Electrical Box (right)

Figure 4.6: Raspberry Pi Box Attached to Chipboard and Wires in Laser Cut Channels

Figure 4.7: Blue Foam Protects Children From Sharp Wood Corners (left) and Rug with Foam Cut Out to Reduce Material Between Reader and Tag (right)

Once the board was prepared I needed to make all of the wires to my readers a lot longer so that they could run through the channels of the board as they were far too short, see figure 4.4. As I was using a mixture of female-female and female-male jumper cables the easiest way to make them all longer seemed to be to cut the wires and solder in a length of wire. So this is what I did, I measured the length from the channels to the external box and added a length of wire into each of the 21 wires that attach the readers to the Pi. I slightly overestimated the length I needed for each wire, this was sort of on purpose as I didn't want the wires to be too short and pull on the connections. This mean that when I fit the wires into the channels to tape them down I ended up looping each bundle of wires to use up the excess wire. This can be seen in 4.6.

I added blue foam around the edge of the wood so that there were no sharp corners. I also added foam over the electronics box. I wanted the children to be safe to lie right near or on top of the mat so I didn't want there to be any visible wood that could splinter and injure them 4.7. At this point the hardware was nearly ready so I put the rug over the top and tested the mat. I was getting occasional reading errors when I used the rug that weren't there when I held the tag to the reader directly. To fix this problem I added small blocks of wood under each reader to raise them up in the channel and turned them over so that the raised area where the pins and wires attach was facing down. This meant that the readers were held flush against the bottom of the mat. I also used a Stanley knife to cut out the foam from the rug directly over the readers so that the material in-between the reader and the tag was as thin as possible, seen in figure 4.7. This seemed to fix most of the reading errors.

The only things left to do at this stage were to attach the rug and mark out on the rug where the readers were so that the children knew where to hold the animals down. I decided to use Velcro to attach the rug to the wooden base so that if I needed to access any of the internal wiring I could. This also means that the mat can be repurposed with different themes with minimal effort, you would only need to purchase another rug. I bought several metres of Velcro tape and ran it along every side of the rug and put some sections of tape across the middle as well to secure it well. Then, with the rug attached, to mark out where the readers where I cut circles out of green foam and hot-glued them to the rug.

## 4.4 Final Stage: Music Variation and Error Tolerance

As I neared the end of my build I had a few days before the planned evaluation session. My supervisor suggested that I add some more variation to the music options to hopefully increase the engagement from the children. This would most likely come in the form of varying the music based on location in addition to the animal. This way it not only mattered that you were using the seal on the mat but also where on the mat you placed the seal 4.8. This way, using the seal on the top right hand corner produces a different sound to using it on the bottom left. This initially concerned me for two reasons: firstly, the number of musical combinations, that I would have to record MP3's for, increases exponentially as I add more variations. If location isn't taken into account there are

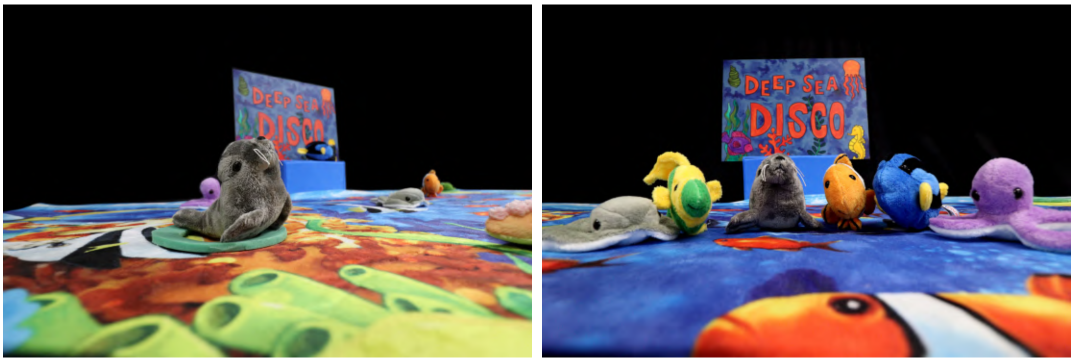


Figure 4.8: Seal on Music Making Circle (left) Plush Toys (right)

16 possible sound options including silence based on having four different tags, three of which can be used simultaneously at any one time. However, if the three locations are taken into account that number becomes 125 which I did not have the ability to make in the time available. Following from this point, the second concern I had was that one of my design aims was to reduce ambiguity to better meet the needs of the autistic children. If not every combination has a reliable predictable outcome I feel like the purpose and result of the music making becomes ambiguous.

I decided to approach the addition of new music methodically. Some animals would change their sounds depending on location but others wouldn't. This would link to the proxy design activity we had planned for the evaluation session where each animal is given different characteristics to represent those of different children and their needs.

While testing the mat for the reading errors I mentioned in 4.3, I began to notice that occasionally a reader would briefly incorrectly read a blank when a tag was present. This led to the music restarting because it thought the tag had been taken off and replaced. One solution to this was to build in a one gap margin of error by storing the last set of tags that had been read and not stopping the music or starting another until both the current reading and the last reading are blank. This would mean that any gaps of one missing reading would be smoothed out and the music would play without the harsh sounding restarts. Until this point my code was implemented in such a way that the code would first check how many tags were present before then determining which song


Figure 4.9: Finished Mat Implementation

to play. However, if I wanted to store and check the last set of tags as well this would be a problem. If I got the set of readings: 201 (tag 2 on reader 1, no tag on reader 2, and tag 1 on reader 3), 200, and 201 I would like the code to read the middle reading as if it was still 201. However, the way the code was implemented it would be immediately sent down the wrong path because only one tag was present (the 2 on reader 1) instead of two (2 on reader 1 and 1 on reader 3). So I decided at this stage to refactor most of the code. This was not a small job as it meant changing the entire way the music was implemented. It coincided nicely though with my plan to introduce more music variations depending on location. I was going to have to change the music code to implement this anyway so I found a way to do both at the same time. This time instead of splitting the code depending on how many tags were present I stored all the possible combinations of tags in arrays based on the tags present and checked whether the current or last tags were present in a particular array. I then only played the appropriate song only if it wasn't already playing and if the last tags were the same as the current tags, this is shown in figure 7.2. This way songs wouldn't change if I got one incorrect reading. Testing the DSD mat after changing the code, the changes between music were a lot smoother and there were less mistakes in the music that played. The final implementation of the mat is shown in figure 4.9.

## 4.5 Implementation Evaluation

Reflecting on my implemented design, one area which I think the build could be improved is in the hardware used to read from the RFID readers. As I explained in 4.2 the Pi uses the SPI to collect data from the readers but it only has the physical hardware to read from one peripheral device at a time. To counter this I used the RPi.GPIO library to cycle through readers which were connected via the Pi's GPIO pins. However, the RPi.GPIO library states that it is not best suited to "real-time" applications, which the DSD mat is [4]. This has led to the occasional error while reading. For future designs I would look into alternative solutions possibly using a smaller chip that communicates to a central Raspberry Pi via bluetooth.

# 5 Study

## 5.1 Research Questions

As I approached testing my implemented design I returned to my research questions discussed in 1.3. I hoped to find out, firstly, what makes an effective inclusive social play technology and secondly, what behaviours my mat would encourage and what behaviours it would dissuade. I kept these in mind throughout the study process and at the end of this chapter I attempt to answer them using what I found.

## 5.2 Participants

At the start of the project I planned to run an evaluation and analysis session in the same school where the initial play observations were done by the Bristol Autism and Social Play group. This would make the comparison between no-technology and the DSD mat a more fair and even test. However, unfortunately, the ethics confirmation for the study did not come back before schools broke up for summer holidays. I had tried to sort out what needed to be done for the ethics submission very early on in the project but circumstances (just one example being multiple people from the engineering ethics board going on annual summer leave around the same time meaning they were unable to sign off on things) all coincided to mean that the ethics confirmation came back on the 24th of July, the Monday after schools closed.

I realised around a week and a half before that the ethics was unlikely to come back in time to test in a school so I started looking at other recruitment options for the study. I contacted five charities that work with autistic children in the Bristol area asking if they would be able to send out an email to parents about participating in the study. One charity got back to me saying they would be able to send out an email so I followed up with a leaflet about the study which they posted to their Facebook page, the leaflet can be seen in 7.3. I took leaflets to three local primary schools and spoke to parents outside the gates. I left leaflets in local cafes and GP centres. I posted the study leaflet to all of the relevant Facebook pages I could find. I asked my landlady to post it to my street Whatsapp group as I know several families live on the road. I asked my uncle in the University Faculty of Music to send it to colleagues and my supervisor did the same with the HCI department. Finally, in the last remaining days I called and emailed several other Autism charities about putting out a Facebook or email notice, I got through to three more Facebook pages this way.

If I had more time for the project I would have delayed the date of the study to try and recruit more people. However, due to the time needed to run adequate evaluation and analysis and to write up my results I couldn't afford to do this. I think that I approached most of the avenues open to me for recruiting. Delaying the study would mean going back to people with different dates who might not have been willing to share information about the study for a second time.

In the end I recruited three children for the study – three 5 year old boys, one with autism and two neurotypical boys who were twins. The ethics confirmation for this study required that all the parents of children participating had to read the study information sheet and sign a consent form. This was done on the day of the study before we began. I also made sure all the children were aware that they did not have to continue to participate if at any point they wanted to stop.

## 5.3 Data Collection

I used go-pro cameras to capture video and audio from from the session. One go-pro was fixed to a table to capture steady footage throughout the session. Another go-pro was carried around the room by Hayati Havlucu, a researcher with the Bristol Autism and

Social Play group, to capture any angles that were not visible for any reason from the main camera. We filmed the children during their free play around the mat while it was turned off and then again with the mat on, these two sections of free play were split up by the expanded proxy design session which ran between them.

## 5.4 Analysis

I analysed the footage from the study by first coding the behaviours I observed. I used a video annotation software to categorise behaviours into types and note down my observations. I could then export this data and extract different elements from the data such as the relative times spent interacting with other children versus time spent on solitary activities. I used this data and my overall observations to draw out two further key themes which I will discuss in section 5.5.

### 5.4.1 Method of Analysis

It is common in studies researching social play to code instances of certain kinds of observed behaviour such as: social initiations, social responses, outcomes of interactions, solitary play, observing play, associative play and cooperative play in order to determine increases, decreases and overall themes [3], [7]. Mildred Parten, in her paper "Social Participation Among Pre-School Children", compiled a list of six types of play behaviour amongst young children which have been widely used as a helpful way of categorising play [19]. In table 5.1 I give a brief description of each of the types.

### 5.4.2 ELAN Analysis of Video Observations

I used a software called ELAN for video annotation [**Elan**]. Using this, I could annotate the video with notes about play characteristics and behaviours. To protect the anonymity of the children involved I gave each child a letter and number: A1 for the autistic child, N1 and N2 for the neurotypical children. I use tiers to track different types of behaviour

| | |
|---|---|
| Unoccupied | Child watches whatever takes their interest in the moment. They may play with own body, follow or watch. |
| Onlooker | Child watches a specific child or group play. They may ask questions but will not enter or engage in the play themselves. |
| Solitary | Child plays on their own. |
| Parallel | Child plays beside a child or group using similar toys but there is a different intention to the play or game. |
| Associative | Child plays with other children with the same intentions but each acts as they wish. |
| Cooperative | Child plays with other children coherently working towards a shared goal in an organised fashion. |

Table 5.1: Mildred Parten's Play Characteristics

for each child. I kept track of which kind of play characteristic the child was exhibiting using Parten's social play types. I added "guided" as a type in addition to Parten's six types as the parents were present during my study which led to play behaviours where the parent was explicitly guiding the child in what to do. I also added tiers for interactions with other people such as: "speaking to a researcher", "observing A1 playing" and interactions with objects like "jumping on the mat" or "holding plush toys".

There were several occasions where one child was exhibiting solitary play behaviour while another child was exhibiting parallel play alongside them. For the first child it seemed visually clear from their body language that to them the play was solitary and totally self guided any social element to the play was initiated and maintained by the second child. This interested me as I think it shows the blurry lines between what we consider "social" play. Throughout my analysis I interpreted unoccupied, guided and solitary play as "non-social" and onlooker, parallel, cooperative and associative play as being "social" in some way.

After annotating the video I exported the data so that I could view it in a spreadsheet

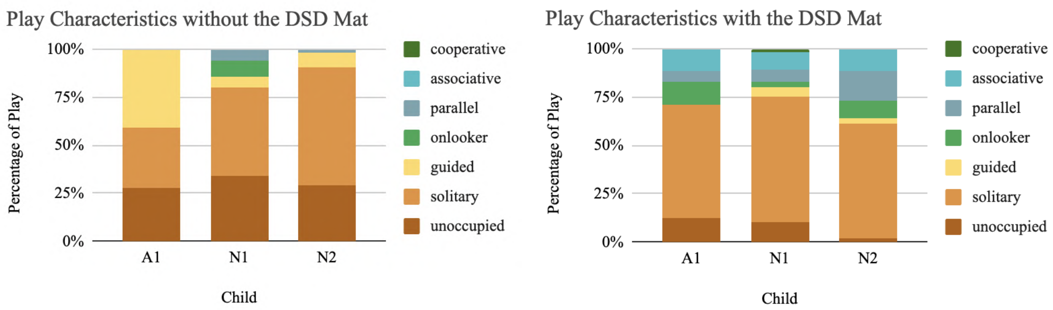


Figure 5.1: Play Characteristics by Child With (left) and Without (right) the DSD Mat Graph

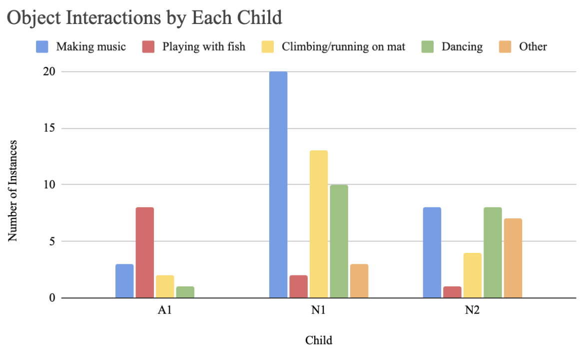


Figure 5.2: Instances of Object Interactions by Type and Child Graph

and compare and analyse the length of time each child spent exhibiting each type of behaviour and what kinds of interactions they were having.

### 5.4.3 Extracting the Data

I exported my data from ELAN to excel so that I could begin to sort it and draw out interesting information. I lay out the data below before going on to draw conclusions from it in the next section 5.5. I separated the footage into the free play before the expanded proxy design session and the play after the design session where the mat was turned on and working. I totalled the amount of time each child spent exhibiting each kind of play both without the mat (7.1) and then with the mat (7.2).

## 5.5 Findings

After analysing the footage from the study I started to look at what the data suggested. I briefly summarise some of the overall ideas that are suggested by the data and then I will go on to explore two themes in more detail: playing at a distance and using the body to play.

### 5.5.1 General Observations

In figure 5.1 you can see the percentage time each child spent exhibiting each play characteristic during their play before the mat was turned on and after the mat was turned on. The colours of the graph are split so that warm orange and yellow colours indicate non-social play characteristics and cool green and blue colours indicate social forms of play as described in section 5.4.2. We can see that there was a visible increase in social play characteristics while using the mat. The graphs also suggests that the increase in social behaviour was not due to the presence of the mat and toys as the mat was present during the initial free play graphed in figure 5.1. Instead the abilities of the mat to make music with use of the toys must be part of the increase in social behaviours. The graphs also show that unoccupied and guided play reduced for all children while using the mat. This suggests that the mat's abilities engaged the children more and required less encouragement or guidance to get involved.

Although the results are encouraging, social play never made up more than 50% of any child's play characteristics even when using the mat. Interestingly, as someone who was present during the study session, it wasn't immediately obvious during the session that there was a significant increase in social behaviours. Looking at the raw data many of the instances of social play characteristics appeared in short stints that could be observed during the video analysis and annotation but might have been less obvious in real-time in the room. For example, N2 exhibited no onlooker behaviour in the free play before the mat was turned on but 9.5% of their play with the mat was categorised as onlooker. However, looking through the instances of play characteristics, 12 instances of N2's onlooker play were less than 10 seconds long. These short periods of time they spent observing the other children's play could have been easily missed while sitting in the session but are significant and noticeable when analysing the footage. This was interesting from a researcher's perspective to notice as I think it might be easy for parents or teachers observing play to pass play off as solely solitary or unoccupied when there are elements of social behaviour going on between the children that may be too subtle to notice in real-time.

I also wanted to look at how each child was interacting with the mat and the toys. During my annotation of the video I kept one tier of annotations for each child that tracked interactions with objects which could include: the mat, the toys, their own toys, or other objects in the room. There were some unusual interactions with objects for instance N1 making faces into the camera or N2 opening the electrical box, but usually object interactions fell into four categories: attempting to make music with the mat by placing toys on the green circles, playing with the toys separately from the mat, running or climbing over the mat or dancing to the music from the mat. The instances of these interactions are shown in table 7.3 and graphed in figure 5.2. All the children exhibited all four of the main object interaction styles, they all attempted to make music, played with the toys, climbed on the mat and danced. N1 had many more instances of making music than the other children while A1 spent more time playing with the toys separately to the mat. I also noted in my annotations that A1 spent most of their time playing specifically with one toy: Ben the Blue Tang. In fact, out of the 11 instances of interactions with the toys (the sum of both playing with the toys separately to the mat and trying to make music with toys on the mat), A1 played specifically with Ben 9 times.

### 5.5.2 Theme 1: Playing at a Distance

I tried to incorporate the idea of playing at a distance in my design by creating something that was, at least in part, modular 3.1.3. The toys could be moved around with the idea they might be taken from the music mat to the disco area. This idea was raised during the proxy design session where different toys might like to make the music and be in

Figure 5.3: A1 Observing Play (left) All children Playing Around the Room (right)

charge or play slightly further away from the group.

In the study the children took this much further than I had anticipated. They wanted to play in all corners of the room, taking the toys and sometimes the speaker with them. They appeared to still want to be involved in the play but at a much greater distance, pictured in figure 5.3. This behaviour was exhibited by A1 frequently. They would take the toys “Ben the Blue Tang” who’s personality card said that he liked his own space and run to another corner of the room only to look back at the researchers and other children by the mat. The intention behind a modular design was to provide the opportunity for control within play, discussed in chapter 2 (2.5), I think here A1 was expressing a desire to be involved but in their own controlled environment, in their own space. In 5.1 you can see that A1 showed increased onlooker behaviour when the mat was turned on, increasing from 0% to 11.7% of their play time. The graph does not show however that most of this behaviour was seen when they were very far away from the mat. They were often very engaged with what was going on this can be seen in figure 5.3. Towards the end of the session A1 seemed to feel more comfortable trying the mat for themselves and they started to branch into more directly social forms of play such as parallel play and associative play. In the last five minutes of the session they took part in their first instance of associative play, playing musical statues with both N1 and N2. I think that having the safe distance from which to initially observe play was a building block for A1 to branch into parallel and associative play.

Figure 5.4: N1 Swimming on Mat (left) All children on the Floor Around the Room (right)

Space was also something all the children played with in their proxy design ideas. It was clear they understood some toys would want to be apart and some would want to be together. Even N2, whose design involved all the toys being squeezed together in a small space, see 3.6, in feedback given by the parent had chosen to do this knowing that Ben the Blue Tang liked his own space. In fact they discussed putting Ben in the squeezed space in order to make him “cross”. This may seem like the opposite of the desired outcome — ignoring boundaries and going directly against the preferences of a child. However, I think it shows a clear understanding of differences in preferences and a willingness to play with that and test the boundaries to see what the outcome will be. This again is a reflection of the desire to **control** the play experience, see (2.5). This could be reflected in future designs. Perhaps the sounds could change depending on proximity of children to the mat and also to each other. Both N1 and N2 at times picked up the speaker to play with the sound and where it was coming from. This could be something interesting to use for future designs to play with both physical proximity and sound proximity.

### 5.5.3 Theme 2: Using the Body to Play

Again this was an idea I tried to incorporate in my design by creating something tangible, see 2.5. The mat and toys were designed to be soft and inviting to touch, climb on and squeeze. However, just as with the previous theme, the children in the study took this idea much further. They wanted to run, roll and dive across the mat and the floor pictured in figure 5.4. N1 in particular, on multiple occasions, "swam" on the mat as if they were in the sea, seen in figure 5.4. All the children also spent time dancing to the music, a kind of play that uses the body.

Originally, the design factor behind developing a tangible object was to reduce ambiguity, see 2.5. However, the way the children played with the mat suggested that the mat was providing sensory regulation which was one of my other design factors. This type of play is probably indicative of the age group involved in the study, I originally tried to recruit children between the ages of 4 and 10. All the children who participated in the end were 5 years old. I think, reflecting on my work, this was definitely the lower age limit of children who could happily engage and benefit from play with the mat. The mat, to work as designed, requires some cooperation to coordinate who goes where and makes what sounds. I think that although there were small glimpses of this kind of play it may have been more effective and enjoyable for a slightly older group of children. However, as I explained in 5.2, there were many challenges that came up in recruitment.

Towards the end of the session the children all joined in with a game of musical statues. The music was controlled by researchers at the mat while the children all ran around the room and danced. This required less cooperative play and coordination and the children were free to move their bodies and play in their own ways while still playing "together" within the same game.

If I was to design for this age group again I would try to incorporate the use of the body more into play. It was one of the aims of my design to create something tangible that was sensorily enjoyable to play with. The mat and toys were designed to be soft and inviting to touch and interact with. The music and stage element also invited dance and use of the body. However, just as with theme 1, the children in the study took this idea much further. They wanted to run across the mat, lie on the mat and and use their bodies a lot more.

### 5.5.4 Returning to Research Questions

I can now return and answer my research questions which I outlined at the beginning of this chapter 5.1. My first question about what makes an effective inclusive social play technology was something I researched a lot throughout the background and design phases of this project. My reading suggested that there were three features that would be key in developing an effective play technology, something modular, musical and tangible. I think my findings from the study show that these were successful attributes of a social play technology but that I could have taken them even further in my design. All three features show up in theme 1 (5.5.2) and theme 2 (5.5.3) as elements that the children utilised and appeared to enjoy about the mat. However, evaluating the success of the mat, I think for future designs I could go further in making a game that is “more” modular in the sense that you can contribute to play from greater distances. The music appeared to be a success and all the children showed their enjoyment through dancing during the study. The tangible elements of the mat, the soft rug and the plush toys, were also a success. However, like the modular element I think I could take this even further in future designs. The children all wanted to use their bodies more during play by rolling or diving on the mat and I think this is something that should be incorporated into the design if it was going to focus on this age group.

To answer my second question about what behaviours the DSD mat encourages or dissuades, I think there is evidence to suggest that it does encourage social forms of play. It definitely appeared to engage the children and they were interested in exploring it - either for themselves or observing someone else playing with the mat. Answering the second question at first glance seems straightforward. I could observe play with the mat and see what behaviours the children exhibited. However, due to the nature of the study it is hard to rule out what behaviours were caused by other variables in the situation: the parents being present, the relationship between the children — N1 and N2 being brothers and A1 being new, the room itself, and the interactions of the researchers with the children.

## 5.6 Evaluation of Analysis

One limitation of projects involving people of different neurotypes is the ability of the researcher to make assumptions or judgements about the minds of others. Katta Spiel makes the point that often the researchers making evaluative judgements about the success of a trial are neurotypical and therefore may not appreciate the internal experience of participants or what constitutes a good experience for an autistic person. Spiel points out that many researchers infer experience through an “empathic understanding” which may be skewed if the behaviour is tied to an entirely different internal experience for the autistic person. [25]. Being an autistic person myself, although I perhaps have slightly more insight into the autistic experience and can recognise behaviours and their motivations in myself, I know that everyone’s experience of autism is different and so my evaluations are still somewhat limited. This also means that perhaps I have less insight into the experiences of the neurotypical children. This may influence the conclusions I come to.

Another limitation of my evaluation and conclusions is that one common feature of ASD is an anxiety or discomfort with change and unknown things [27]. These experiences can lead to feelings of stress, anxiety or overwhelm. The introduction of the DSD mat was certainly an unknown variable or change to their usual experience. It is possible that this influenced the reaction of the autistic child and that perhaps after some time to get accustomed to the mat their behaviours and responses would be different. In this case I was limited by the time-frame but if the research was conducted again, perhaps for example, conducting a number of sessions over a period of weeks, in order to reduce any anxiety about change, would lead to a fairer outcome.

# 6 Conclusion

In this report I researched the importance of social play, its relationship to autism, and the technologies used to assist in social play. I used this research to develop three design criteria that I thought my own inclusive social play technology must incorporate: musical, modular and tangible. I undertook an iterative design process to create the DSD Mat — an RFID based, musical mat using all three of my design criteria. I built the mat in phases, from one RFID reader to three built into hardware using music I composed. I recruited for a study and tested the mat with children. I used ELAN to annotate and analyse footage from the study. Extracting the data from my annotations, I highlighted trends and saw that the mat increased social play behaviours in all the children. I explored two themes: playing at a distance and play using the body. I discussed ways in which I thought my research could be used to influence further work. I then returned to my initial research questions to discuss what makes a successful inclusive play technology and what behaviours my mat encouraged. Throughout my work I reflected critically on what I was doing and suggested limitations to the conclusions I drew.

Overall, I think this project was successful in exploring designs for inclusive social play technologies. I think my study showed that my design criteria were on target but that I could take these ideas further. My data showed that the DSD mat was successful in increasing social play behaviours. However, all the children still engaged in more solitary play than social play. I think building and testing the DSD mat did lead to greater insight into what could be built and what design ideas might increase social play further. I think I learned useful information from building and testing the DSD mat and I believe my findings could contribute helpfully to further designs within this space.

# 7 Appendix

```
GPIO.setwarnings(False)
GPIO.setmode(GPIO.BOARD)
GPIO.setup(29, GPIO.OUT)
GPIO.setup(31, GPIO.OUT)
GPIO.setup(33, GPIO.OUT)

GPIO.output(29, 0)
GPIO.output(31, 0)
GPIO.output(33, 0)
```

```
def select_board(rid):
        if not rid in boards:
                print("ID: " + rid + " not found")
                return False

        GPIO.output(29, 0)
        GPIO.output(31, 0)
        GPIO.output(33, 0)

        GPIO.output(boards[rid], 1)
        return True
```

Figure 7.1: Code Used to Select Reader By Manipulating GPIO Output

```
# ONE ZERO PRESENT

oneandtwo = [['0','1','2'], ['0','2','1'], ['1', '0', '2'], ['2', '0', '1'], ['1', '2', '0'], ['2', '1', '0']]
oneandthree =  [['0','1','3'], ['0','3','1'], ['1', '0', '3'], ['3', '0', '1'], ['1', '3', '0'], ['3', '1', '0']]
oneandfour =  [['0','4','1'], ['4', '0', '1'], ['1', '4', '0'], ['4', '1', '0']]
twoandthree =  [['0','3','2'], ['0','2','3'], ['3', '0', '2'], ['2', '0', '3'], ['3', '2', '0'], ['2', '3', '0']]
twoandfour = [['0','4','2'],  ['4', '0', '2'], ['4', '2', '0'], ['2', '4', '0']]
threeandfour =  [ ['0','4','3'], ['4', '0', '3'], ['3', '4', '0'], ['4', '3', '0']]

#DRUMS2 COMBINATIONS
oneandfour2 = [['0','1','4'], ['1', '0', '4']]
twoandfour2 = [['0','2','4'], ['2', '0', '4']]
threeandfour2 = [['0','3','4'], ['3', '0', '4']]


if tags_present in oneandtwo or last_tags in oneandtwo:
        if playing_list[4] == False and tags_present == last_tags:
                reset(playing_list)
                mixer.music.load(song5)
                mixer.music.play(-1)
                playing_list[4] = True


if tags_present in oneandthree or last_tags in oneandthree:
        if playing_list[9] == False and tags_present == last_tags:
                reset(playing_list)
                mixer.music.load(song10)
                mixer.music.play(-1)
                playing_list[9] = True
```

Figure 7.2: Code Used to Select Music Based on Tags Present

# Inclusive Social Play Study

**Final Call!**

**Who I'm looking for:**

- children aged between 4-9
- both neurotypical and autistic children - the study aims to look at mixed groups and encouraging inclusive social play

**About the study:**

The study involves observing social play behaviours. We will first run a small activity with the kids getting them to think about the way they play and what different children might need to enjoy playing. Then we will observe play with a 'play technology' - which will involve soft toys and music making.

The project is part of the University of Bristol Human-Computer Interaction group (BIG - Bristol Interaction Group) and specifically part of the Autism and Social Play project.

**Arrangements:**

The study will take place at the University of Bristol in the Queens Building on University Walk BS8 1TR. The session will run from 3-5pm this Thursday 27th of July. This study has been approved by the university ethics committee. Participant information sheets and consent forms will be sent out before the date of the study.

If you would like to be involved you can contact me for more information at:

Zoe Clark: jr22019@bristol.ac.uk

University of BRISTOL

Figure 7.3: Study Leaflet

| | unoccupied | onlooker | solitary | parallel | associative | cooperative | guided |
|---|---|---|---|---|---|---|---|
| A1 | 2:18 | 0:00 | 2:53 | 0:00 | 0:00 | 0:00 | 3:24 |
| N1 | 2:29 | 0:56 | 3:14 | 0:42 | 0:00 | 0:00 | 0:38 |
| N2 | 2:11 | 0:00 | 4:43 | 0:13 | 0:00 | 0:00 | 0:56 |

Table 7.1: Observed Times for Each Child Exhibiting Different Play Characteristics — Without the DSD Mat (Minutes:Seconds)

| | unoccupied | onlooker | solitary | parallel | associative | cooperative | guided |
|---|---|---|---|---|---|---|---|
| A1 | 2:20 | 2:09 | 10:50 | 1:06 | 2:00 | 0:00 | 1:55 |
| N1 | 2:24 | 0:52 | 14:28 | 1:40 | 2:07 | 0:36 | 1:16 |
| N2 | 0:40 | 2:00 | 12:56 | 3:18 | 2:44 | 0:00 | 0:57 |

Table 7.2: Observed Times for Each Child Exhibiting Different Play Characteristics — With the DSD Mat (Minutes:Seconds)

| Child/Object Interaction | Making music | Playing with toys | Climbing/running on mat | Dancing | Other |
|---|---|---|---|---|---|
| A1 | 3 | 8 | 2 | 1 | 0 |
| N1 | 20 | 2 | 13 | 10 | 3 |
| N2 | 8 | 1 | 4 | 8 | 7 |

Table 7.3: Instances of Object Interactions by Type and Child

# Bibliography

[1] M. Anderson-Chavarria, "The autism predicament: Models of autism and their impact on autistic identity," *Disability &amp Society*, vol. 37, no. 8, pp. 1321–1341, 2021. DOI: 10.1080/09687599.2021.1877117 (cit. on p. 3).

[2] A. Battocchi, E. Gal, A. Ben-Sasson, F. Pianesi, P. Venuti, M. Zancanaro, and P. Weiss, "Collaborative puzzle game - an interface for studying collaboration and social interaction for children who are typically developed or who have autistic spectrum disorder," *The 7th International Conference Series on Disability, Virtual Reality and Associated Technologies (ICDVRAT)*, 2008 (cit. on p. 8).

[3] B. A. Boyd, M. A. Conroy, J. Asmus, and E. McKenney, "Direct observation of peer-related social interaction: Outcomes for young children with autism spectrum disorders," *Exceptionality*, vol. 19, no. 2, pp. 94–108, 2011. DOI: 10.1080/09362835.2011.565724 (cit. on pp. 1, 5, 6, 36).

[4] B. Croston, *Rpi.gpio*, 2022. [Online]. Available: https://pypi.org/project/RPi.GPIO/ (cit. on p. 33).

[5] W. Farr, N. Yuill, and H. Raffle, "Social benefits of a tangible user interface for children with autistic spectrum conditions," *Autism*, vol. 14, no. 3, pp. 237–252, 2010, PMID: 20484323. DOI: 10.1177/1362361310363280. eprint: https://doi.org/10.1177/1362361310363280 (cit. on pp. 5, 8).

[6] W. Farr, N. Yuill, and H. Raffle, "Social benefits of a tangible user interface for children with autistic spectrum conditions," *Autism*, vol. 14, no. 3, pp. 237–252, 2010. DOI: 10.1177/1362361310363280 (cit. on p. 10).

[7] C. Frauenberger, K. Kender, L. Scheepmaker, K. Werner, and K. Spiel, "Desiging social play things," in *Proceedings of the 11th Nordic Conference on Human-Computer Interaction: Shaping Experiences, Shaping Society*, ACM, 2020. DOI: 10.1145/3419249.3420121 (cit. on pp. 1, 5–7, 11, 14, 36).

[8] J. A. Haegele and S. Hodge, "Disability discourse: Overview and critiques of the medical and social models," *Quest*, vol. 68, no. 2, pp. 193–206, 2016. DOI: 10.1080/00336297.2016.1143849 (cit. on p. 3).

[9] J. Hollander, *Easy laser cut case design.* [Online]. Available: https://en.makercase.com/ (cit. on p. 27).

[10] R. Jordan, "Social play and autistic spectrum disorders," *Autism*, vol. 7, no. 4, pp. 347–360, 2003. DOI: 10.1177/1362361303007004002 (cit. on p. 5).

[11] C. Kemp, Y. Kishida, M. Carter, and N. Sweller, "The effect of activity type on the engagement and interaction of young children with disabilities in inclusive childcare settings," *Early Childhood Research Quarterly*, vol. 28, no. 1, pp. 134–143, 2013. DOI: 10.1016/j.ecresq.2012.03.003 (cit. on pp. 1, 5, 7).

[12] Lugico, *How to connect multiple rc522 rfid reader to raspberry pi?* 2022. [Online]. Available: https://stackoverflow.com/questions/58946367/how-to-connect-multiple-rc522-rfid-reader-to-raspberry-pi (cit. on p. 22).

[13] O. Metatla, J. C. Read, and M. Horton, "Enabling children to design for others with expanded proxy design," in *Proceedings of the Interaction Design and Children Conference*, ACM, 2020. DOI: 10.1145/3392063.3394431 (cit. on pp. 12, 14, 15, 19).

[14] A. Miura, D. Knotts, and M. Platt, "Children as our technology design partners," 1998 (cit. on p. 14).

[15] B. A. Morris, H. Havlucu, A. Oldfield, and O. Metatla, "Double empathy as a lens to understand the design space for inclusive social play between autistic and neurotypical children," in *Extended Abstracts of the 2023 CHI Conference on Human*

*Factors in Computing Systems*, ACM, 2023. DOI: 10.1145/3544549.3585828 (cit. on pp. 5–9, 11).

[16] A. Nonnis and N. Bryan-Kinns, "Mazi," in *Proceedings of the 18th ACM International Conference on Interaction Design and Children*, ACM, 2019. DOI: 10.1145/3311927.3325340 (cit. on pp. 8, 10).

[17] A. Nonnis and N. Bryan-Kinns, "Olly: A tangible for togetherness," *International Journal of Human-Computer Studies*, vol. 153, p. 102 647, 2021. DOI: 10.1016/j.ijhcs.2021.102647 (cit. on pp. 8, 10).

[18] M. Palmer and D. Harley, "Models and measurement in disability: An international review," *Health Policy and Planning*, vol. 27, no. 5, pp. 357–364, 2011. DOI: 10.1093/heapol/czr047 (cit. on pp. 3, 4).

[19] M. B. Parten, "Social participation among pre-school children.," *The Journal of Abnormal and Social Psychology*, vol. 27, no. 3, pp. 243–269, 1932. DOI: 10.1037/h0074524 (cit. on p. 36).

[20] M. Reding, *What are the child development stages?* 2023. [Online]. Available: https://cpdonline.co.uk/knowledge-base/safeguarding/child-development-stages/#:~:text=Child%5C%20development%5C%20incorporates%5C%20four%5C%20main,%5C%2C%5C%20intellectual%5C%2C%5C%20emotional%5C%20and%5C%20social. (cit. on p. 5).

[21] H. Reis, I. Eusébio, M. Sousa, M. Ferreira, R. Pereira, S. Dias, and C. I. Reis, "Regul-a: A technological application for sensory regulation of children with autism spectrum disorder in the home context," *International Journal of Environmental Research and Public Health*, vol. 18, no. 19, p. 10 452, 2021. DOI: 10.3390/ijerph181910452 (cit. on pp. 8, 9).

[22] L. Scheepmaker, C. Frauenberger, and K. Spiel, "The Things We Play with, Roles of Technology in Social Play," en, in *CHI PLAY 2018*, Melbourne, QLD, Australia: ACM Press, 2018, p. 12, ISBN: 978-1-4503-5624-4. DOI: 10.1145/3242671.3242695 (cit. on p. 8).

[23] Sense, *The social model of disability*, 2022. [Online]. Available: https://www.sense.org.uk/about-us/the-social-model-of-disability/#:~:text=Several%20disability%20rights%20groups%20developed,model%20of%20disability%E2%80%9D%20in%201983. (cit. on p. 3).

[24] R. Slutsky and L. M. DeShetler, "How technology is transforming the ways in which children play," *Early Child Development and Care*, vol. 187, no. 7, pp. 1138–1146, 2016. DOI: 10.1080/03004430.2016.1157790 (cit. on pp. 7, 8).

[25] K. Spiel, C. Frauenberger, and G. Fitzpatrick, "Experiences of autistic children with technologies," *International Journal of Child-Computer Interaction*, vol. 11, pp. 50–61, 2017. DOI: 10.1016/j.ijcci.2016.10.007 (cit. on pp. 6, 9, 45).

[26] K. Vaajakallio, J.-J. Lee, and T. Mattelmäki, ""it has to be a group work!"," in *Proceedings of the 8th International Conference on Interaction Design and Children*, ACM, 2009. DOI: 10.1145/1551788.1551843 (cit. on p. 14).

[27] L. Villafuerte, M. Markova, and S. Jorda, "Acquisition of social abilities through musical tangible user interface," in *CHI '12 Extended Abstracts on Human Factors in Computing Systems*, ACM, 2012. DOI: 10.1145/2212776.2212847 (cit. on pp. 10, 11, 45).

[28] E. Whitman, "The impact of social play on young children," 2018 (cit. on pp. 1, 5, 7).