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Playful E-textile Sonic Interaction for Socially Engaged and Open-Ended Play Between Autistic Children

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PhD Thesis

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"In the autism market, not many people want to hear that what people [with autism] need is basic standards of care and humanity."

Damian Milton

“The toy is the child's earliest initiation into art, or rather it is the first concrete example of art”

Jean Baudrillard

Statement of Originality

I, Antonella Nonnis, confirm that the research included within this thesis is my own work or that where it has been carried out in collaboration with, or supported by others, that this is duly acknowledged below, and my contribution indicated. Previously published material is also acknowledged below.

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Abstract

Research on the potential benefits of technology for autistic children is an emergent field in Human-Computer Interaction (HCI), especially within the Child-Computer Interaction Community. This thesis contributes a design approach grounded in theories of play, cognitive development, and autism to expand the discourse on methodological guidelines for performing empirical studies with non-verbal autistic children and to extend the design space to cater to the socio-emotional and sensory needs of this population.

The thesis reveals how sonic e-textile Tangible User Interfaces (TUIs) can be used effectively to mediate children's social participation in playful activities. This is demonstrated through developing three explorative field-studies conducted at a specialist school based in North-East London where two sonic e-textile playful TUIs, namely Mazi and Olly, have been created and tested with three groups of autistic children aged between 5-10. The three studies ran over the period of three years and were designed to investigate the potentials of TUIs as shareable toys during leisure and recreational activities to a) support social and playful interactions among peers and b) provide opportunities for self-regulation. The key contributions of this thesis are the designs of two tangible user interfaces, which offer a set of design approaches to guide researchers through creating shareable and playful tangibles for non-verbal autistic children; a framework for analysis and a thorough evaluation process that other researchers could use to assess the efficacy of playful TUI designs for non-verbal autistic children; and an in-depth discussion about the research process, which offers a new perspective about holistic designs and evaluation of technologies that aim to scaffold play in groups non-verbal autistic children.

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1 Introduction

All children have the right to experience the world and stimulate their senses to gain the skills that are required to be autonomous (Piaget and Inhelder, 1969). As the environment around them is not always designed to cater to their specific cognitive, physical, and emotional needs this is a challenge for autistic children. Autistic individuals might find it challenging to communicate and to socialize with neurotypical people and often experience sensory processing challenges exhibited in repetitive behaviours, interests, and activities (APA, 2013).

This research explores how a particular form of interactive technology – tangible interaction (Ishii and Ullmer, 1997; Shaer and Hornecker, 2009) – might offer increased opportunities for socialization and sensory regulation to small groups of children who like music, during leisure activities in educational settings.

Play is a fundamental part of human existence and is especially important for children's development (Lillard, 2015; Mastrangelo, 2009; Elkind, 2008). However, the literature shows that autistic children often find it difficult to engage in play especially with others. Despite the potential benefits of Tangible User Interfaces (TUIs) for supporting play and communication (Shaer and Hornecker, 2009) studies on social interactions and play are particularly focused on skills development and often are based on touchless screen-based devices, robots, and virtual environments (VE) (Andreae et al., 2014; Bhattacharya et al., 2015; Malinverni et al., 2014; Mora-Guiard et al., 2017; Porayska-Pomsta et al., 2018) or conducted with verbally fluent children (Frauenberger, Spiel, & Makhaeva, 2019). Furthermore, some of the technologies and methodologies used are typically high on cognitive demands, highly structured, have rules, and often imply and rely upon attentional, affective and verbal skills and have educative and/or developmental goals. Some of these approaches highlight the tendency within the Human-Computer Interaction (HCI) community to focus on children's *in*abilities, using digital entities to simulate neurotypical human interactions, which may, in turn, end up exacerbating human disconnectedness. Moreover, this reliance on affective and verbal skills might exclude many children since around 40% of autistic children are nonverbal (Tager-Flusberg et al., 2013; CDC, 2020). Therefore, it is important to expand the research space to also cater to the needs of those children who are minimally or nonverbal.

The two sonic TUIs developed for this PhD, made with e-textiles, address and minimise some of the aforementioned issues by introducing concrete interactions in real contexts that are accessible to direct observation and physical manipulation, yet multifunctional and open to interpretation. In addition, within the HCI community, no research was found that looks into the challenges of self-regulation experienced by autistic children, especially when they are exposed to social activities and contexts such as free play (Rodgers et al., 2016). This PhD would like to fill these gaps. By proposing a shift in paradigm that challenges the notion that autistic people should aspire to simulate neurotypical behaviours in order to adhere to the societal norms, a methodological approach is developed over the course of three empirical studies that embraces diversity and promotes the designs of technologies that support varied and free forms of play with the intention of providing the children with the optimal environment and tools to socialise with peers. In order to contribute to this discourse, this PhD investigates the potential of TUIs during leisure and recreational activities to a) support socially engaged play and b) provide opportunities for self-regulation.

To achieve the aims set by this inquiry three strategies were adopted. Firstly, the researcher conducted a long-term research collaboration (+3 years) with the Garden School (sometimes referred to as Garden for brevity), a provision for children aged 4-16 that specialised in autism and based in North East London, UK. This offered the opportunity to work with groups of autistic children and, therefore, allowed to test how they responded to the two sonic e-textile tangible technologies made by the researcher. This collaboration was possible as the researcher worked at the Garden as Teaching Assistant prior to starting the PhD, and this allowed her to keep in contact with the school and to tailor the studies following evidence-based approaches implemented and learned while working at the Garden that fitted well within the school' system.

Secondly, the approaches used and the designed TUIs were centred around the children and their experiences and welcomed some collaborative practices. Throughout the three studies, two artefacts were designed and evaluated in the context of a semi-structured classroom setting with three different groups of children attending primary. A multidisciplinary approach that includes user-centred design, experience design, research through design, and ludic design, that focuses on the needs of the children, helped addressing one of the goals of this research which was that of embracing children's needs, likes, and preferences and reflecting them into the designs of Mazi and Olly. A framework for observation, inspired by evidence-based practices and principles of social interactions, was first developed during the first months of this PhD research to specifically address some key questions of this research. The framework was then expanded throughout the studies and combined with an adapted version of Parten's play stages (Parten, 1932).

Thirdly, in order to disrupt the dominant narrative within the HCI field that technology is dissociated from social factors, this work proposes a shift in the interaction paradigm that sees design as a problem-solving activity and challenges the notion that autistic people should aspire to simulate neurotypical behaviours to adhere to societal norms. This is achieved by proposing a methodological approach that embraces diversity and promotes designs that support self-regulation and social interactions by being open, multimodal, and multifunctional. This view allows taking a holistic approach to playful e-textile sonic TUI development for autistic children, focusing on the broader context in which the technology is deployed - the ecology, not just the technology (Hourcade, 2015; Smith et al., 2013).

1.1 Research questions

With these three strategies in mind, the main research questions (mRQs) that arise from this inquiry and that this PhD explores are:

- mRQ1. How do groups of minimal to non-verbal autistic children respond to playful e-textile sonic TUIs?
- mRQ2. Can we design and evaluate playful e-textile sonic TUIs to provide sensory regulation and to encourage social interaction in nonverbal autistic children?
- mRQ3. Which design features of the playful e-textile sonic TUIs presented in this PhD are supportive of social play and sensory regulation?
- mRQ4. What are the challenges and opportunities created by playful e-textile sonic TUI designs when working with autistic children that have a high level of support needs?

In the attempt to answer these questions three studies were developed and carried out at the Garden school over the course of three years. The emphasis was on developing playful, open-ended, tangible interfaces where children could intuitively use their own senses and movements in order to achieve the desired outcome.

1.2 Research methodology

As discussed in Chapter 3, the studies followed an empirical inquiry conducted using a qualitative methodology (Heath et al., 2012) influenced by theories of embodied interactions (Dourish, 2001; Luff et al., 2013). This was then combined with quantitative analysis. The work is based on a mix of design methods and processes including user-centred design (UCD), research through design (RtD), experience design (ED), ludic design (LD), and shareability. This mix of approaches is used to compensate for some of the limitations of a purely user-centred design process and it aims to expands on the importance of located, playful, pleasant and experiential approaches to design. This is done to enable the creation of artefacts that foster social play, sensory and emotional regulation by addressing the needs and likes of the children. Therefore two sonic e-textile playful TUIs were developed to be used in three different studies. The TUIs are called Mazi (from the Greek 'Together') and Olly (a Greek word meaning 'All'). Mazi was developed in 2018, and Olly was made in 2019. The researcher developed these novel artefacts as an approach to learn about human experience and move beyond the physical objects she created to discover insights about how to best support play for autistic children. The first two field studies of this PhD are presented in Chapters 4 and 5 and describe in detail the design and thought processes that went into the making of the two tangibles and how data were collected and evaluated. These two studies were carried out with two different groups of children where Mazi and Olly were tested individually. The TUIs adopted the same design principles but offered an exploration of different design strategies. The third and final study is explained in detail in Chapter 6 and provides an account of both technologies deployed at the same time with a third group of children. This study, named 'Olly Mazi', which translates from the Greek 'All Together', explored further whether the music influenced children's interactions, and offers a comparison of behaviours and preferences demonstrated by the children when using the two TUIs.

As highlighted in Chapter 3, where the research methods are discussed further, the data produced by these studies are then analysed through video analysis of the children's visible conduct and are presented as a set of findings at the end of each study. The framework for observation, which was first developed during Study 1, is also introduced in the same chapter (3), alongside its subsequent improvements, and it is also introduced again in each study's chapter. As previously mentioned, the findings are evaluated using a mix of quantitative and qualitative approaches using the video recordings, pre and post-study interviews with teachers and Teaching Assistants (TAs), their observations sheets, and the post-study questionnaires conducted in study 3.

1.3 Research background and personal motivations

In order to understand how this research came to be, the following section provides a contextual background to how this inquiry began and how the researcher started the collaboration with the Garden school.

Prior to this PhD, the researcher worked for two years as a Teaching Assistant (TA) at the Garden School, which collaborated to this PhD for its entire duration. Before working at the Garden, the researcher worked as a playworker in a Special Needs Education (SEN) playground based in North-East London called Kids, and consequently moved to the Garden school to improve her knowledge about autism and evidence-based practices.

During her experience at the school, it occurred to her that when children were asked to do work-stations, i.e. when the children sat 1:1 with their TA to do scholastic activities like practicing literacy, numeracy, and so on, aside from the iPad, little to no electronic interactive toys were used by the teachers or TAs. Also, when using the light-room, a room equipped with interactive touchless visuals (one big projection on the floor and two on the walls) and sound devices (some light beams attached to the ceiling that pointed to the floor so that children could play with the light beam to activate sounds by interrupting the light beam with their body shades), most of the children were not interested in playing with such technologies, and they rather played with physical toys available to them in a basket, often in solitary mode or with adults.

Furthermore, at the Garden, the longer playtime experience that the children were offered was after lunch. There are two playgrounds at the school, one used by the primary and secondary children (at different times) and a smaller one used by Reception, Early Years, Year 1 and Year 2. For example, the children usually gathered in the dining hall of the school or in their classrooms at around 12:00 pm for their lunch, and as they finished eating they were free to join the main playground areas until 1:00 pm. Children were also offered shorter breaks throughout the day where they would go outside in their pods. For example, they had a break in the morning before commencing the activities (for around 10 minutes), one halfway through the morning (around 15 minutes), and finally one in the afternoon before leaving (10/15 minutes). During lunch playtime however, there was generally a limited number of staff available due to the fact that most of the teachers did not attend the playgrounds and the TAs commonly took turns for their lunch breaks.

Consequently, at any time during playtime after lunch, the number of TAs on playground duty was much lower than in any other activity. Most of the children would often find a way to entertain themselves but, it was more likely that those that had higher support needs, would, if and when motivated, interact with an adult rather than with other pupils. Children would also request stimuli from an adult to regulate their sensory and emotional needs and conversely, the TAs spontaneously offered themselves to stimulate a child if it was seen that the child was dysregulated or needed comfort. This suggested that children not just had limited opportunities to socialise with peers but also they lacked the means to autonomously self-regulate themselves.

At the beginning of the PhD, in 2017, contacts were kept open between the researcher and the headteacher of the Garden school who kindly accepted the collaboration. The initial idea behind the first research proposal was that of building TUIs to promote multisensory experiences in educational settings. Since then, the focus of the research shifted to scaffolding play during recreational activities. The reason being that although selection criteria for the first study included children who expressed challenges with sensory processing, after meeting with the occupational therapist (OT) in study 1, it became clear that the group of children that were selected by the Headteacher needed opportunities in areas like social communication and play.

Under the direction of the school's Occupational Therapist, attention was therefore given to building TUIs that would scaffold social play while potentially offering individuals the opportunity to self-regulate, i.e. to regulate their arousal state. This could be achieved by e.g. using novel materials (other than plastic) such as e-textiles and soft interfaces to allow the children to manipulate the interface in many ways (twist, squash, pull, push, press, flicker) and to offer them a wide variety of choices in how they used the TUIs. The researcher was fascinated by the thought of using textile materials due to its familiar affordances and versatility. Furthermore, she observed that many children liked to have something soft to manipulate and touch. Crucially, studies demonstrate that autistic children like textures and engage more in physical contact with plush toys than other plastic or virtual toys (Cascio et al., 2008; Jeong et al., 2018). Therefore, the main materials used for making Mazi and Olly were conductive textiles, lycra and wool.

Rodgers et al. (2016) found that anxiety levels for autistic people are usually higher in social contexts. Therefore, to scaffold a positive and socially engaged play experience the technologies needed to address the both the socio-emotional and sensory needs of the children. Following the dance teacher's advice (who facilitated the three studies), whose guidance influenced the overall layout of the sessions, the research strategy was to a) run the studies within a familiar setting, b) to consider the lighting, and c) to introduce the TUIs to the environment and the kids in a seamlessly manner so that children's expectations were not disrupted and they felt comfortable.

1.4 Notes on participants and collaborators

In this work, the researcher opted to use the identity-first language (e.g., autistic people instead of people with autism) as she referred to a large UK survey conducted by Kenny et al. (2016) which suggests that people with autism prefer to use this terminology. However, the researcher understands that some readers might be concerned with this choice, as she is aware that using one terminology might represent some but not other people's opinions. Sue Fletcher-Wilson et al. (2019) make a similar point in this regard by highlighting how diverse the opinions are within the community; professionals seem to prefer person-first (e.g. people with autism), while people in the spectrum seem to have a slightly higher preference for using identity-first language (autistic people). Also, the researcher sympathises with Spiel's view[2] on using identity-first language as a political act that "acknowledges" autistic people's preferences.

[2] https://katta.mere.st/person-first-or-identity-first/

As this PhD research was in collaboration with a specialised school in the UK it is important to briefly highlight how the Garden school worked at the time of the studies. The Garden is a specialised provision school for 4-16 years-old autistic children that offers a safe and inclusive environment for children to flourish. The school developed a bespoke child-centred curriculum to meet the learning style of the pupils and aims to offer the best learning opportunities "*to develop the key skills of communication, independence, personal and social skills, emotional regulation, physical development, and life skills*"[3]. The school implements a topic-based curriculum and the subject areas are based on the National Curriculum. The National Curriculum[4] "*sets out the programs of study and attainment targets for all subjects*" of the English education system ensuring that all pupils receive the same level of teaching. The pupils attending the Garden school, have a diagnosis of autism that follows the Diagnostic and Statistical Manual of Mental Disorders version five (DSM-V) (APA, 2013).

When choosing which teacher would be best to collaborate with during the research project, for general assistance and practical research development and implementation, the dance teacher, was the most suitable partner due to her interest in the research, willingness to help, personality, and style of lesson delivery. Her free-form and hands-off style of intervention when teaching her dance lessons and her positive attitude toward the children made her the most appropriate candidate for facilitating the research's testing sessions and for general advice. The collaboration with the dance teacher started in the first exploratory study done with Mazi (Chapter 4) and went on throughout the thesis with feedback, conversations, interviews, and consultations on design decisions and study procedures. The dance teacher was facilitating the testing phases of the TUIs during her Planning, Preparation, and Assessment time (PPA), which means she took the time to write her observations and give feedback. Staff did not have any allocated hours to specifically work on (or toward) the research and 'participants' and TAs were not paid to contribute to this research.

Throughout the PhD the Headteacher of the school, who, alongside the dance teacher, was the researcher's main point of contact throughout the first years of this

[3] https://www.the-garden.org.uk/Our-Curriculum/Curriculum/
[4] https://www.gov.uk/government/collections/national-curriculum

PhD, resigned from her post in late 2019 and was substituted by a new interim Headteacher who since then kindly kept collaborating to this body of research.

1.5 Contributions

This PhD offers a number of contributions. It contributes to the field of Human-Computer Interaction (HCI) and Child-Computer Interaction (CCI) by 1) presenting three explorations and studies of two e-textile sonic Tangible User Interfaces (TUIs) called Mazi and Olly, developed to support social play in groups of minimally verbal autistic children; 2) providing evidence of their impact on groups of non-verbal autistic children; 3) producing a framework for observation and an evaluation process that other researchers could use to assess the efficacy of playful TUI designs for non-verbal autistic children; 4) offering a fresh but grounded methodology that considers and embraces a neurodiverse play environment; and 5) presenting the design processes behind Mazi and Olly, and a set of design guidelines to help researchers interested in making TUI designs that are friendly to neurodivergent types of play.

1.6 Associated Publications

Parts of this PhD research have been presented at national and international conferences and scholarly publications. The associated publications are as follows:

> **Antonella Nonnis** and Nick Bryan-Kinns. 2021. Olly: A tangible for togetherness, *International Journal of Human-Computer Studies*, 2021, 102647, ISSN 1071-5819, https://doi.org/10.1016/j.ijhcs.2021.102647
>
> **Antonella Nonnis** and Nick Bryan-Kinns. 2020. Όλοι: music making to scaffold social playful activities and self-regulation. In *Proceedings of New Interfaces for Musical Expression* (NIME '20), Royal Birmingham Conservatoire, Birmingham, UK.
>
> **Antonella Nonnis** and Nick Bryan-Kinns. 2019. Mazi: a Tangible Toy for Collaborative Play between Children with Autism. In *Proceedings of the 18th ACM International Conference on Interaction Design and Children* (IDC '19). ACM, New York, NY, USA, 672-675. DOI: https://doi.org/10.1145/3311927.3325340. **Best Demo Award**

Antonella Nonnis and Nick Bryan-Kinns. 2019. Mazi: Tangible Technologies as a Channel for Collaborative Play. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (CHI '19). ACM, New York, NY, USA, Paper 440, 13 pages. DOI: https://doi.org/10.1145/3290605.3300670

Chapter 4 largely contains portions of the conference paper "Mazi: Tangible Technologies as a Channel for Collaborative Play" (Nonnis and Bryan-Kinns, 2019), while chapter 5, contains parts of the journal article "Olly: A tangible for togetherness" (Nonnis and Bryan-Kinns, 2021).

1.7 Public Exhibitions

This PhD research has engaged wider audiences through, for example, exhibitions of the developed technologies, at the following:

2020 Digital Dada Salon, online exhibition

2019 ACM Interaction Design and Children Conference, Idaho, USA

2019 Queen Mary University of London, UK, Heart'n Soul exhibition, UK

2019 Ars Electronica Festival, Linz, AT

2018 Ars Electronica Festival, Linz, AT

1.8 Additional Publications

Additional work, unrelated to the topic of this PhD was also published, as follows:

Giacomo Lepri, Andrew McPherson, **Antonella Nonnis**, Paul Stapleton, Kristina Andersen, Tom Mudd, John Bowers, Pete Bennett, Sam Topley. 2020. Play Make Believe: Exploring Design Fiction and Absurd Making for Critical NIME Design. New Interfaces for Musical Expression Workshop (NIME '20), Royal Birmingham Conservatoire, Birmingham, UK. **Best Workshop Prize**

Disruption to PhD due to COVID-19

The disruption caused by COVID-19 has had a major impact on the final stage of this research as it affected the last study of the PhD. This was interrupted after 3 sessions of the five that were planned, due to the social distancing measures that the government put in place in March 2020. To mitigate this disruption, the researcher substituted face-to-face interviews, which she usually did with the teachers after the studies, with questionnaires that were sent out to teachers and TAs via email. Also, all the observation sheets completed by the dance teacher and the TAs and kept at the Garden during the study, were digitised and sent to the researcher via email. The researcher kept in contact with the teaching assistants and the dance teacher for months after the study was interrupted via an app called WhatsApp and emails. In fact, she was contacted in early summer 2020 via WhatsApp by one TA who wanted to share with her the response of one particular child who kept asking for the Olly Mazi several months after it ended. The researcher also organised a Zoom video call with the dance teacher several months after the study ended, where she was able to gain few more insights on her thoughts about the study. Finally, the researcher was able to carry out an extended analysis of the study and to elaborate a richer discussion of the findings using the data she collected during the three testing sessions that she was able to carry out prior to the lockdown.

2 Literature review

This chapter presents a critical review of the current literature related to play, autism and technology-based approaches within UK schools, and of the methodological approaches used throughout this PhD. The literature is divided in three main sections. The first part introduces a conceptual overview of play, the definitions of play found in the literature that most align with this research definition of play, and it presents different approaches to play such as psychological, sociological, and pedagogical approaches. Although this inquiry does not take a learning-based approach to design, and it's not goal or task directed or activity based, it is carried out within an educational context, therefore it was important to highlight how later cognitive-developmental theories and progressive educational methods influenced today's play-based learning approaches and to differentiate the approach taken by the body of this work. The chapter also introduces the role of play in the context of autistic children by reporting on play skills and autism and offers a brief reflection on the opportunities that autistic children have within scholastic contexts to experience open-ended child-led play. The second part of the literature presents an overview of autism, how it is diagnosed, and how it manifests. A further discussion is provided on strategic evidence-based interventions for autistic children used within the UK school system, followed by a section on technology-based approaches used within Special Needs Education. Crucially, the final section reports on the methodological principles of this research by introducing an overview on developments in HCI and the benefits and pitfalls of the approaches presented and used throughout this PhD, from user-centred design to experience design, research through design and ludic design. Finally, an overview of Tangible User Interfaces (TUIs) is presented to help locate the position of Mazi and Olly against published works. The chapter finally concludes by summing up the main key points and take-aways outlined throughout.

2.1 Conceptual overview of play

The benefits of play on child development have been studied extensively (Almon, 2003; Burdette and Whitaker, 2005; Frost, 1998) with some researchers showing that play deprivation in childhood may lead to more aggressive young adults (Frost, 2006). Defining play is a complex matter because it has both qualities of action and of activity. However, it is commonly agreed that play is good for children's cognitive, motor, emotional and social development (Ginsburg, 2007; Jarvis et al., 2016; Lillard, 2015; Mastrangelo, 2009; Piaget and Inhelder, 1969). In 2013, the United Nations Convention of the Right of the Child (UNCRC) fully implemented Article 31[5] by adopting the General Comment 17, which formally values the child's right to play and participate in leisure and recreational activities, as well as cultural life and the arts.

The psychologist Piaget considered play to be connected to the child's three developmental stages, what he called 'practice games', 'symbolic games' and 'games with rules', while Vygotsky considered play as a guided endeavour occurring and developing at a social level. The sociologist Mildrean Parten Newhall (1932), on the other hand, theorized play by dividing its development into six stages represented by the children's levels of participation. These are well summarised in the section 1.11.2 below. For Piaget (1962), the presence of others imposes rules on the playful endeavours, and games with rules are almost the only form of play that persists in adulthood. Similarly, Parten (1932) considered the first stages of play to be directed towards individual or private play while the latter stages evolved into social play.

When reviewing findings on autistic children at play, however, evidence shows that they manifest less symbolic and complex play (Stahmer, 1995; Hughes, 1998), less functional and social play (Toth et al., 2006), and increased repetitive behaviours (Libby et al., 1998; Toth et al., 2006). It is thought that playing with peers, especially during unstructured dynamics like playtime, is often a challenge that many autistic children avoid by simply playing in solitary mode (Symes and Humphrey, 2011). Since social interactions are experienced atypically by most autistic children it is our responsibility as researchers to develop design strategies and methodologies that consider and embrace a varied play environment.

2.2 Play definition

In literature, the definitions of play are many and varied across disciplines, from philosophy, to education and psychology. For example, Aristotle, conceived play and leisure as the opposite of work (The Noble Leisure Project[6]), while Piaget, defined it as a process of learning "*the work of childhood*" (Piaget, 1962). Huizinga (1949), in his historical approach to play as a cultural phenomenon, offers a

[5] https://downloads.unicef.org.uk/wp-content/uploads/2016/08/unicef-convention-rights-child-uncrc.pdf
[6] https://blogs.harvard.edu/nobleleisure/aristotle-on-work-vs-leisure/

definition of play as "*more than a mere physiological phenomenon or a psychological reflex. It goes beyond the confines of purely physical or purely biological activity. It is a significant function-that is to say, there is some sense to it*". However, Huizinga defines play as "*the direct opposite of seriousness*" (Ibid), whereas Occupational Therapists (OTs) Sylvie Ray-Kaeser & Helen Lynch (2017) observed that play "*requires serious consideration*" as it is the activity of children. Pedagogical approaches to play (such as those presented in chapter 1.11.3) have taken full advantage of the intrinsic qualities of play and have helped stirring progressive educational reforms on play-based learning approaches. However, Wing (1995) emphasised the distinction between play and work in school contexts by qualitatively analysing how children perceived classroom activities as work activities or as play activities. For example, children identified aspects of activities that made them more work-like or more play-like such as obligatory activities (adults initiated) or spontaneous activities (child-led) (Wing, 1995).

OTs Lane and Bundy (Lane & Bundy, 2012) promoted a less pedagogical approach to play by valuing it for its sake. An "Occupational Therapy Perspective on Play for the Sake of Play" is also been presented by Ray-Kaeser and Lynch (2017) who emphasize the need for more research to explore how guided-play or free-play can be effectively used by OTs as a means to enable disabled and neurodivergent children's participation in play (Ibid).

Gadamer (2004) gave an interesting phenomenological account to play. His hermeneutic of play emphasized freedom over rules and considered the child's agency central to the act of play "*the structure of play absorbs the player into itself, and thus frees him from the burden of taking the initiative, which constitutes the actual strain of existence*". Similarly, Levinovitz (2017) emphasized the difference between toy-play and games, that is, the former allows and enables freedom and agency, while the latter is governed by rules. A difference in definitions this between toy-play and games that is highly valued in this PhD and reflected in the TUI designs, which are classified in this thesis as *augmented* toys and not games.

For this research, play is considered an intrinsically engaging activity that has no other aim than that of being fun and pleasant and where children can lead the play and self-express.

2.3 Approaches to play

To understand play in the context of autism it is important to offer an overview of the different schools of thought that have developed throughout the years into different approaches to play. From the literature, play can be categorised with respect to the children's cognitive development and or to their social engagement (Besio et al., 2017). The following three sections will briefly introduce three different approaches to play; a psychological one, a sociological one, and a pedagogical one.

2.3.1 Psychological approaches

Among the most influential scholars in the field of phycology, Piaget (1896-1980) and Vygotsky (1896-1934) considered play to be a crucial component of early child development. For Piaget, the function of play was that of serving knowledge due to a process of information-seeking in which the child continually learns through exploring. Piaget followed a constructivist view of knowledge that is not ready-made but a continually evolving construct formed by experiencing the world through interacting and acting on it. Vygotsky on the other hand was a socialist as well as a constructivist and based his theories on Marxist ideals, emphasising the socio-cultural influences on child development as well as the role of language and symbolic play (Bodrova and Leong, 2015). Piaget defines play as a process of assimilation i.e. repeated for "*purely functional pleasure*" (Piaget, 1962) that poses no demands on comprehension. Vygotsky sees this definition as too limited and describes play not on the basis of the pleasure it causes but instead on its capacity to fulfil the children's needs, inclinations, as well as their reasons to act, and their affective aspirations (Vygotsky, 1967).

Piaget divides play into three categories and compared them to different stages of intelligence.

1) Practice games
2) Symbolic Games
3) Games with Rules

Practice games are those ludic activities that are part of the pre-verbal stage of infants, under the sensory-motor intelligence, when, ludic activities can potentially extend to all actions. The phase of **symbolic games** emerges between 18 months and two years, and unlike practice games, requires "*ludic representational structure*" and implies make-believe representation skills, which are evidence that a child has reached that cognitive stage (Piaget, 1962). These games belong to what Piaget calls representational intelligence. There are two types of symbolic play; functional symbolic - as the object serves the function it was meant for, or imaginatively symbolic - as the child develops representational and make-believe skills and can use objects in ways other than that intended for their use (Boutot et al., 2005). Recently, both symbolic and functional play has been found to be strongly associated with verbal skills, but functional play seems to affect long-term gains in expressive language (Toth et al., 2006). In contrast to the previous two phases, just the third category called **games with rules**, is part of what Piaget calls reflexive intelligence, and this requires social interactions. Rules for Piaget are imposed by the presence of others and games with rules are almost the only ones that persist in adulthood. In contrast to early play stages, considered as a process of assimilation, where play is characterised by ludic qualities, in games with rules a process of accommodation (opposite of imitation) dominates over assimilation as children develop skills that enable them to accommodate to rules and to other children's play styles "*If it is true that practice play results from the child's pleasure in exercising his newly acquired powers, and that ludic symbolism is primarily assimilation of reality to the ego and intensification of this same pleasure through fictitious control of the whole natural and social world, then the disappearance of the earlier games in favour of adapted construction on one hand, and the evolution of games with rules on the other, can be easily explained*" (Piaget, 1962).

In contrast to Piaget, Vygotsky's theory on play and development focuses mainly on **symbolic play**, which is considered as a *vehicle* for separating reality from actions. For him these types of play prepared the children for adult life and he considered make-believe play a major contributor to children's development of written language (Vygotsky, 1986). He argued that object play is part of the first-order symbolism alongside drawing, whereas writing and make-believe play are part of the second-order symbolism. Piaget interpreted language acquisition as a complex process of assimilation stressing the child brain's dynamic abilities. Vygotsky instead, emphasised the social nature of language acquisition and considered play to contribute to both personal and social development at the same time - Piaget's model did not seem to see these two levels of play coexisting. Whereas for Piaget, social influences were not part of the play experience in any way before games with rules, though paradoxically, interaction with the environment was crucial for development to happen, for Vygotsky, the socio-cultural environment created by interacting with others was a critical element of development from infanthood. Within the first seven years of life, a child first play solitarily and for individual purposes and then progressively develops social play skills and collective symbolism. Vygotsky always saw the child in a social context and considered the latter to be always part of child development, as children cannot be separated by their socio-cultural influences. For him, the optimal development is given by adult-guided play, while for Piaget play is child-directed.

Both Piaget and Vygotsky view development as something that happens in sequential order and saw the interaction with the world as crucial for cognitive development. The main difference between them lays perhaps in the fact that whereas Piaget focused on envisioning the developing child as a scientist exploring the world, Vygotsky focused on the importance of the social context and language for cognitive development to happen.

2.3.2 Sociological approaches

A third scholar worth mentioning for her innovative approach and extensive work, specifically on the sociological aspects of play, is Mildrean Parten Newhall (1902-1970). As a sociologist, rather than studying individuals, she was interested in studying group behaviours, especially children's group behaviours during playtime. Parten divided the development of play into six stages and theorised social play by observing and classifying 2 to 5 years old children's levels of participation during free play. Parten's six stages of participation are briefly reported as follow:

1. **Unoccupied behaviour**: No playing or interaction with players, just observing
2. **Onlooker behaviour:** Observing others playing without attempting to join.
3. **Solitary play:** Playing close to each other but focused on own activity.
4. **Parallel play**: Playing next to each other but not with each other.
5. **Associative play**: Interacting during play with each other and using similar materials.
6. **Cooperative play**: Playing together with a shared goal, coordinating behaviours.

Similarly, to Piaget, she considered play a free endeavour that is child-led. For Parten, the level of involvement of the child increases with the stages but is not clear whether she saw that as a sequential progression like Piaget and Vygotsky did. According to Parten, the stages of play increased with the level of social complexity but overlapped. She observed that pre-schooler's social participation increased with age, suggesting that the formulation of social play hierarchies were reflected on the children's participation during free play structures (Rubin et al., 1976). In her book, Parten (1932) that: "*The shift away from solitary play, however, was preceded by a period of popularity for this type of play. The most social groups, associative and cooperative, tended to occur more frequently with greater Nursery School experience.*"

While a child would exhibit more solitary play at the age of 1 to 2 years, they would tend to favour a more cooperative one at the age of 4. By the age of 5 children showed a decline in solitary play and preferred more associative and cooperative ones. Interestingly, Parten assigned negative values to the first stages of play "*unoccupied, solitary, and onlooker activity might be considered negative indices of social activity*" (Parten, 1932), while for Piaget these, which he called practice games (sensorimotor stage) are the most important in an infant as they lay the foundations for the next stages to develop.

2.3.3 Pedagogical approaches

Progressive educational approaches inspired by Piaget, Vygotsky, and Parten's theories of play and child development, emerged since the beginning of the 20th century. These have proposed and emphasised a more child-centred education style. For example, the Montessori method and the Reggio Emilia approach are among the best known European non-traditional methods of education considered as play-based learning programs and have stirred progressive educational reforms worldwide. Play-based learning has been defined "*as a teaching approach involving playful, child-directed elements along with some degree of adult guidance and scaffolded learning objectives*" (Pyle and Danniels, 2017). Although inspired by the same philosophy, the Montessori and Reggio Emilia approaches offer different perspectives and practices on child development and play. These are briefly introduced here from three points of view: historical, scholastic, and environmental.

2.3.3.1 Maria Montessori Method

Maria Montessori (1870-1952), a constructivist like Piaget, saw the child as an active human being eager to learn and develop through work, functional activities and play. She was considered by some to be the first person to develop strategies for, and to work with, children with high support needs (Pickering, 1978). Maria was the first physician woman in Italy who during the late 19^{th} century worked in a psychiatric hospital in Rome for the 'mentally disabled' children of the city. Maria believed that these people would benefit from a tailored education, so she designed a multi-sensory set of materials that matched the children's different abilities, from "*simple to complex, concrete to abstract and percept to concept*" (Pickering, 1978). Most of the activities were designed in order to stimulate muscle movements as she believed muscle memory to be the strongest in the child, and the one that is most ready for development. The materials used represented their attributes. These activities, she believed, helped the child's self-regulation and development. Among others, she studied the pioneering work on SEN and sensory stimulation of Jean Itard and Edouard Seguin, who inspired her with taking a scientific approach to education based on methodical observations and sensory and motor training (Seguin, 1907). Maria also noticed that children with extra needs required more adult support than typically developing children but that they achieved by being guided and by using incremental steps of complexity. The structure of the classroom was so that the activities, which targeted subcategories of learning, were provided in trays on open shelves to enable the children to see them and make informed choices. The set of materials, designed by Maria, were freely chosen by the children and the educator's role was to enhance the learning experience of the child by asking questions and supporting exploration. The classrooms were formed by groups of children of different ages (spanning 3 years) (Edwards, 2002).

Inspired by the ideas of Frederick Froebel in the late 19^{th} century (Froebel, 1859), Montessori, like Piaget, believed that for development to occur children needed to touch the material world at a concrete level, by manipulating and exploring physical objects. She also believed that children learned by imitation. For Montessori, objects' manipulation was the perfect tool for "*sensory, motor and intellectual training*" (Montessori, 1912). Interestingly, Maria spoke quite negatively about make-believe play as she considered it a type of play that was imposed by adults and not pertinent to child development. Montessori was convinced that if the children were presented with the possibility of really mopping the floor or building a house or a garden they would have not being interested in pretend play as she "*saw children's pretence as a manifestation of their unsatisfied desires (Montessori 1997)*" (Lillard, 2013). This argument resonates with Baudelaire's opinion on dolls, expressed in the “Philosophy of toys” (Baudelaire, 1853), where he highlighted the difference between play objects such as toys or dolls. Expanding on Baudelaire's argument as to why dolls are inappropriate play toys (Baudelaire, 1853), in his essay on "Toys" Barthes explains that such objects represent “*a microcosm of the adult world”* with “*reduced copies of human objects*” (Barthes, 1972). Therefore, play and toys play, but not dolls play, seem to provide the perfect ground to children’s imaginative freedom.

The playground for Maria is therefore the perfect context in which the educators are enabled to observe the “*liberty of the pupils in their spontaneous environment*” (Montessori, 1912). Smilarly, Vygotsky, believed that the environment creates the framework for interactions to happen, while Montessori talked about the importance of the children’s *prepared environment* to enable children’s freedom of choices. Other approaches, such as the Reggio Emilia approach, which is further discussed in the following section, considered the environment a *third teacher.*

2.3.3.2 Reggio Emilia approach

The Reggio Emilia (RE) approach emerged in northern Italy from the homonymous city, after WWII, thanks to a group of parents who were determined to create the best educational experience for their children “*with first priority given to children with disabilities or social service needs.*” (Edwards, 2002). Under the social-constructivist director Loris Malaguzzi (1920-1994), the system evolved throughout Europe and beyond. Malaguzzi, like Vygotsky, considered Piaget’s stages of development as too limiting and did not consider the child as an isolated knowledge-maker. He described children as being social from birth, intelligent, curious, and full of potentials, and he envisioned an "*education based on relationships*" that focussed “*on each child in relation to others. [..]*” (Edwards, 2002). Malaguzzi considered the arts to be fundamental to children’s development as they allow expression of multiple ideas through the use of different mediums. Artists and especially visual artists were often invited in schools to promote children’s engagement and allow personal expression through creative exploration.

Reggio offers a learning experience through a relationship-driven context that was first developed for children under 6 years, but that was extended by educators in the United States into primary education. The environment “*supports exchange and relationships through physical qualities of transparency, reflectiveness, openness,* *harmony, softness, and light (Ceppi & Zini, 1998; Gandini, 1993).*" (Edwards, 2002). Teachers usually work in pairs and their role is that of following child-lead activities by either actively engaging with the children or attentively observing them; they act as facilitators of development by scaffolding children's learning. The environment for Malaguzzi had to be flexible to adapt to the child's needs and contain appropriate elements for different levels of development and age. In RE, the teacher, the environment, the children, and the interactions between these parts, all play an equally fundamental role in supporting learning (Gandini, 2011). Play, for Malaguzzi, is one of the main sources of learning by direct experience. Gandini (2011), an educator and advocate of the RE approach in the States, explained "*[...] Malaguzzi's very first explorations and experiences with children were based on play with a purpose. His views were contrary to ritual play man-aged and controlled by adults, where children were expected to repeat gestures and words chosen by teachers. In Reggio, when children arrive at school in the morning, they play with their friends using materials or games or toys.*"

Both Malaguzzi and Montessori were contrary to adult-directed learning, and both advocated for the benefit of direct physical manipulation and for designing aesthetically beautiful environments that scaffold development and cater to the children's needs. Where RE and Montessori diverged the most was perhaps in their views of the role of the teachers. RE required two teachers in each classroom and they worked in pairs, while in the Montessori's classrooms the ratio between children and teacher was generally higher. Montessori designed beautiful and engaging materials specifically targeting certain goals, while Malaguzzi adopted the use of open-ended materials for the children to explore. Although in both approaches play is considered child-lead and the teachers evaluate the child performances by careful observations, in the RE approach the teachers "*construct the experiences of children on the basis of observation and documentation, while the teacher in a traditional Montessori method follows steps in offering the prepared materials and sees that the children use them in the expected sequence*"(Gandini, 2011). This emphasis on child centred and child-lead approaches proposed by the RE approach, and the teacher's observational skills valued by both Montessori and Malaguzzi, echo the ethos of this PhD and are mirrored in the methodology and approaches used for the three studies. Rather than supporting learning the work in this PhD aims to support a neurodiverse play environment.

2.4 Play and autism

When reviewing the literature on autistic children at play, their displayed behaviours are usually different than that of typically developing children (Toth et al., 2006). Autistic children often manifest reduced social play and more repetitive behaviours with the use of toys than their neurotypical peers (Libby et al., 1998; Toth et al., 2006). When playing with others, they show reduced proximity, less social interaction, and more solitary play than children with other developmental disorders (Watson, 2003). It is thought that playing with peers, especially during unstructured dynamics like playtime, is often a challenge that many autistic children avoid by simply playing by themselves (Symes and Humphrey 2011). However, according to Charman et al. (1997), under unstructured conditions, autistic children show intact functional play skills but limited pretend play, while there is mixed evidence that in structured or prompted conditions autistic children produced less functional and symbolic play than the mentally delayed control group. For autistic children is common to receive prompts by adults to encourage their participation (APA, 2013), and it is therefore interesting to ponder on how prompts and structure might have an inverse effect on children's positive experiences by reducing their opportunities for meaningful play.

2.4.1 Playful contexts/activities for autistic children

In SEN schools in the UK, for example, autistic children spend much more time interacting with adults and playing in controlled environments where they often receive prompts, than playing spontaneously with peers (Miller et al., 2010; Besio et al., 2017). This in turn might affect children spontaneity, play experiences and development. As discussed in Chapter 2.3, because play is very efficient in helping children to achieve learning outcomes within educational settings, free play, and child-led activities are concepts not extensively explored (Wood, 2007). Terpstra, Higgins and Pierce (2002) propose several methods for teaching social play skills to autistic children in classroom settings. They identify four types of interventions which include a) teaching isolated play skills in the context of preteaching, (b) script training for play skills, (c) using peer models, and (d) using pivotal response training. In each of this approaches the child is thought a specific play skill such as cause-effect understanding, sociodramatic play, and social interactions. Spiel and Gerling (2020) recently presented a literature review on the purpose of play and neurodivergent population within the HCI community and found that the predominant forms of play are based on medical and education settings and are "*driven by an extrinsic purpose*" (Ibid). Therefore, this PhD research aims to bridge this gap in the literature and to support extrinsic play.

2.4.2 Play skills and autism

The development of autistic children is often described as atypical, but theories of development for autism can still be studied within traditional perspectives (Burack and Volkmar, 1992). From birth, children learn to imitate and use motor skills to interact with the environment and play. Play, even in its basic forms, requires a variety of skills such as social, regulatory, motor, language, and communication. Furthermore, play can be intrapersonal (Solitary Play) or interpersonal (Social Play), intrinsic (spontaneous), or extrinsic (directed) and can occur with objects, with peers, functionally and/or symbolically. Among other things, through play, children practice and develop language, non-verbal communication (facial expression, body language), turn-taking, joint attention, imitation, self-regulation, and socialization (Golinkoff et al., 2006) - all skills that are useful to successful social interactions. By imitating both neurotypical and autistic children develop social skills, communication and language skills, share experiences and emotions and understand others as distinct beings (Toth et al., 2006).

Crucially, Rodgers et al. (1996) found that autistic children perform better than neurotypical ones in object task imitation but significantly worst in pantomime imitation. Autism is often co-morbid with alexithymia (Heaton et al., 2012), which is associated with challenging autistic children's abilities to recognise their own emotional states, which in turn might affect their social cognition (Silani et al., 2008; Hill et al., 2004) and might hinder opportunities to socialise with peers (Reid and Asaro-Saddler, 2013). A more recent study by Rodgers et al. (2003) found that autistic children performed worse on object and facial-oral imitation than typically developing children but, in contrast to a previous study (Rodgers et al., 1996), hand-gesture imitation was not different across groups. Nonetheless, task type and sensory feedback seem to influence the imitative performance of this population (Ingersoll et al., 2003). For example, Ingersoll et al. (2003) found that autistic children were more likely to imitate actions on toys that produced a sensory effect (light and sound). Therefore, it is difficult to generalize a consistent understanding of autistic children's imitative skills (Sevlever et al., 2010).

Another recent study (Toth et al., 2006) found that proto-declarative joint attention (desire to share an experience with someone else) and immediate imitation skills are associated with verbal skills at around the age of 3-4, while toy play, and deferred imitation are predictors of communication development from 4 to 6.5 years. Interestingly, Jarrold et al. (1993) found that symbolic play can be used to assess language impairment more than IQ levels. However, the challenges experienced by some autistic individuals with planning and language might hinder their ability to develop symbolic play skills (Mastrangelo, 2009). Motor imitation is also strongly correlated with language and communication abilities (Stone et al., 1990). Given this link between sensorimotor and social domains, autistic children are disadvantaged as they experience challenges in both domains. Since around 40% of autistic children are nonverbal (Tager-Flusberg et al., 2013; CDC, 2020) and experience challenges in communication, social interaction, sensory processing (APA, 2013), motor skills (Bhat, 2020), and social cognition (Silani et al., 2008; Hill et al., 2004), finding new approaches and strategies to develop technologies that encourage socially engaged play in this population is increasingly important as technologies permeates our lives. Furthermore, Strain and Schwartz (2001) demonstrate that social play is dependent on the context and it cannot be taught as a set of discrete skills.

2.5 Defining autism

In order to understand play and autistic children's play in more depth, this section introduces an overview of autism and how it manifests. The meaning of autism has become an umbrella term to define behavioural traits. Today, it is understood that autism has a genetic and biological component to its origins (Schopler and Mesibov, 1987). Autistic children often present common characteristics identified in the dyad of impairments (APA, 2013) which affects areas related to:

- Social Communication and interaction
- Imagination and flexibility of thought and unusual sensory responses

The American Psychiatric Association (2013) recently released the fifth edition of its Diagnostic and Statistical Manual of Mental Disorders (DSM-V). The DSM-V classifies the severity of autism based on the levels of support that a person receives from Level 1 - requiring support, to Level 3 - requiring substantial support.

The diagnosis of autism is carried out in clinical settings and relies on the level of expertise of the administrator and the diagnostic tools used. Different theories support the understanding of the diagnosis of autism, and account for both deficits and assets. These are the Theory of Mind (ToM) (Baron-Cohen, 1989), the Executive Function (Joseph and Tager-Flusberg, 2004), the Weak Central Coherence Theory (Happé, 1997), the Hyper-systemizing theory (Baron-Cohen et al., 2009), and the Enhanced Perceptual Function (Mottron et al., 2009).

ToM is the cognitive ability that every person has to make sense of the world we live in. The concept of Mind-Blindness (Baron-Cohen, 1989) establishes that a person with autism has difficulties in understanding, conceptualizing, and acknowledging the emotions and opinions of others. ToM is one of the manifestations of one's ability to form metarepresentation. Metarepresentational development determines a fundamental aspect of social skills which is that "*other people know, want, feel, or believe things; in short, having what Premack and Woodruff (1978) termed a 'theory of mind'*" (Baron-Cohen et al., 1985). Baron-Cohen et al. (1985) thought that autistic children are unable to form beliefs about the mental states of others and thus they lack metarepresentaton skills.

Executive Function can be defined as the way in which people monitor, express, and control their thoughts and actions. Similarly, executive dysfunction pinpoints the inability of behaving towards achieving certain outcomes, sequencing, plan, adopting flexible thinking, and sustaining control over one's thoughts and actions. Autistic children may display one or all of these 'cognitive dysfunctions' finding it difficult to self-regulate, self-express, and self-organise (Joseph and Tager-Flusberg, 2004).

Other models explore the assets of autism and advance what is today commonly called the *ability hypothesis.* For example, Central Coherence is the ability to focus both on the details as well as on whole chunks of information. Weak Central Coherence (WCC) (Happé, 1997) emphasises the notion that autistic people have an inclination towards the detail, a local bias that weakens their central coherence and creates global impairments.

Similarly, the hyper-systemizing theory (HST) proposes that the excellent attention to details of autistic people is due to sensory hypersensitivity (Baron-Cohen et al., 2009). It differs from the WCC theory as it does not connotate negatively detailed information processing (i.e. local bias/inability to global), but rather sees attention to details as a positive and purposeful ability that allows an understanding of systems.

Lastly enhanced perceptual function (EPF) (Mottron et al., 2009) was proposed as an alternative to the WCC theory and demonstrates that both "high functioning" and "low functioning" individuals with autism had intact global processing skills and superior performance for local visual stimuli.

2.5.1 Sensory processing and self-regulation in autism

As a consequence of the many challenges experienced by autistic individuals, many may find it difficult to self-regulate, self-express, self-organize, and to process the many sensory inputs received from social and environmental interactions. This perhaps explains why what is typically considered a positive activity such as play can at times be a demanding task for many autistic children.

Autism presents sensory processing challenges that most frequently fall into two main categories: 1) hypersensitivity and 2) hyposensitivity (Grace and Baranek, 2002; Greenspan and Wieder, 1999), but two other categories have been found to be autistic children's common sensory features: 1) repetitive and seeking behaviours; 2) enhanced perceptions (Baranek et al., 2014). A prevalence of sensory features in preschool and school-aged autistic children ranging from 40% to 90% has been recently reported (Baranek et al., 2014). This thesis refers to sensory features to indicate both positive and negative experiences that include manifestations of fascination and distress in relation to sensory processing and modulation issues (Baranek et al., 2014).

Around the 1960s, Jean Ayres, an American Occupational Therapist (OTs), developed what is today called "Sensory Integration" theory (SI). Ayres noticed that a common feature exhibited by autistic children was a "*disturbance in sensory processing*". Sensory integration or processing refers to the person's ability to take in information, through our various senses, from the external world, process it, and respond or react to it. Thus, sensory processing is the ability to interpret sensory stimuli, while sensory modulation is the capacity to regulate those stimuli. When the perception of these sensations is unbalanced our bodily reactions may exhibit atypical characteristics. Researchers have shown that, among other things, sensory processing issues can affect: behaviours, self-regulation, social skills, attention and cognitive skills (Case-Smith et al., 2015; Roberts et al., 2007). Self-regulation is an internal mechanism that blocks out irrelevant information and enables self-control over certain impulses like emotions, behaviours, and self-awareness. This research refers to self-regulation as a "*...process whereby students activate and sustain cognitions, behaviours, and affects, which are systematically oriented toward attainment of their goals*" (Schunk and Zimmerman, 1994). Self-regulation allows to plan, control and monitor attention and performance (Harris, 2005), and alongside the theory of mind is implicated in children's social skills (Bosacki and Astington, 1999).

Jahromi et al. (2013) found that self-regulation, especially emotional regulation, predict prosocial engagement in autistic children. Furthermore, the control of attention seems to contribute to self-regulation (Rueda et al., 2005). Language is also an important factor for self-regulation (Reid and Asaro-Saddler, 2013), and considering that a vast percentage of autistic children are non-verbal and do not use language for self-regulation (Joseph et al., 2005) it is important to develop strategies that address these challenges. According to Laurent and Fede (2021), self-regulation for autistic children is a challenge due to neurological, cognitive, physiological and sensory processing differences and attentional preferences. The authors (Laurent and Fede, 2021) sustain that a child is self-regulated when they are able to shift between different energy states (from asleep to frenzied), depending on the demand required by the environment. When there is a discrepancy between the energy levels and the environmental demand, regulatory strategies which usually stimulate the sensory system are necessary to rebalance regulation levels (Laurent and Fede, 2021). These stimuli are often achieved in what we see as forms of repetitive and restricted movements. Considering the challenges that autistic children experience in some areas of executive functioning - such as flexibility, planning, and self-monitoring - children's ability to self-regulate might be negatively impacted if the environment does not provide opportunities to self-regulate (Hill 2004).

2.5.1.1 Repetitive movements

Autistic children repetitive and seeking behaviours may be exhibited in the child's fascination or fixation for something, which usually manifests in a stereotyped behaviour like rocking, hand-flapping, twiddling strings, light-gazing, tapping body parts, and/or finger flickering (Baranek et al., 2014; Murdoch, 1997). It is thought that autistic children perform these behaviours to increase or lower their arousal level and to self-regulate (Case-Smith et al., 2015), and is suggested that the use of repetitive behaviour is a way of managing anxiety and sensory inputs (Suarez, 2012). Contrarily, repetitive and stereotyped movements are often considered inappropriate by society at large, as they may interfere with social interactions and communication, learning, attention, and well-being. Ultimately, they are perceived negatively and interventions tend to reduce or eliminate them (Murdoch, 1997; Nind and Kellett, 2002). The aim of this PhD research, however, is to move toward an inclusive ideology that values individual's differences (Murdoch, 1997; Nind and Kellett, 2002). As Nind et al. (2002) observed "*inclusion involves schools and other social structures making changes to take away barriers to participation and to facilitate rights to choice and self-determination* [..] *This defining characteristic of stereotyped behaviours lacking any function is challenged by those (such as Nijhof, Joha and Pekelharing, 1998) who view the behaviours as having a homeostatic function, helping individuals to achieve equilibrium in their sensory stimulation*" (Nind and Kellett, 2002). According to Baker (1998) successful group games are based on the children's obsessive behaviours as they enable a more inclusive play environment. They suggested that by using a 'child's obsession' to increase their motivations, the desire of autistic children to engage in social interaction with peers increases.

These values open up the design space for playful TUIs, and defy the traditional views that stereotyped behaviours have no adaptive function. This point particularly resonate within this PhD's perspective.

2.5.1.2 Hypersensitivity vs Hyposensitivity

Autistic children might exhibit sensory processing challenges that most frequently fall into two categories such as hyper-sensitivity and hypo-sensitivity (Grace and Baranek, 2002; Greenspan and Wieder, 1999). Therefore, it is important to briefly introduce the impact that these sensory features have on the children lives.

For example, hyper-sensitivity indicates a very low threshold to stimuli, meaning that a child is easily over-stimulated, and their perception of sensory stimuli is very high. This often causes overresponsive reactions (hyper-reactivity) and is usually indicated by visible responses, such as distress, grooming, avoidance, sensory seeking patterns, and ritualized behaviours (Baranek et al., 2014). Researchers observed more challenging behaviours and dysregulation particularly in hyper-responsive kids (Baranek et al., 2014; Liss et al., 2006). Hypo-sensitivity, on the other hand, which reflects in hypo-responsivity, indicates low sensitivity to sensory stimuli and very high thresholds, which can result in the child's lack or delayed responses to stimuli, such as spoken words (Čeponiene et al., 2003) and low arousal. Both hypo and hyper-responsiveness often co-occur in autism.

Autistic children can be both hyposensitive and hypersensitive to different sensory modalities. For instance, they can be hypo-sensitive and show inconsistent or delayed responses to spoken words, but they can also exhibit hyper-sensitivity features toward auditory stimuli e.g. they might have difficulties with filtering background noises while conversating, and have enhanced musical perception like perfect pitch recognition, musical tones and frequencies discrimination (Heaton et al., 2008). While hyposensitivity is said to emerge during the first year of life, hypersensitivity seems to develop following, or in tandem with, hypo-responsiveness. Studies found that sensory seeking and repetitive behaviours increase from infancy through early school years and then decrease again (Baranek et al., 2014). Repetitive behaviours are also considered a sign of rigidity, perhaps due to the child's challenges with executive function.

Hyper-responsivity and hyper-sensitivity are also linked to high arousal levels in autistic children and both are thought to increase anxiety levels (Liss et al., 2006). Researchers found that arousal levels might also be linked to tactile defensiveness (Baranek et al., 1997), which is linked with social withdrawal and anxiety (Green and Ben-Sasson, 2010). Thus, hyper-responsivity, and especially tactile defensiveness, high arousal levels, repetitive movements, and anxiety levels are all interconnected and difficult to study in isolation and they all influence each other (Baranek et al., 1997; Cascio et al., 2008; Liss et al., 2006). It is reported that between 22% to 80% of autistic children experience anxiety (Rodgers et al., 2016) and that there is a link between anxiety and social interactions that may be bi-directional (White et al., 2009a).

2.6 Evidence-based interventions using auditory and tactile stimulation

The most common evidence-based interventions for hypersensitivity and anxiety used in therapeutic and educational contexts are cognitive behavioural therapy (CBT), sensory integration (SI), and auditory stimulation therapies (Green and Ben-Sasson, 2010). SI is still used today as a rich therapy to help modulating various sensory inputs (although the term is often confused and misused with sensory-based treatments) (Case-Smith et al., 2015). Ayres' SI therapeutic interventions have been described as "*clinic-based interventions that use sensory-rich, child-directed activities to improve a child's adaptive responses to sensory experiences*" (Baranek et al., 2014). The therapy is always delivered by a specialised and trained Occupational Therapist (OT), usually on a 1:1 basis with sessions of 30-60 minutes, and over a long period of time (6-12 months). The objective is to engage the child through a slow process of desensitisation by offering the right amount of challenges and using multisensory equipment. By engaging the child in these activities, beyond improving SI and modulation, the therapy aims to have a broader impact on the social life and participation of individuals. In her studies, Ayres found that hyper-responsive kids benefitted more from SI than hypo-responsive kids.

Deep pressure on the other hand is an intervention used in support of tactile defensiveness, anxiety, and self-regulation is. Whereas deep pressure has been found to affect the nervous system, increase dopamine level and decrease stress hormone cortisol, which are all contributing to self-regulation (Field et al., 2005), light touch seems to alert the nervous system as it is a superficial stimulus - similar to tickling. Deep pressure touch evokes calming reactions (Grandin, 1992; Olausson et al., 2002; Riquelme et al., 2016). It seems that, for the way the message of deep-pressure touch travels through the body it has the ability to override other *"arousing inputs, such as auditory, visual and light touch stimulation*" (Lin et al., 2014). Deep pressure can also decrease anxiety levels (Krauss, 1987) and it is used as one of the treatments for desensitisation of sensory stimuli i.e. in SI therapy. Several studies experimented with and demonstrated the beneficial and calming effects of deep-pressure by using different types of pressured touch stimuli like hug machines (Edelson et al., 1999; Krauss, 1987); garments to wear on sleeves (Zissermann, 1992) or on the chest (Duvall et al., 2016; Vandenberg, 2001); and hand massage (Escalona et al., 2001).

Other types of sensory stimulation which have been used by many academics for different purposes include auditory integration therapies (AIT) (Sinha et al., 2006), music therapies (MT) (Reschke- et al., 2011; Wigram and Gold, 2006), neurologic music therapies (NMT) (Thaut, 2005), and rhythm auditory stimulation (RAS) (Thaut and Abiru, 2010; Trost et al., 2014). These have the dual aim of desensitising the auditory system and positively impact other domains, such as the motor system, language, independent functioning, and social interaction.

A recent review on the benefits of music therapy on autistic children's motors and social skills development, highlights the challenges of creating a unified framework for developing technologies in support of music therapy for motor and social skills development, especially as today's technologies are ever more ubiquitous (Ragone et al., 2021). Music, however, is a powerful medium that could also contribute to children's emotional regulation (Zacario and Whitebread, 2015). Allen and Heaton (2010) suggested that it can be an efficient therapeutic tool for alexithymia because through the association of certain emotions to musical outputs the children's understanding of their own emotional states could be scaffolded. O'Connor et al. (2011) noted that autistic individuals auditory processing's alterations are more severe with vocal inputs than non-speech sounds, and in healthy verbal autistic adults there is evidence for some hypersensitivity to some speech components (Heaton et al., 2008). Children might also experience issues with processing speech in noisy environments (Alcántara et al., 2004).

By contrast, with respect to musical preferences, autistic people seem to respond to music similarly to typically developing people. Allen and Heaton (2010) showed that they deliberately use it for mood management while Boso et al. (2009) and Salimpoor et al. (2015) demonstrated that similarly to most neurotypical people, they prefer harmonious to dissonant sounds. Furthermore, there is evidence that autistic children have superior pitch memory, labelling skills and enhanced sensitivity to pitch detection (Bonnel et al., 2003; Heaton, 2003). Hardy and LaGasse (2013) suggest that other elements of music such as rhythm contribute to sensorimotor regulation.

2.7 Technology based approaches in SEN settings

Interactive technologies have been deployed in schools in Special Education Needs settings (SEN) for several years (Andersson and Cappelen, 2013; Farr et al., 2010; Hendrix et al., 2009; Kern and Aldridge, 2006; Mora-Guiard et al., 2017; Tam et al., 2017; Tsang et al., 2007; Winoto and Guan, 2016; Ragone et al., 2020).

Kientz et al. (2013) provided a taxonomy of the development of interactive technology for autistic children that include: Personal Computers and the Web; Video and Multimedia; Mobile Technologies; Shared Active Surfaces; Virtual and Augmented Reality; Sensor-Based and Wearables; Robotics; and Natural User Interfaces (Kientz et al., 2013).

For example, a Natural User Interface often used in academia is the Kinect® camera (Malinverni et al., 2014; Bartoli et al., 2013; Sampath et al., 2013; Ragone et al., 2020), a commercially available technology that was not specifically designed for autistic children but that is often used by researchers because it enables touchless interactions such as voice inputs and gestural control. Ragone et al. (2020) proposed a Kinect® motion-based system as an alternative to traditional musical instruments called OSMoSIS, which allows for a wider range of interaction styles, especially for children whose motor skills are compromised. Ragone et al. (2020) tested OSMoSIS with a group of autistic children both in mainstream and SEN schools and the results highlighted signs of engagement, social interaction, pretend play, and enjoyment (Ragone et al., 2020). However, issues were found with the choice of the sounds used. Among these, the authors mentioned that some children found water drops and woodblocks to sound unpleasant. Gelsomini et al. (2017) used a Kinect® camera as one of the components for building an inflatable mobile robot called Puffy. The robot is made of soft (inflatable body) and hard components (technology) and it proposes tasks to the children *"that aim at promoting cognitive skills at different levels*". Alongside the Kinect®, Puffy used a projector, a Mini PC, one Arduino, a speaker, lights, and a moving base, which allowed it to interpret children's non-verbal interactions such as *"gestures and movements, facial expressions and emotions".*

By contrast, Hourcade et al. (2012) used Shared Active Surfaces in the form of multitouch tablet applications to support the social skills of autistic children by "*providing many simple, open-ended, mistake-free applications instead of concentrating on one, and in focusing on activities as opposed to technology*".

Commercially available technologies particularly developed for Special Needs Education (SEN) are many and often include auditory stimulation such as the Soundbeam[7], Cosmo[8] and the Skoog[9]. Soundbeam is an intangible musical instrument aimed at students and adults with severe learning disabilities that can be played as an invisible keyboard. It is often used in support of Music Therapy (Swingler, 1998) and is a system that uses a combination of up to four ultrasonic sensors and eight mechanical switches to trigger electronic sounds via the Musical Instrument Digital Interface (MIDI) protocol, either in solo mode or with more players. Ellis and van Leeuwen (2002) used the Soundbeam with 26 high support needs autistic children through a "Sound Therapy" approach, where children were enabled to play music by means of rocking their bodies and waving their hands. Another accessible interface that was made specifically for children with Special Education Needs is Cosmo, a tangible system made of hardware and software components. The hardware consists of six hard plastic switches that when pressed light up and/or play sounds and music and these are paired to the Cosmo activities app. via an iPad via Bluetooth. The software offered a multitude of activities focused on various skill development. Kossyvaki and Curran (2020) tested Cosmo with a group of five autistic children with intellectual disabilities and found positive outcomes in social communication.

Finally, the Skoog is an accessible single-user tactile musical interface shaped like a cube and made in rubber. On the four sides of the cube and on its top face there are 5 buttons that when pressed, touched, and/or stroked activate a series of notes (Houchin, 2018). The Skoog is another instrument that pairs via Bluetooth to an iOS device. Crucially, the three systems mentioned above require a connection to a computer.

More recent studies on social skills development for autistic children focus on Virtual Environments (VE), Augmented Reality (AR), robots, and computer vision in general (Andreae et al., 2014; Bhattacharya et al., 2015; Jeong et al., 2018; Mora-Guiard et al., 2017). This may be due to the increased availability of such tools and or perhaps because some verbal autistic individuals might be more able to develop compensation strategies and potentially transfer this type of interaction to real-life

[7] https://www.soundbeam.co.uk/
[8] https://www.filisia.com/cosmo/
[9] http://skoogmusic.com/

situations. For example, the work of Mora-Guiard et al. (2017; 2016) on full-body interaction aimed to foster relationships between a child with autism and a neurotypical peer in a VE. The full-body interaction system projected the children's respective avatars onto the floor in a virtual environment, and through handling a physical object such as a butterfly net, the children can interface with a large circular interactive environment. The avatars serve as a model for the interactions between the children. The study adopted a participatory design approach experimented in a lab and a school setting and focussed on: socialization, collaboration, and user engagement. On the other hand, Jeong et al. (2017) found that deploying a Virtual Reality (VR) avatar system in a paediatric inpatient-care context when compared to a physical plush robot decreased the social opportunities among peers. Interestingly, Kootz et al. (1981) investigated the response to distal and proximal stimulation and found that autistic children preferred proximal stimulation such as touch, taste, and smell to distal stimulation such as hearing or seeing (Kootz et al., 1981).

Sahin et al. (2018) proposed an AR intervention for autistic children using Smart glasses, which are intended to motivate the users to engage with the face of another person. The focus was to "d*eliver assistive social communication and behavioural coaching in schools*" (Sahin et al., 2018). Casas et al. (2012), presented an Augmented Reality mirror "*for teaching key developmental abilities for individuals with ASD*" (Casas et al., 2012). Gelsomini et al. (2017) also published a set of guidelines to design a robot companion for children with disabilities and these are divided into two categories, the robot's role played when interacting with children, and its features. The former is represented by its feedback, its role as facilitator, prompter, restrictor, emulator, social mediator, affective and emotional agent. The robot's features consist of appearance, multimodality, multisensoriality, and configurability. However, this approach of using robots to facilitate human-human interactions might exacerbate human disconnectedness and reflect a view of autism that compares autistic people to machines rather than seeing them as humans[10]. Furthermore, some of these studies have a corrective tendency i.e. coaching and teaching, that this PhD research does not follow.

[10] https://www.wired.co.uk/article/autisim-children-treatment-robots

This PhD work proposes a different approach from the aforementioned studies in that it moves away from supporting developmental and educative goals or specific skills. This research considers the challenges with representation and abstraction of thoughts faced by autistic children and addresses the sensory processing and self-regulation challenges experienced by autistic children in social activities and contexts. Instead of having multiple individual sensor inputs connected wirelessly, as in e.g. Soundbeam and Cosmo the two tangible technologies built for this PhD aim to afford shareability and appropriation.

2.8 Developments in HCI: more human than computers

To better understand how playful tangible interactive technologies could be designed for autistic children it is useful to first understand the history of Human-Computer Interaction (HCI) and its trends. Human-Computer Interaction has its roots in human factors and ergonomics. The three paradigms, so-called the three influential waves of HCI, have informed the field of HCI (Harrison et al., 2007).

The first wave lasted from around the late 1960s to sometimes in the early 90s and was concerned with understanding how to fit together the human and the machines. Researchers became concerned with developing measures to understand the human performance (Fitt's Law) and the ergonomic of things, and the machines required very specialised and technical people. The introduction of the first computers did not incorporate any User Interface, as these were used in batch mode with punched-card input and line-printer output. The second wave or paradigm (from the 1970s to around the beginning of the 21st century), was concerned with aspects of cognitive science and the mind of the user. The challenge around this time was to understand how the human mind processes and perceives information. Around 1983 the human mind and the computer were considered parallel systems - and the model human processor - was born. *"The Model Human Processor was an early cognitive engineering model intended to help developers apply principles from cognitive psychology"* (Carroll, 2012). The PC became available to millions of people and the focus shifted from the tasks to the context of the interaction, which at that time was the workplace. The Lisa Macintosh released in 1984, was the first popularized and successful product to use the graphical user interface (GUI) text editor. The very basic graphic visual feedback of the first GUI, even if monochrome, made the machine more appealing than ever as *"from the point of view of the user, the interface is the system."* (Norman and Draper, 1986).

It was becoming increasingly recognized, above a minimum threshold of functionality and performance, that one of the most important factors of an application's success was its 'user-friendliness', both for experienced users and for new users. The third wave of HCI, began across the '80s and the '90s when designers and *cognitive engineers* started to recognise the importance of aesthetical qualities and emotions as central to the interaction with technological artefacts (as much as their functionality and usability). Product usability has often tended to underestimate traditional cognitive approaches, segmenting an understanding of the user experience from the way we perceive the world. Consequently, in response to the flood of new computer scenarios, the desire for a more powerful, persuasive user experience than that available with graphical user interfaces (GUI) and the related WIMP implementations (windows, icons, menus, pointing devices), was growing increasingly.

Technological advancement then made it possible for computers to become mobile and ever-present in different aspects of life not necessarily work-related (Weiser, 1999). Frauenberger (2019) recently expanded the current paradigms of HCI introducing a new and fourth wave to the existing three - entanglement. Entanglement acknowledges the intimate relation that today people develop with current technologies and the ontological "*interrelationship that humans have with their tools*"[11]. This fourth wave clearly distances itself from a user-centred design approach and emphasises the importance of moving beyond users and toward designing for the relationships with the things we create.

2.8.1 User-centred design

User-centred design (UCD) focuses on understanding the user and the context in which the technology is deployed, and it is an iterative process that aims to incorporate principles of human *inter*actions within the development of the systems in order to address the user's need and goals. In the past two decades the term UCD has often been criticised (Gasson, 2003; Buchanan 2001) and replaced with the term human-centred design (HCD). In 'The Inmates are Running the Asylum', Alan

[11] https://frauenberger.name/research/entanglement-hci

Cooper (1999) talked about personas as representing the user "*and what he wishes to accomplish*". Personas are fictional characters that have a face, a name, goals, and needs and are based on a collection of data about real and/or potential users (Blomkvist, 2002). The term user is more often considered a generic terminology that is de-humanising the people using the systems (Baron-Choen, 2011).

Norman coined the term user-centred design (UCD) around 1986, and explained it as a design method focused on designing for the users of the systems that enables a good understanding of the people that use the systems (Norman and Draper, 1986). Furthermore, UCD aims to develop systems that are pleasant to use (Norman and Draper, 1986), but paradoxically, it does so without acknowledging the aesthetical qualities or the emotional values of technological interfaces. In UCD, researchers and designers use a mix of methods and tools such as investigative (e.g., case studies, ethnography, contextual design, video-analysis, survey, observations, interviews, usability testing, participatory design) and generative ones (e.g., contextual inquiry, brainstorming, card sorting, participatory design). Generative research is used to generate information about the user(s) while investigative research is used to evaluate and assess (aspects of) interfaces.

The process of UCD consists of four main steps: understanding the context of use, user requirements, design, and evaluation[12]. These steps, which are not unique to UCD, are often called lifecycles and different models are used to identify each phase of the design process and how they relate to one another. A variety of lifecycle models are one-directional (e.g. that follow a sequential progression of steps), such as the waterfall lifecycle and the star lifecycles. By contrast, UCD adopts an iterative lifecycle model where system specifications are constantly refined around the needs of the user and "*the requirements, design, implementation, and evaluation phases are repeated [..] adding depth and complexity during each iteration*" (Hourcade, 2015).

In this PhD, the UCD process and iterative lifecycles have inspired the design process of the three studies (see chapter 3.3).

2.8.2 Experience-centred design

One of the major critiques that Norman received was that UCD is an overly reductive approach, preoccupied mainly with issues related to utility, usability, and

[12] https://www.interaction-design.org/literature/topics/user-centered-design

functionality, above those related to emotions and aesthetics (Spillers, 2004). Norman acknowledged the importance of aesthetical enjoyment and emotional values when interacting with technology almost 20 years after his first book on 'User-Centred System Design', in a new book called 'Emotional Design' (Norman, 2004). In this book Norman (2004) admitted that in the past he prioritised form, usability and function over beauty and pleasure because he thought "*the topic of aesthetics was well-covered elsewhere*". He suggested that segmenting the two domains, usability, and functionality vs the aesthetical and emotional ones, needed not happen insofar as attractive interfaces work better if they value all of them (Norman, 2004). *"The seeds were sewn for a new conception of user-centred design focusing on the experience of people living with technology and not just using it"* (Wright and McCarthy, 2010).

Blythe et al. (2003) claimed that usability is just one aspect of designing user-centred systems and that the emphasis of designing for work and task-oriented products should shift towards leisure and entertainment as the difference between usability and users desires became increasingly blurred. McCarthy and Wright (2004) abolished the idea that mind, emotions, and body were separated entities and suggested a holistic view of experience highlighting the interplay between emotions, actions, and motivation. Instead of focusing on increasing productivity, the aim shifted to that of enhancing the user experience. This concept laid then the foundation to user-experience design guidelines, sensible to the lived and felt experiences of the people affected by the technology. The book defines a clear connection between expectations/anticipation and past/present experiences, and the authors talk not only of personal experiences but "*from other people's points of view*" too (Wright and McCarthy, 2010). Experience-centred design recognises that designers should not just be just observers, but rather active participants. They "*bring their own ways of seeing, values, sensibilities, and interests to the design process*" (Wright and McCarthy, 2010). A key point for Wright and McCarthy (2010) lays within the designer's empathetic values. Spiel et al. (2013) instead, claimed that empathic approaches are limited with autistic children if used alone, and assessment of children's experiences should come from a multitude of data points and sources and consider "*that autistic children contribute to the construction of the experience as well*".

In order to overcompensate some of the limitations of the UCD approach, this PhD research borrows values of experience centred design (ECD) (McCarthy and Wright, 2004; Wright et al., 2008; Wright and McCarthy, 2010) and ludic design (Beyer and Holtzblatt, 1997; Holtzblatt and Jones, 1995). These approaches enable a situated understanding of people's experiences when using technologies and emphasise the importance of playfulness. However as advocated by Spiel at el. (2013) the researcher is aware that autistic children often experience the world differently from neurotypical people, and being neurotypical herself, she proposes a novel holistic approach for both the design and assessment of playful TUIs for autistic children. This is particularly suited to scaffold and assess non-verbal interactions by exploring novel materials properties and affordances, and using mixed approaches and multiple viewpoints.

2.8.3 Ludic and Open Design

In *Designing for Homo Ludens,* William Gaver proposed the first idea of ludic design (LD) by opposing the view that technologies "*provide clear, efficient solutions to practical problems*" (Gaver, 2002). His guidelines for LD were that designers need to:

1) Be engaged with the end-user of the artefact in order to balance their personal experience to that of the "*people whom they are designing*" for.
2) Enable appropriation of technology by adopting 2 tactics:
   a) creating suggestive media that "*are designed to encourage or impel ludic activity, and media in that they are tools through which people experience, create, or communicate freely"* and
   b) leave space for ambiguity because "*it allows people to find their own meaning in uncertain situations. Used in design processes, concepts and products, ambiguity gives space for people to intermesh their own stories with those hinted at by technologies*"
3) Design for pleasure. Designers "*should be provocateurs, seeking out new possibilities for play and crafting technologies that entice people to explore them. In the end, designers themselves need to be Homo Ludens*" (Gaver, 2002).

Other researchers have highlighted the importance of designing for fun and outlined the relationship that exists between fun factors, empowerment, engagement, and participation (Blythe et al., 2003). By introducing the concept of ambiguity into the design domain, Gaver disrupted the general utilitarian view of technology that existed within the HCI community and opened up new possibilities for design explorations (Gaver et al., 2003). For example, the Drift Table (Gaver, 2004) was an "*object of inquiry*" (Dow et al., 2012) and it was a provocative tangible design that didn't have a commercial scope but rather it was made for creating new understanding and knowledge around ludic activities in the house. Developed by Gaver et al. (2004) the Drift Table was a coffee table designed for home entertainment and ludic purposes "*motivated by curiosity, exploration, and reflection rather than externally defined tasks*" (Ibid).

This design-oriented approach, referred to as Research Through Design (Zimmerman et al., 2010; Dow et al., 2012) helped designers to learn about aspects of human experiences that looked beyond usability and functionality aspects, such as curiosity and reflection. LD was particularly relevant at the time because technologies began to support activities outside of the workplace. In Opera Aperta, Eco (1997) emphasized the concept of ambiguity as "*una delle finalità esplicite dell'opera, un valore da realizzare a preferenza di altri* [one of the explicit purposes of the work, a value to be achieved in preference of others]". Ambiguity therefore allows artefacts to be open and enables freedom and a multiplicity of interpretation. For Eco (1997) "*The work of art is a fundamentally ambiguous message, a plurality of meanings that coexist in a single signifier*" and it consists of "*dialogues between form and openness*".

Interestingly, Baudelaire (1853) argued that toys are "*the child's earliest initiation into art, or rather it is the first concrete example of art*" (Baudelaire, 1853). The Open Work therefore opens up the design space of e.g. interactive toys to be considered not as finished products but rather as an art form that is open to interpretations and appropriations and completed by the people that interact with it. Drawing from Duchamp's ideas of the 'unfinished work' of art, Eco blurred the meaning of artists and audience, designers and users, and emphasised the equal importance played by audience and users in participating to the completion of the piece (Monteverdi & Balzola, 2004). Similar to Raffle and colleagues (Raffle et al., 2004) this research considers playful TUIs for children to be 'enhanced toys', which consequently become a work of 'interactive art' that extends beyond museum exhibits and into children's daily scholastic activities.

2.9 Child-Computer Interaction (CCI)

In the book 'Child Computer Interaction' Hourcade (2015), refers to the academic field of Child-Computer Interaction (CCI) as "*the study of the design, evaluation, and implementation of interactive computer systems for children, and the wider impact of technology on children and society*". CCI as a field of research first began with the work of Papert, in 1980 (Papert, 1980), who emphasised how teaching children to use computers and programming languages could be beneficial to their understanding of the systems and their cognitive development (Read and Bekker, 2011). In 1996, Druin led the field of HCI to broaden up its scope by inviting the Association of Computing Machinery (ACM) to consider children an important part of the CHI conference's discussion and developed the Chi-kids community as part of the ACM SigChi (Druin, 1996). Child-Computer Interaction and Interaction Design for Children are terms often used interchangeably within the HCI community (Read and Bekker, 2011). The Interaction Design for Children Conference (IDC) began in Europe in 2003 (Bekker et al., 2003) and has since then become an annual event and a specialised area of research distinct from HCI. Read et al. (2008) highlighted that CCI is "*different from HCI*" and that it has "*different priorities and different methods*" (Read et al., 2008).

2.9.1 Child-Computer Interaction (CCI): overview of research methods

In CCI researchers developed a more Child-Centred Design approach similar to user-centred design, which focuses on children as the main users (Pardo et al., 2005) instead of adults. A child-centred approach was needed as children have different needs and abilities than adults (Kelly et al., 2006). For example, children and pre-adolescents have different levels of experience than adults and might struggle to understand and explain abstract concepts. Moreover, children as they grow master their use of language as an efficient communicative tool, therefore it might be difficult for them to clearly express themselves or to understand others. Furthermore, children's expectations might be different than those of adults. Another challenge when designing technologies with and for children, regards the interpretative skills of the researchers and how information gets translated into design ideas (Frauenberger et al., 2012). Frauenberger et al. (2012) developed a mindful interpretation approach based on a phenomenological perspective to children's interpretation that serves as an inspiration to design solutions that are "*faithful*" to children's input (Frauenberger et al., 2012).

A technique used in child-centred design is the child-persona technique which, similarly to personas in UCD, helps designers creating abstractions or archetypes of children "*when participatory design practices are limited or impossible due to policy, legal or ethical reasons*" (Markopoulos & Read, 2008). The Child-persona framework, introduced for the first time by Antle (2008), is based on theories from psychology that are translated into concepts for interaction design and create a narrative based on children's needs, developmental abilities, and experiential goals. Data collection approaches in child-persona often use tools such as observations and interviews. However, child informant-based tools, in which children are asked to validate persona as a design tool during design sessions, are also used to complete missing information about the children (Antle, 2008).

As explained in Tsvyatkova & Storni (2019) the methodologies often used in CCI are of three kinds and include user-centred design (UCD), learner-centred design (LCD), and participatory design (PD). Learner-centred design is "*an approach for designing various educational technologies and effective learning environments in order to support the needs of learners at different ages*" (Tsvyatkova, & Storni, 2019). As LCD is a curriculum-focused method that does not value free play, and, as play is not an activity highly valued in current UK schools' curriculums, or it is thought to children following neurotypical ways of play, the LCD approach is the less discussed here because outside of the scope of this PhD.

Each methodology uses approaches which sometimes cross over methods. For example, aside from child-personas, which are used as both a generative and investigative tool (Antle, 2008), other approaches also used within the UCD approach often include a) user experience evaluation, which helps to evaluate how children interact with a system and their emotional experiences (Zaman and Abeele, 2010; Xu et al., 2009), b) usability evaluations, which focusses on the efficiency of a system and its learnability (Hanna et al., 1997; Markopoulos and Bekker, 2003; Donker & Reitsma, 2004) and c) ethnography, which studies people and cultures in situated contexts (Falcão et al., 2012; Ringland, 2020).

In PD, on the other hand the most used approaches include cooperative inquiry, which is defined as a design-centred learning approach and incorporates the child in the design process by often asking them questions (Druin, 1999; Colombo et al., 2004; Yip et al., 2013), cooperative evaluation, which includes children as team partners in the evaluation process (Monk et al., 1993), and fictional inquiry, which aims to bypass traditional socio-cultural structures to reframe the context of meaning-making (Dindler & Iversen, 2007). A similar approach to the child-personas, that uses informant sessions is the Bluebells, which is defined as a balance between child-centred and expert design (Kelly et al., 2006), and it's often used by designers to gather more information about certain aspects of a system usually concerned with its look and feel. Bluebells is divided into a set of activities which the authors define as before play (adult activity), during play (children's activities), and after play (adult activity) (Kelly et al., 2006). A different approach sometimes used in PD is the IDEAS, which, similarly to the three studies developed for this PhD, encompasses evidence-based approaches such as the TEACCH (see Chapter 3.2, for details on TEACCH) to provide structured support in to the PD process (Benton et al., 2012).

Within the field of CCI, child-centred design researchers use techniques such as the **think-aloud** protocol, which consists of participants speaking while going through evaluating a system (Als et al., 2005; Baauw & Markopoulous, 2004; Donker & Reitsma, 2004); **thematic analysis**, which allows researchers to find recurring themes in written text - often transcribed from verbal conversations (Read et al., 2018; Badillo-Urquiola et al., 2019); **video analysis**, which enables researchers an in-depth post-study analysis of children's interaction (Antle et al., 2009; Almjally et al., 2020; Bhattacharya et al., 2015); **surveys**, which are "*a systematic method for gathering information from (a sample of) entities for the purpose of constructing quantitative descriptors of the attributes of the larger population of which the entities are members*" (Jansen, 2010) and can be done either online or in-person and can be open or pre-structured (Horton et al., 2019; Allsop et al., 2011; Read, & MacFarlane, 2006; McNally et al., 2017), and **observations**, which are done by looking at children in a specific context while carrying out daily activities (Donker and Reitsma, 2004). Observations often include notes taking in the form of written text and/or drawings and allow researchers and designers to gain an in-depth understanding of children in their natural environment (Montessori, 1912; Garfinkel, 1996).

For example, Donker and Reitsma (2004) discussed the usability of educational software aimed at teaching reading skills based on two kinds of data collection used in usability testing such as observations and think-aloud protocol. They reported the observations to be "*especially useful to determine the presence of anticipated problems, while talk aloud provided information about the importance of these problems and about problems that were not anticipated*" (Donker and Reitsma, 2004). More recently Read et al. (2018) used thematic analysis to evaluate a study focussed on the 'at home' experiences of parents and children using tablet games. Families were sent a diary at home that they were requested to complete weekly, and in which they "*recounted activity with digital game technology, culminating in an interview in the family home*" (Read et al., 2018). The collected data was then analysed using four codes found from the "*first rapid examination of the data and from the research questions*".

Almjally et al. (2020) on the other hand recently conducted a video analysis to investigate children's spontaneous gestures when programming TUIs and GUIs. The authors video recorded, and subsequently analysed, the engagement of 34 participants in a learning activity while using a TUI and a GUI. The videos were coded using the ELAN software and the authors created the coding scheme by adopting a taxonomy inspired by mathematics' gestures to explore the children's use of spontaneous gestures when learning programming languages.

Ringland (2020) proposed an online ethnography study of the Autcraft community - a semi-private server for autistic children, where she highlighted the potentials of the system as giving the "*children the options of embodied experiences they need to access social play*" and stressed that "*these spaces, though some of them are digital, are no more or less "real" than the physical spaces making up a schoolyard or playground*". The author talks of Autcraft as a "*playground that is more comfortable for many autistic children"* (Ringland, 2020). The research however, considers this view particularly problematic in many ways. First, not all children have access to a computer. This was recently highlighted by the COVID-19 pandemic which has shown how the digital divide is still a major challenge around the world. Second, digital and virtual experiences could yes be considered real experiences, but they do not automatically translate to real-world situations and contexts. Moreover, Autcraft lacks the many sensory stimulations afforded by real life. The view that

Autcraft is a "*playground that is more comfortable for many autistic children*" seems to resonate with Milton's criticism on what is often incorrectly understood about autism "*that autistic people are somehow less than human, animalistic or machine like, only capable of compiling and broadcasting strings of information*"[13], hence, incapable of carrying out real-world relationships.

However, among the most common generative and investigative approaches of the past decade, PD and Co-Design are the most prevalent (Van Mechelen et al., 2015; Garzotto & Gonella 2011; Bell & Davis 2016; Barendreg et al., 2016; Van Mechelen et al., 2019; Landry et al., 2012; Fitton et al., 2019; Read et al., 2014; McNally et al., 2017; Horton et al., 2012) - especially with neurodivergent and disabled children (Constantin et al., 2019; Cullen & Metatla, 2019; Frauenberger et al., 2017; Constantin et al., 2020; Brulé et al., 2019; Spiel et al., 2017; Malinverni et al., 2014; Gaudion et al., 2015; Frauenberger et al., 2011).

2.9.1.1 CCI and children's participation

Druin (2002) classified children's involvement in the design process in four categories: **users**, **testers**, **informants** or **design partners**.

Children can be **users** at the start and at the end of the design processes by being observed by researchers to better understand children's preferences, dislikes, likes, triggers, needs and abilities. Children involved in the design as **testers** instead, usually do so iteratively and test low-fidelity to high-fidelity prototypes but also finished products. However, testing at a later stage is most common with children (Hourcade, 2015). A common technique used at early prototyping phases when testing technologies is the Wizard of Oz, where adults control the response given by the technology unbeknownst to the child who's testing. As **informant**, children also participate when acting as consultants "*making their contributions at key points of the design process*" (Hourcade, 2015). For example, Brederode (2005) found that children's focus groups, interviews and questionnaires are often approaches used to voice children's opinions (Read et al., 2004) both for designing and evaluating technology. Finally, considering children as **design partners** (Druin 1999, Druin 2002; Guha et al., 2013) means that they act as equal partners within the design team in each phase of the design process, from finding requirements to evaluating the

[13] https://www.wired.co.uk/article/autisim-children-treatment-robots

technology, and it is an approach closely related to PD and Co-Design (Guha et al., 2005).

Aside from work developed by (Wilson et al. 2019) PD approaches heavily relies upon being verbal, either through speaking to participants and stakeholders and/or by asking them to speak out and externalise their likes, emotions, experiences, needs and ideas. For example, Frauenberger et al. (2017) described some of the PD approaches that designers could use with autistic children. These included brainstorming sessions, interviews, collage, low-tech prototyping, fictional inquiry, contextual mapping, and co-operative inquiry. The study of Mia, an 8-year-old autistic girl who participated in the different phases of the design process, explores how "*different common design techniques e.g. brainstorming, mind mapping, research diaries for idea generation and low-tech prototyping for conceptualisation*" could be used in PD with autistic children. Worryingly, all these methods require children to speak. For those researchers whose work focus on non-verbal autistic children such as Perés et al. (2005) groups of 'high functioning' children who could "*give verbal feedback*" were invited as part of the design team to be sure that "*the design decisions were on the right track*" (Perés et al., 2005).

Evidence-based approaches such as the SCERTS (Alcorn et al., 2013; Frauenberger et al., 2012) and the TEACCH (Rao & Gagie, 2006; Marwecki et al., 2013; Benton et al., 2012) have been used in combination with PD to evaluate the impact of technologies on autistic children's experiences and interactions. For example, aside from Benton et al. (2014), which as briefly introduced above, adopted the TEACCH to inform PD approaches e.g. for structuring the environment and providing additional support, Porayska-Pomsta et al. (2010) used SCERTS in combination with PD approaches "*to inform the delivery on enjoyable experiences within the ECHOES environment*". ECHOES is a tool for learning for 5 to 7 years old children – a technology-enhanced learning (TEL) environment. Bernardini et al. (2014) explained that SCERTS was used in the ECHOES to inform the design of a virtual agent that acted as a social partner to children with 'high functioning autism', and its use aimed to optimise the interaction style of the agent.

In contrast to Porayska-Pomsta et al. (2010) and Benton et al. (2014), who used the SCERTS model and the TEACCH approach to the design the social partner behaviours of a virtual agent or to inform Participatory Design approaches, this PhD research uses them to inform the design of the studies presented in the following chapters, the framework for analysis and the design of the artefacts created.

2.10 Tangible User Interfaces

As seen in section 2.3.3.1 tangible and manipulative interactions intrinsically possess cognitive, and physical learning attributes that promote and scaffold many aspects of child development and wellbeing. Therefore, it is important to understand how interface development moved away from GUI development and the WIMP archetype and became concerned with physical interfaces for children.

Over the last decades, interaction designers have broken out of the traditional approach of using keyboard-screen-mouse when interacting with computers opting toward using the full range of human perception modalities (Shaer and Hornecker, 2009). In the mid ‘90s, the development of the first Tangible User Interfaces saw a fertile ground in the attempts to move toward ubiquitous computing and Augmented Reality. The term 'Tangible Interaction' (Hornecker and Burr, 2006) has come to embrace many of the developments that emphasize:

- Tangible manipulation
- Social interaction
- Embodied facilitation
- Expressive representation

Tangible User Interfaces (Ishii and Ullmer, 1997) encompassing HCI approaches, were initially envisioned as an alternative to common Graphics User Interfaces (GUI) that would bring a more intuitive, accessible, and less restrictive interaction more akin to human-human interaction. At the same time, they sought to augment the user sense of satisfaction and control over the instrument both virtually and physically without having to limit the natural wide range of human expressions.

Therefore, there was a shift from a click-and-type or mouse-based interactions, to one where tangible interface don’t just controlled digital data but also represented and modified them in the physical world through embodied interactions. Distancing his work from the GUI paradigm, defined as ‘painted bits’, Ishii coined the term ‘tangible bits’ (Ishii and Ullmer, 1997) which represented the possibility of interacting with the digital world (the bits) in the physical world (the tangible) and within less constrained interaction modalities. Tangible Embodied Interaction became an established field of research and part of the ACM International Conference proceedings TEI since 2007. Around 2012, Hiroshi's vision of 'tangible bits' (Ishii et al., 2012) expanded further into the realm of 'radical atoms' whereby TUIs become context-aware. This emphasised the hackable aspects of the materials used to make physical objects as they could be synchronised with computational models; interaction became bidirectional.

2.10.1 TUIs frameworks

While the field of TUIs established itself, many frameworks and taxonomies were developed (Shaer and Hornecker, 2009) on TUIs which followed different approaches. Among these we find the coupling of physical and digital interactions (Ullmer and Ishii, 2001; Holmquist et al. 1999; Fishkin 2004); sensor-based interactions (Bellotti et al. 2002; Rogers and Muller, 2006); tangible interactions (Hornecker and Buur, 2006); and domain specific e.g. tangibles for learning (Marshall, 2007; Antle et al. 2007; Price, 2013). For example, Zukerman's framework on digital manipulatives (2005) aimed at "*thinking about tangible interfaces in education with specific focus on abstract problem domains*" (Ibid). Not long after, Marshall (2007) proposed an analytic framework for the use of tangible interfaces to enhance learning activities. Antle et al. (2007) developed the Child Tangible Interaction (CTI) framework based on theories of cognition and learning and divided it into 5 main high-level themes concerned with: 1) **space for action** (where action "*affects computation*"), 2) **perceptual mapping** (which explores the relationship between physical properties and digital aspects), 3) **behavioural mapping** (which relies on the children's view of causation), 4) **semantic mapping** (which considers the representational meaning of objects into digital aspects) and 5) **space for friends** (concerned with the embodied characteristics of tangibles and their affordances for multiple users interaction modalities).

On the other hand, Hornecker and Buur (2006) developed their framework on tangible interactions to facilitate a better understanding of the social aspects as well as the interaction's experience offered by TUIs. The framework is based around 4 themes such as **tangible manipulation**, which refers to the tactile qualities of TUIs and their physical manipulation properties, **spatial interactions**, which refers to the situatedness of tangible interaction within a real space and through movements in space, **embodied facilitation**, which is related to the spatial and object configuration of TUIs and how this can enable group behaviours, and **expressive representation**, which refers to the "*expressiveness and legibility*" of TUIs (Hornecker and Buur, 2006). Hornecker and Buur's work on tangible interactions (Ibid) contributed to the bigger research agenda on embodied interaction (Dourish, 2001 a).

Dourish (2001 a) emphasised that the properties of tangible computing and social computing are part of embodiment. The concept of embodied interaction reflects different trends that have recently emerged in HCI, such as tangible computing (Ishii et al., 2012) and tangible interactions. For Dourish tangible computing exploits our physical and tactile skills, while social computing is based on the relationship of action and context (Dourish, 2001 b). He emphasised the concrete, physical and socially situated aspects of tangible computing, and extended the concept of context-aware interaction beyond Ishii's definition of bidirectional transformation/deformation between computer and human, to TUIs that play a critical role in shaping actions.

The work developed in this thesis sits between these two main approaches to TUIs development - embodied interaction (Dourish, 2001 a; 2001 b) and tangible interactions (Hornecker and Buur, 2006), and focus on the social and physical implications that derives from interacting with tangible objects.

2.10.2 TUIs as a way to enhance work practices

One of the first uses of TUIs was to literally represent physical objects to control digital information. For example, TUIs were designed as a physical representation of digital landscapes, environments or architectural elements. One of the first examples of 'tangible bits' was the 'metaDesk' project, envisioned as an augmentation of the GUI interaction paradigm by adopting similar metaphors into real physical objects (Ishii and Ullmer 1997). The metaDesk system, which consisted of a flat surface illuminated from the back via video projections representing specific landmarks such as those found at the MIT campus i.e. the Media Lab and the MIT dome, was used in combination with physical objects (phicons) and lenses, and with the Geospace application (Ishii and Ullmer 1997). The Geospace app represented a 2D map of the MIT campus which could be visited in 3D mode by moving an 'active lense' (a physically embodied screen) above the 2D landmarks. Physical icons such as a physical object representing the dome of the MIT campus, could be placed onto the 2D map to reposition its view (as this was bound to the position of its physical model). By adding a second icon and manipulating the physical objects, the 2D visual representation of the map on the desk could be zoomed and moved around accordingly.

Similarly, in an attempt to move away from the GUI-metaphors, the Urp project (Underkoffler and Ishii 1999) offered direct control and manipulation of digital info via controlling and manipulating physical objects in real world interactions. The Urp was envisioned to help urban planners design better environments. In the Urp system (Underkoffler and Ishii 1999), digital architectural elements and the simulation of urban environment are made tangible by placing physical prototypes of architectural buildings onto a flat surface to control and modify a) the position of the sun over them, hence to understand how to best design buildings based on the shadows projected on their surroundings (via video projections over the physical designs of these buildings), b) the reflections of the lights throughout the day onto these buildings, c) the blowing of the wind and the d) traffic congestions. By changing the spatial relationship of the buildings, the user could rotate them to emulate the position of the sun, the speed and direction of the wind, the impact of the lights on these buildings and the surrounding traffic to understand more intuitively how these factors impact urban planning.

Prior to the metaDesk and the Urp projects, however, to further explore how tangible interactions could move away from the WIMP paradigm and be integrated within real life objects the Marble answering machine, developed by Bishop in 1992 and described by Crampton (1995), aimed to do just that. The marble answering machine enabled a person to interact with different marbles to activate an answering machine and to control the incoming and outgoing telephone calls. This was one of the first conceptual explorations of the use of tangible user interfaces.

However, these tangible interactions were still constrained by the fixed forms of the physical objects they represented and the environments they interacted within. Sandscape (Ishii et al., 2004), for example, was a type of TUI that offered a more dynamic kind of ‘organic’ tangible interactions by enabling users to change dynamically the form of a landscape through altering the terrain to simulate height, slopes, shadows and other aspects of digital landscape modelling. These simulations were then projected onto the sand model to represent the effect of the computational analysis generated by interacting with the sand.

2.10.3 TUIs for collaborative work and social interactions

2.10.3.1 TUIs and collaborative work

Since they were first envisioned, TUI were exploited for their inherent qualities to support direct manipulation in collaborative interaction between people and digital data (Brave et al., 1998). At first TUIs were mainly developed as tabletop tangible interactions, desk or board interactions and interactive displays, hence were still designed around few parameters of the WIMP paradigm such as window and icons. These allowed interaction between people through the spatial organization of data, bi-manual interactions and "*ease of collaboration between collocated users*" (Pangaro, J., et al. 2003) and by encouraging simultaneous multi-users interactions. Waldner, et al. (2006) proposed a set of design guidelines for collaborative tangible tabletop's interactions (Ibid) which included:

a) The affordance of the tangible interfaces, which had to suggest how these could be used
b) The differentiation of the tangibles, which needed to be reflected in the different functions they carried out
c) The possibility to offer parallel inputs to enable both collaborative and independent interactions
d) The ability to offer interactions that replicated or mimicked natural human interactions.

However, although they offered a more natural way to interact, control, and manipulate data using two hands and multiple inputs, this modality of interaction through tabletops was still limited by the inability of computers to act or output information through changing the states of the tangible objects in use. Basically, computers could 'answer back' just by displaying outputs through visual and/or sounds, hence they behaved passively (Ishii, 2008).

Therefore, the 'actuated workbench' (Pangaro, et al. 2002) aimed at tackling this issue by using an array of electromagnets coupled with a software interface that could be moved around a tabletop surface by the computer. This novel modality of interaction aimed to "*provide real-time physical synchronization of two tabletop interfaces for remote collaboration*" (Pangaro, et al. 2002). In fact, TUIs could support not just co-located interactions, but they also facilitated remote collaborations. By applying the ‘actuated workbench’ technology to the ‘Urp’ scenario Ishii made it possible to *“have two distributed Urp tables in different locations, connected and synchronized over the Internet*” (Ishii, 2008) allowing “*both teams to discuss changes to the situation in realtime*” while providing “*a common reference for otherwise ethereal qualities such as wind, time, and shadows*” (Ibid).

A further generation of TUIs, which falls under the concept of ‘radical atoms’ (Ishii et al., 2012), expanded the ‘tangible bits’ concept and paradigm, to a new type of interaction, by proposing TUIs that can transform their physical characteristics and thus escape the constraints of passive and rigid physical objects. InFORM (CHI 2013) is one of the first examples of such TUIs - a dynamic display or computational surface, which moves more than 50 pins up and down to simulate pixel reconfiguration and facilitate remote collaboration between people. This collaboration was created by interacting with a shared digital object via gestures synchronised through remote technologies, and by using a screen placed perpendicularly at the end of the grid system where users were made visible to each other giving them the illusion of telepresence.

2.10.3.2 TUIs and social interactions

However, when designing systems aimed at groups of people in collocated spaces, to facilitate socialization, and to enable the same rights of participation around a technological device, Hornecker et al. (2007) suggest addressing the principle of **shareability**. As explained by the authors, central to the notion of shareability is the concept of **entry** and **access points**, where the former “*invite and entice people into engagement*” and the latter enables “*users to join a group’s activity, allowing perceptual and manipulative access and fluidity of sharing*” (Ibid). **Entry** points allow people to plan their approach by providing an *overview* of the system and entice them with a point of attraction or *honey pot effect* aimed at stimulating active interest and *minimize barriers to access.* **Access** points refer to characteristics that enable a group activity to happen i.e. afforded by a combination of *perceptual access* (enabling social awareness), *manipulative access* (enabling active interaction), and *fluidity of sharing* (enabling easy flow of interaction). Moreover, there are controversial findings on whether the size of a device positively affect socialization and collaboration (Andrews et al., 2010, Zagermann et al., 2016), but it's agreed that a shared overview facilitates collaborative intents (Brudy et al., 2018).

Rogers et al. (2009) and Marshall et al. (2007) demonstrated that tangible interactions might offer more equal opportunities than screen-based devices. Harris et al. (2009) noted that multi-touch interfaces offered more opportunities for collaborative interactions between children than single-touch ones. Similarly, Rogers et al. (2009) highlighted that a single-input technology constrained participation, while Marshall et al. (2009) emphasised how a limited number of access points could lead to competitive access. Marshall et al. (2009) explored "*how children fight for and maintain control of physical versus digital objects in terms of embodied interaction and what this means when designing collaborative applications for shareable interfaces*". They found that children were a bit more 'forceful' when using multi-touch tabletop interfaces than physical interfaces. This was exhibited by "*arm shielding*" and "*flapping arms*" or by raising the objects to avoid other children to touch them and interfere with their contributions (Marshall et al., 2009). Interestingly, they demonstrated how the "*physical and interactive properties of an interface or object can interact with the structure and orientation of children's bodies when they are competing for access*" (Ibid). These works indicate that the configuration of space and the physical properties of objects might influence interactions both with the and between people (Hornecker and Burr, 2006; Dourish, 2001 a).

Some researchers within the HCI community have exploited the principles of shareability in multi-touch displays (Xambó et al., 2017; Jacucci et al., 2010; Harris et al., 2009; Marshall et al., 2008) and urban games (Laureyssens et al., 2014) or in museums exhibits (Hornecker, 2010). Rarely have these principles been applied to technology for children (Marshall et al., 2009). For example, Xambó et al. (2017) tested a tabletop collaborative music interface combined with tangible artefacts called Reactable with groups of adults and children in a public setting such as a science and technology centre in the UK. In their paper they explored the access points aspect of shareability as "*components that both invite visitors to interact with an artefact by providing visibility and advanced information, and, at the same time, allow visitors active engagement with the artefact*" (Xambó et al., 2017). To the researcher's knowledge, no prior research explored the concept of shareability, ambiguity and openness to develop non-screen based playful TUIs that support self-regulation and playful experiences friendly to neurodivergent children.

2.10.4 TUIs as educational toys

The incidental properties of tangible interaction and their benefit for learning and development through physical exploration and direct manipulation have been explored extensively well before the invention of computers. As seen in (2.3.3.1) at the cross of the 19^{th} and 20^{th} centuries the 'Froebel Gifts' (Froebel, 1859) and the 'Montessori materials' (Montessori, 1912) exploited the inherent qualities of physical object to scaffold children's learning experiences, and since the advent of computers many scholars have taken the analogue tangible interaction archetype into the digital world.

For example, Resnick et al., (1998) proposed a new kind of manipulative materials called 'digital manipulatives' and embedded computational abilities into children's toys such as "*blocks, beads, balls, and badge*". The aim was to facilitate children's comprehension of abstract concepts such as science and robotics (blocks), decentralised systems and emergent phenomena (beads), kinematics (balls), and ideas spreading and system simulations (badges). Since then, many TUIs for playful learning activities have been developed and studied to support a variety of skills such as literacy education (Frei et al., 2000; Sylla et al., 2015), programming and problem-solving skills (Raffle et al., 2004; Good, Howland, & Thackray, 2008; Howland, Good, & Nicholson, 2009; Horn et al., 2012; Almjally et al., 2020), and cognitive and motor skills (Kim, H., et al., 2016; Zuckerman et al., 2016; Mironcika et al., 2018). For instance, the 'Tern' system, was first envisioned to be used in the classroom in addition or as a replacement of computers and it used a series of augmented interlocking wooden blocks to teach children basic programming skills (Horn et al., 2012). Topobo (Raffle et al., 2004), one of the first commercially available construction toy with kinetic memory, was developed to enable children to understand programming and dynamic structures by combining passive and active components together to simulate biomorphic forms. A similar example to Topobo, but focused on literacy education, was 'Curlybot' (Frei et al., 2000), which was shaped as a curved semi-spherical small object and worked by recording and playing back the gestures that the user applied to it. The 'Tok' prototype on the other hand supported storytelling skills by enabling children to manipulate digital content through a set of 23 physical blocks (Sylla et al., 2015) combined with an electronic platform where the blocks were placed on to create narratives.

2.10.5 TUIs for music and performative arts

Alongside educational purposes for curriculum subjects, creative outputs such as music and performances were among the oldest applications of TUIs development as they enabled creative musical expression for both novices and expert musicians, adults and young children, one or many users. Applications for musical TUIs can be categorised in four main areas (Shaer and Hornecker, 2009) including musical instruments such as the 'reacTable' (Jordà et al., 2006), controllers such as the 'Squeezables' and the 'musicBottles' (Weinberg and Gan 2001; Ishii et al. 2001), sequencers such as the 'Tquencer' (Kaltenbrunner and Vetter, 2018) and sonic toys such as the Fisher's Price™ music table. For example, the Squeezables were built as a multi-user musical interface and allowed up to 3 users to play simultaneously using a set of six soft gels balls mounted on a table via strings by applying pressure and pulling them. Each ball represented and enabled the control of different musical parameters such as the arpeggio, the synth, the melody, the rhythm, the theremin and the voice. Jensenius and Voldund (2012) explored the ball metaphor to create musical instruments as a way to implement more natural designs which moved away from hard plastic materials.

The most famous tangible music interface, however, is perhaps the 'reacTable' (Jordà et al., 2006) developed by a team of luthiers from Barcelona. The 'reacTable' is based on a translucent tabletop display and physical artefacts that when placed onto the interactive surface enable multiple-users to create continuous sound outputs altered by the manipulation and the arrangement of the objects. "*Each of the objects has a dedicated function for the generation, modification or control of sound*" (Ibid). Since then, its interaction paradigm has been applied to a variety of applications such as interactive exhibits (Xambó et al., 2017, Hornecker, 2010), computer games (Laureyssens et al., 2014) and children' socialization (Viallafuerte et al., 2012). 'Musical Lego®' have also been explored to enhance children's musical expressivity even without prior musical knowledge (Jackobsen et al., 2016).

2.10.6 TUIs for play and leisure

TUIs have also been used as an inspiration for toy designs for entertainment and edutainment (Ryokai et al., 2004; Feltham, 2008; Gaver et al., 2004; Lampe and

Hinske, 2007; Raffle et al., 2004; Raffle et al., 2007; Petersen, 2007; Murer et al., 2013). For example, the I/O Brush (Ryokai et al., 2004), designed for children above 4 years, is an early example of playful TUIs for children which uses an augmented paint brush and the surrounding physical world as a colour and textures palette for novel art exploration. The brush detects also the movements of the user and it records the visual properties of the things it's pointed at which are then replicated in the digital canvas.

A further example of an augmented game is the Knights Castle (Lampe and Hinske, 2007), a Playmobil Knight's Empire Castle playset used as the basis to enrich children's pretend play by "*using background music, sound effects, verbal commentary of toys, and different forms of tactile and visual feedback in reaction to the children's play*". Van Huysduynen et al., (2016), explored of how a set of TUIs called 'MagicBuns', which used a combination of various feedback such as vibrations, sounds and colours, enabled different play behaviours between eight children in two age categories, 4 to 6 years and 10 to 12. In line with the literature, they found that younger children used the light modality the most and showed more parallel play and preferred one interaction modality and simpler rules, while older children used the TUIs to create more complex and social play activities and explored more interaction modalities such as the sound and vibration modalities, but also used the light or the physical shape of the TUIs to start off their games.

Playful TUIs have also been developed for adults - the 'Drift Table' was one example. Murer et al. (2013) instead proposed the design of LoLLio, an augmented lollipop which enables a tangible artefact to be used as a game controller while providing taste-based feedback. LoLLio explores a playful gustatory modality and was designed to enhance playful game experiences.

More recently, Frauenberger et al. (2020) and Scheepmaker, Frauenberger and spiel (2018) explored the process of designing "*social play things*" within a more inclusive setting. By collaborating with a group of verbal autistic children aged 7 to 12 in a mainstream school context they carried out a series of workshops which culminated with some insights for co-designing interactive objects with neurodiverse children (Frauenberger et al., 2020). These can be summarized as enabling children's control while balancing the complexity of interactions, providing the right balance between openness and structure through a process of modularity, manipulability, freedom with a frame, and layers, allowing solitary detours within the group context, and to interpret impulses from objects whether these were triggered voluntarily or not. Scheepmaker et al. (20018) defined playthings as boundary objects "*that are plastic enough to adapt to individual interpretations of playfulness and the constraints of the several co-players involved, yet robust enough to maintain a common or shared activity that is meaningful across players*" (Ibid, p. 459).

This PhD research echoes the work above but extends it further so that the concept of shareability is introduced and play becomes a socially engaging activity per se (Spiel and Gerling, 2020) rather than being elicited through a PD process and/or gamified design activities.

2.10.7 TUIs as a learning aid for SEN

TUIs therefore, provide the foundations for more inclusive design endeavours. For example, Hengeveld et al. (2008) developed an adaptable TUI called Linguabytes aimed at stimulating language for children with multiple conditions. The system was used during speech therapy sessions with children who had a developmental age of between 1 to 4 years and who had severe motor and cognitive impairments and it was reported to be most effective for those children who understood 2D representation. Farr et al. (2010) made a comparative study between neurotypical children and autistic children on the social effects of using the construction TUI Topobo vs a physical construction toy such as the Lego® during a playful activity. As we already saw, Topobo was made of assembling parts for building different creatures, while the physical toy consisted of Lego® pieces. The study demonstrated that within a structured task Topobo encouraged more parallel and collaborative play than solitary play when compared to the Lego® toys.

Research on playful TUIs for learning aimed at non-verbal autistic children with a high level of support needs mainly focus on screen-based devices (Silva et al., 2014; Sitdhisanguan et al., 2012; Winoto and Guan, 2016; Perés et al., 2005) and tablets (Sitdhisanguan et al., 2012). For instance, Sitdhisanguan et al. (2012) tested a computer-based training system for 'low-functioning' autistic children using different interactions styles; two Window Icon Menu Pointing Device (WIMP) based systems, consisting of a computer and a mouse pointing device and a computer touch-screen, and a TUI-based system consisting of a tabletop and "*wood blocks and toys for physical representation and manipulation of learning subjects*" (Ibid). The authors found that the TUI-based system offered 'improved ease of use' and better learning opportunities when compared to the WIMP-based systems. The MEDIATE multisensory environment (Perés et al., 2005) on the other hand allowed a group of children to express themselves by interacting with three sensory interfaces such as tactile, visual and aural. The interaction with the system is through the children's body movements and the interaction with the tangible elements attached on a vertical display.

2.10.8 Sonic TUIs for autistic children

Some of the MEDIATE sensory textures can be explored to create music (Gumtau et al., 2005). However, sonic and musical TUIs deployed for Special Education Needs (SEN) settings are often in support of specific skills development such as motor development (Tam et al., 2017; Cibrian et al., 2017; Soundbeam Project) and music therapy (Cibrian et al, 2017). Other are deployed through screen-based interactions, such as tabletop or screen devices (Villafuerte et al., 2012).

A recent example of a sonic tangible interaction for autistic children which is not based on the window/display/screen metaphor, is Polipo (Tam et al., 2017) - a toy aimed at developing fine motor skills by promoting engagement, sense of control, and cause-effect understanding. Once the children finished carrying out an action on it they were rewarded with a preferred rhyme. The design development and specific targets followed specific therapeutic guidelines so that the resulting tangible enabled the therapists to check for progress against the set goals. However, Polipo was still based on a 1:1 therapeutic approach, where the child is taken out of context to practice playing with a plastic toy and an adult therapist, for improving specific learning skills. Similarly, Kossyvaki and Curran (2020) tested Cosmo (Cosmo) as a music-making intervention to enhance the engagement and social communication in autistic children with co-morbid severe intellectual disabilities (Kossyvaki and Curran, 2020).

Cappelen and Andersson (2012) on the other hand, presented the design of novel interactive multi-modal technologies aimed at groups of children with severe disabilities in the form of different musicking objects made in e-textiles. Their work critiqued the limited affordance of traditional instruments and of current music technologies that relied on non-accessible interfaces and switches that disempower the users. However, their approach was still heavily oriented towards improving the use of technology within the realm of music therapy.

2.10.9 TUIs materiality

MEDIATE was one of the first multi-sensory environment created for autistic children that used soft materials such as polyurethane foam instead of PVC plastic. Karana et al. (2008) first coined the phrase ‘materials experience’ to define the experience that people have with the materiality of products which enable sensory-richness. Hornecker (2012) noted that contrarily to digital artefacts or GUIs, where affordances are only perceived instead of being ‘real affordances’ (Norman, 1999), physical artefacts “*inherit a multitude of incidental properties (and affordance)*” from the materials that are used to make them (Hornecker, 2012). This is both an opportunity for TUIs design but also a challenge. It’s a challenge because the designers’ capability to restrict affordances to the ones desired by them is limited due to the “*potentially endless*” (Hornecker, 2012) affordances of physical artefacts. The rich sensory feedback received by interacting with one object made using novel materials, such as fabrics therefore, enables a multitude of affordances and uses. This can also be a design opportunity as it offers users a rich sensory experience which allows them to find different ways of appropriating the tangible for new or unexpected uses.

2.10.9.1 E-textile TUIs

E-textiles, also known as smart textiles or electronic textiles are analog fabrics with electronic and digital components embedded in them. Recently, e-textile or electronically conductive fabrics have been used within the field of HCI to create a variety of ubiquitous computing such as interactive wearables to detect body movements in performative contexts (Liang, Stewart, & Bryan-Kinns, 2019) or to understand social interactions (Skach, Stewart, & Healey, 2019) soft robotics for elderly (Chang, Šabanovic, & Huber, 2013) and children (Andreae et al. 2014). Textiles materials can be re-purposed and engineered without affecting its properties (Heinzel, & Stewart, 2021).

Spookies are one of the earliest examples of soft toys for children (Berglin, 2005) and they were built to encourage free play in dyadic interactions. More recently, Vazquez et al. (2016) developed MalleableBirds a musical fabric-based surface designed to encourage autistic children to practice motor skills. Similarly, BendableSound (Cibrian et al., 2017) was an elastic multisensory surface targeted at developing motor skills in autistic children and it was used in support of Neurological Music Therapy (NMT) sessions. The TUI was based on a technology designed to resemble a flat soft screen interface and it was a therapeutic intervention based on 1:1 use, where children played sounds when they touched the screen. As part of the Music Ball project, Jensenius and Voldsund (2012) developed a ball to support musical expression in children with ADHD which was stuffed with foam and covered it in fabric. The ball triggered lights and audio stimuli activated by an accelerometer hidden inside the thick foam of the ball. Grierson and Kiefer (2013) presented NoiseBear, a wireless malleable soft toy design made by using conductive textile for pressure sensing, to control the continuous stream of data output such as sound synthesis.

Other e-textile TUIs were also envisioned to be used in other therapeutic contexts. For example, Vaucelle et al. (2009) presented the design of wearables soft haptic interfaces to use in support of touch therapy sessions. Moraiti et al. (2015), designed a DIY toolkit to enable Occupational Therapists without prior programming knowledge to create smart soft interactive objects to use in therapies sessions. Most recently Zhiglova (Zhiglova and Yulia, 2018) presented an interactive textile carpet concept to support literacy education such as storytelling through the use of detachable soft fabric shaped characters and speculated on the potential social benefits that such carpet could have for non-verbal or minimally verbal autistic children who have high support needs.

As better discussed in chapter 3.4.2, the designs of the TUI developed for this PhD were inspired by the children's likes and combine the sensory rich qualities of soft materials and their multiple affordances with the intangible nature of music and aimed to create playful shareable objects inspired on the children's interests and their socio-emotional and sensory needs.

2.11 Summary

The literature highlighted a contextual overview of play as a process of learning happening concurrently to cognitive and social development. Play has been assigned various definitions throughout history and across disciplines. It is conceived by some as 'the work' or 'the occupation' of the child (Piaget, 1962; Ray-Kaser and Lynch, 2017), while others emphasised the distinction of play and work as perceived by children (Wing, 1995). – play is more child-led and the work is adult initiated. Play was then valued for its intrinsic leisurely qualities of freedom and children's agency (Gadamer, 2004) and the definition found in the literature of toy play was highlighted to distinguish free play from game play. That is the former (free play) allows freedom and child's agency while the latter (game play) is governed by rules.

Finally play is presented through a psychological, sociological, and pedagogical lenses by offering an overview of the different approaches to play, some of which have influenced this PhD work in different measures. The literature reported on the different play patterns and behaviours exhibited by autistic children compared to neurotypical children's play. Furthermore, it's briefly highlighted how the lack of intrinsic playful opportunities for autistic children can compromise their development, and emphasis it's given to create opportunities for free open-ended and socially engaged play in specialised school contexts for autistic children.

An overview of autism is then given to better contextualise the work carried out in this research and repetitive behaviours and hypo-sensitivity/hyper-sensitivity, are presented in detail to facilitate the reader's understanding of the diagnosis. Evidence-based interventions such as auditory and tactile stimulations are also briefly introduced as key stimuli that are explored later in this thesis.

The literature showed that technology-based approaches used in SEN settings across the UK and beyond, especially those in support of social interactions through playful activities, are often developed with Virtual Reality (VR), Virtual Environments (VE), Augmented Reality (AR), and/or Robots, and frequently focus on developmental and educative goals and/or specific activities. This PhD research however - oriented toward the needs, preferences and "*desires for play of neurodivergent people*" (Spiel and Gerling, 2022) aims to closing the gap in the existing literature on the purpose of play of autistic children, by expanding the work developed around playful e-textile sonic TUIs for non-verbal autistic children.

A brief introduction on the development of the field of HCI is provided to emphasise the shift of attention in the HCI community from the tools used by people to the people using the tools, and finally to our lived experiences. A shift in paradigm that was reflected in the less utilitarian design approaches developed within the field in the past decades such as experience-centred design (focussed on the experiences of people) and ludic and open design (focussed on critical reflection and playful explorations through design).

The literature also demonstrates that many researchers within the Child Computer Interaction (CCI) community often use Participatory Design (PD) approaches to empower children and promote their agency. The concept of Tangible User Interfaces (TUIs) is then finally introduced as an alternative to the GUIs and the WIMP archetype offering an overview of TUIs development within the field of HCI. It then focuses on TUIs specifically used as learning aids for children with different conditions and introduces TUI designs that are soft and more inclusive. An overview of sonic TUIs used in SEN contexts is also provided which underlined how auditory feedback is often used within scholastic contexts to support music therapy sessions (Cibrain et al., 2017; Cappelen and Andersson, 2012), motor development (Tam et al., 2017), and/or specific social skills (Villafuerte et al., 2012).

Through the literature, the researcher highlighted a gap in TUIs design for open-ended and socially engaged play for non-verbal autistic children, which she aims to explore further in the rest of this thesis (particularly in Chapter 4, 5 and 6) through adopting principles from the presented works such as that of shareability (Hornecker et al., 2007), ambiguity (Gaver, 2002; Gaver et al., 2003), and embodied and embedded interactions (Dourish, 2001 a; Luff et al., 2013) to design and assess Mazi and Olly. A more in-depth reflection of where this work is situated within the bigger body of the TUI literature is provided in the following chapter (section 3.4.2).

3 Research Methodology

The following chapter explains the methodology adopted to carry out this PhD research and it introduces the investigative and analytical tools used to address the research questions of this PhD. The chapter explains the research design, the ethical approval process, and the procedure and structure of each study; it gives a contextual overview of the Garden school and the three studies conducted there and discusses the methodology of research. This employs a mix of investigative instruments such as field-notes, interviews, audio recordings, observations, video recordings, and questionnaires. The researcher used a pseudo-ethnographic approach better explained in section 3.3, by conducting the studies in a naturally occurring context, the school, and by immersing herself in the children's doings during the observations that she carried out in the formative phase of the studies (pre-test), and during the testing phase. The structure of each study is well explained in table 3-1.

The researcher combined her understanding of the children, gained through the observations done in the formative phase of the studies, with the information and knowledge she already had of the Garden school and of non-verbal autistic children. Having worked at the Garden before starting the PhD (as mentioned in chapter 1.3), the researcher tailored the designs and the studies based on a multitude of information collected from different channels. After presenting a statement of positionality, in section 3.3.1, the chapter introduces when and how the data collection took place and how this data and the literature informed the design of the studies and of Mazi and Olly, which the researcher made in study 1 and 2.

The chapter also presents the analytical framework used to guide the observations for assessment carried out by the TAs and the dance teacher during the testing phases of the studies, and to guide the video analysis done by the researcher in the analysis phase. The framework was developed by the researcher throughout the PhD and was inspired by the context of research and few theoretical models of social interactions. The researcher's video annotations, and the teacher's observation sheets are combined together to form the quantitative and qualitative results reported in the findings of each study presented in chapter 4, 5 and 6. To conclude, the researcher gives a detailed explanation of how the analysis was conducted using the teacher's comments and the framework that she developed.

3.1 Research design

To achieve the goals set by this research inquiry, the researcher developed three studies with three groups of autistic children in 2018, 2019, and 2020. The testing phase of the first two studies happened over a period of 5 weeks, once per week, on Thursday afternoons, in the dance studio of the Garden, whereas the testing phase of final study happened for just three weeks and was interrupted due to COVID-19. The dance studio was always booked for 30 minutes but the length of each session changed and is therefore introduced in the 'testing phase' sections of each study. The dance teacher was asked to lead all the sessions of each study, and the researcher was always present in the room as an extra support. Most of the children were assisted by Teaching Assistants on a 1:1 basis, meaning that 1 adult worked with 1 child. Throughout the testing sessions of the three studies, the participating children received the same amount of support that they did during normal school hours and were accompanied by their respective TAs. In few occasions the class teachers accompanied one of the pupils.

3.1.1 Ethical approvals

Queen Mary University's Ethics of Research Panel fully approved the research. The study was conditionally approved by Queen Mary Ethics of Research Committee (Panel E) on the 15th of November 2017; full approval in principle was ratified by the Chair's Action on the 5th December 2017. This was confirmed by the Administrator on the 12th December 2017, on receipt of requested documents. This approval was valid for a period of two years. For the final study, the researcher had to reapply to the Committee. Approval was received to carry out the final study on the 16th of January 2020. Selection of children was carried out either by the Headteacher or by the dance teacher. Information sheets were circulated to parents/carers and participating teachers alongside consent forms, which were usually returned back within 2 weeks. Because the children collaborating to this research were minimally verbal to non-verbal, consent was given by their parents. However, during the studies children's assent was always prioritised and they were free to withdraw from the study at any point if they wished to do so and/or if it was visible during and after the sessions that the child was dysregulated or uncomfortable. No child withdrew from the studies. Parents have approved to publish their children's pictures without blurring their identities for academic purposes and scholarly publications. The information sheets contained information related to the aims and scopes of this PhD research, introduced the methods and approaches used for data collection and evaluation, and some details about the dissemination of the work including the use of clear pictures for academic publications. The signed ethic approvals (of the parents, teachers, and TAs of the Garden school) are stored at QMUL for the duration of this PhD.

3.1.2 Procedure

After a discussion with the dance teacher it was decided to work with groups of around 5 participants. For the first two studies, 5 children were recruited by the Headteacher from different classrooms, while for the final study the researcher worked with a group of 7 children attending the same class. These were selected by the Dance Teacher. In Study I, one girl and one of the four boys came from the same class and the children's ages ranged between 6 to 9 years. In Study 2, the same girl that participated in Study I, and two of the same boys were re-selected alongside two new boys. Children's ages ranged between 5 to 10. In Study 3, the children were selected by the dance teacher as the Headteacher was replaced by an Interim person, and she decided to work with a group of children coming from one classroom, the Reception class (5 years of age). The dance teacher thought that proposing a playful social activity to the younger and newer children of the school would have been beneficial to their scholastic experience. Furthermore, she thought that it would have been easier to work with one class for logistical reasons. Interestingly, this class was formed by 4 girls and 3 boys. This was interesting as in the previous two studies there was a bigger rate of males to females. However, gender differences and how these affected play dynamics were not evaluated in this PhD.

Table 3-1 shows how the studies were structured and at what point of the PhD each phase started and ended. All the studies were structured as follows:

- a formative phase, which includes recruiting the participants and obtaining ethic approvals, and the data collection of the children's information for requirements gathering through observations, interviews and children's documentation, the creation of the children's profiles, and the beginning of the conceptual design
- an iterative prototyping phase, in which designs ideas and sketches are finally prototyped (or fixed) and pilot tested

- the testing phase (when the TUIs are tested with the children over a period of 5 or 3 weeks in each study) and
- the final analysis (where the findings are reported and discussed).

	TIMETABLE OF STUDIES	
STUDY 1	**October - end of February 2018**	**Formative Phase - Target & Recruitment & Ethics + dance teacher interviews +** Data gathering (including: class teacher's + TAs interviews + children's profiles collection + pre-study children's observations + conceptual design)
	February - April 2018	**Iterative Prototyping Phase** (Detailed design + pilot testing + fixes)
	26th April - 24th May 2018	**Testing phase 1** (Testing TUIs with children – 5 weeks per study)
	April - June 2018	**Analysis** (During-study & post-study data gathering including: qualitative results from teacher's and TAs observations based on framework + quantitative analysis of video recordings + collated results)
STUDY 2	**December 2018 - mid-February 2019**	**Formative Phase - Target & Recruitment & Ethics + dance teacher interviews +** Data gathering (including: class teacher's + TAs interviews + children's profiles collection + pre-study children's observations + conceptual design)
	February - April 2019	**Iterative Prototyping Phase** (Detailed design + pilot testing + fixes)
	25th April - 24th May 2019	**Testing phase 2** (Testing TUIs with children – 5 weeks study)
	July 2019 - January 2020	**Analysis** (During-study & post-study data gathering including: qualitative results from teacher's and TAs observations based on framework + quantitative analysis of video recordings + collated results)
STUDY 3	**October 2019 - end of February 2020**	**Formative Phase** - Target & Recruitment & Ethics + dance teacher interviews + Introduction to new Headteacher + Data gathering (including: class teacher's + TAs interviews + children's profiles collection + pre-study children's observations)
	January - February 2020	**Iterative Prototyping Phase** (Fixes + pilot testing)
	27th February - 12th March 2020	**Testing phase 3** (Testing TUIs with children – Interrupted after 3 weeks due to COVID-19)
	April 2020 - January 2021	**Analysis** (During-study & post-study data gathering including: qualitative results from teacher's and TAs observations based on framework + quantitative analysis of video recordings + collated results)

Table 3-1 Timetable of the three studies carried out for this PhD research

Even the testing phase was an iterative process as the technologies were improved, and sometimes fixed, throughout the testing sessions. Before the first study began, the researcher organised a meeting with the parents of the five selected children. Four of the five children's parents attended a 1-hour meeting and were introduced to the research and the researcher. One of the parents expressed their wish to have the results of the study given to her as soon as possible. Hence, the researcher decided to provide parents with visual and written feedback after each session of each study.

In Study 1, and 2, the parents/carers of the participating children received feedback each Friday afternoon, one day after each session. This consisted of a set of pictures of their child and a brief written report where the researcher informed the parents/carers of their child(ren) experience in the sessions. In Study 3, the parents of each child received live pictures sent to them by the dance teacher using an app called ClassDojo during the sessions. This was regularly used by the school's teacher and parents to share information.

A further meeting with one Occupational Therapist (OT) working at the Garden was organised before study 1 and from there the researcher started to define the aim of the research. Attention was therefore given to build TUIs that would scaffold social play, while potentially offering individuals the opportunity to self-regulate during play (i.e. to regulate their arousal and energy levels).

3.2 Contextual overview

The Garden school uses positive evidence-based educational approaches to enable and encourage autistic pupils to reach their full potentials. These include but are not limited to: the Picture Exchange Communication System (PECS) (Bondy, 1994), a system of cards used by people to communicate meaningfully; the Social Communication, Emotional Regulation and Transactional Support Model (SCERTS) (Prizant et al., 2006), which is an educational framework based on core challenges faced by autistic children and an assessment tool; Intensive Interaction (Nind and Hewett, 1994), that teaches the fundamentals of communication; and Attention Autism (2005), which enables the development of joint attention skills. The following paragraphs will explain how these approaches and methods have been implemented within the studies.

For example, PECS is a system of visual and verbal communication (cards or symbols) implemented to facilitate understanding and emotional regulation and to promote independent communication. In the three studies carried out throughout this PhD, PECS and Objects of Reference (OoR) - used with children that did not use pictures, were created specifically to represent Mazi and Olly and were used on the children's classes and individual timetables. Individual visual and tactile timetables were used at the Garden to facilitate children's understanding of their daily scholastic schedule.

Objects (OoR) or pictures (PECS) were attached to a vertical strip of paper in sequential order of progression to show the children what the activities that were planned for that day were and what came next. These were used in the individual class timetable of the children and on their 'now and then' cards, which they carried around and used as a transition tool from one activity to the other. At the Garden the teachers also used a bigger format of PECS for a shared class timetable. Big PECS were used also by most teachers to divide one single lesson into smaller sections. Therefore, in the sessions carried out in the testing phases of the three studies were each divided into smaller sections represented by a symbol of Object of Reference (OoR). The structure of the testing sessions was decided upon discussions with the dance teacher. The break-down of the testing sessions displayed in the dance studio included a set of PECS that were displayed in sequential order and usually moved by the dance teacher. These were:

- taking shoes and socks off
- saying hello
- looking at the teacher while the teacher sang the "under the cloth" song
- looking at teacher touching and listening the TUI
- inviting children to interaction
- celebration, (used just in study I and II)
- sign language for finish to indicate that the session was finished
- goodbye symbol

The PECS and OoR used by the children were intended to provide information about what came next (on the individual timetables) and to transition into the dance space (on their 'now and then' cards). The symbols or OoR used by the children showed a picture or object that represented the TUI(s) tested.

The SCERTS Model (Prizant et al., 2006), is an educational framework used to develop targets in the areas of communication and self-regulation. However, it's also an assessment tool that helps to identify developmentally appropriate goals. SCERTS defines three communicative stages for autistic children: Social partner (SP), when the child uses less than 3 words to communicate (e.g. using sign, language, or pictures), Language Partner (LP) when the child uses more than 3 words, and Conversational Partner (CP) when a child uses 100 or more words and at least 20 are combined creatively (Prizant et al., 2006). Aside from one child (Pete in study 2) the children that participated in this research were at Social and Language Partner stages, and this information fed into the profiles of each child created during the formative phase, which the researcher used as a starting point to inform some design strategies (i.e. when creating symbols and/or Objects of References, and when deciding how much talking the children should have been exposed to during the testing sessions). The SCERTS Model also inspired the evaluation framework developed for this PhD which is better explained in section 3.5.

Another approach used at the Garden is called Attention Autism, a practice developed by speech therapist Gina Davies and used in UK SEN settings to promote children's attention through fun and visually stimulating activities. It is divided into four stages (the bucket; attention builder; turn-taking and re-engage attention; shifting and re-engaging attention) and each of them aims at improving children's participation in social activities. In the three studies carried out throughout this PhD the first stage of Attention Autism inspired the approach proposed by the researcher to introduce the TUIs to the children as the sessions started. For instance, 'under the cloth' was an Attention Autism (AA) inspired song invented by the researcher following AA practices. It was sung to the children by the dance teacher at the start of each session in each study when the TUIs were covered by a cloth. At the end of the song the cloth was lifted leaving the TUI clearly visible to the children and at this point the adults in the room (Teaching Assistants) made surprised exclamations. The children were then invited, or if already there, left free to play with the TUIs.

On the other hand, Intensive Interaction was first developed by Nind and Hewett in 1994 for people with profound learning difficulties and communicative problems (Nind and Hewett, 1994). It targets the development of social interaction for those individuals that are nonverbal or preverbal by adapting the adult partner's traditional way of communicating to that of the individual with autism. The school's TAs, especially in the first study, adopted this strategy to connect to some of the children while playing with the technology.

The school also relies on developing a program based on educational models like the Treatment and Education of Autistic Children and related Communication-Handicap or TEACCH (Schopler et al., 1995). The TEACCH program was developed by Schopler et al. (1995) and uses strategies that include: **environmental modification**, so that physical changes in the space contribute to improvements; **visual schedules**, so that the children are constantly reminded of what they are doing and what's next; **organised work**, to enable a system where the child understanding of what's expected of him is facilitated; **learning task organization**, in that the activity is divided into subtasks, which are all made clear to the child beforehand. This approach was adopted throughout the three testing phases of the studies to create a semi-structured environment and to clearly show to the children what to expect from the sessions.

Finally, the Garden school also makes use of commercial software packages like B Squared to track the children's progress and evaluate them using the Performance levels (or P levels), as the pupils work below and towards the standard of the National Curriculum. The national curriculum "*sets out the programs of study and attainment targets for all subjects*"[16] of the English education system ensuring that all pupils receive the same level of teaching. P levels assess the performance level of children below the national curriculum and consist of eight levels of increasing difficulty in areas related to attention, participation, understanding, and so on. The P levels of each child that participated in this study were collected to help forming a holistic picture of each child including their cognitive understanding.

This PhD work draws on the combination of the above-mentioned strategies and approaches and qualitative methods commonly used in HCI, discussed in section 3.3, to create opportunities for social play and to offer a holistic evaluation of the children's experiences.

3.3 Research methods

As previously mentioned, this research methodology follows an empirical inquiry conducted using quantitative and qualitative methodology (Heath et al., 2012) influenced by theories of embodied interactions (Dourish, 2001; Luff et al., 2013). A mix of design methods have been adopted. The work is inspired by a user-centred

[16] https://www.gov.uk/government/collections/national-curriculum

design approach with a focus on values borrowed from experience design, ludic design and research through design, and it explores the importance of located, playful, pleasant and experiential approaches to design. This is done to enable the creation of artefacts that foster social play and emotional regulation by addressing children's needs and likes, and to explore the design space of playful TUIs for heterogeneous groups of children.

This work is based on field-studies inspired also by ethnographic research. Initially, within the HCI community, qualitative research has been concerned with understanding the use of technological equipment in 'perspicuous settings' (Garfinkel, 1996) that are particularly suited to answer a specific research question. It was more concerned with work practices, as mobile technology did not exist, but it evolved as the technology improved and became ubiquitous. Commonly, anthropological ethnography observes people and activities within a specific context and over a long period of time. In pure ethnography researchers do not contaminate the observed phenomena. This research therefore, employs a pseudo ethnography because it takes a liberal approach similar to that used by Gaver et al. (2004) whereby artefacts are used as an object of inquiry and introduced in the observed context to analyse their effect on social play and self-regulation within a semi-structured scholastic environment. The constrained timeframe of the PhD did not enable the researcher to immerse herself in the lives of the children over an extended period of time, but she used her prior experience of working at the Garden as the base for an "*ethnographically informed design*" (Bentley et al., 1992) based on her prior knowledge of many of the people working at the Garden, the approaches used there, and many of the children attending the school. Artefacts are thereby here placed 'in the wild' to explore and analyse how they affect user experiences, social dynamics and ludic activities in groups of autistic children. In the field of HCI, research through design (RtD) explores the space of interface's designs (physical and digital) with a critical and reflexive lens, and it does so to stimulate public discourse and to push the boundaries of common design spaces (Zimmerman et al., 2010; Dow et al., 2012). In RtD researchers develop new artefacts as an approach to learn about human experiences and this encourages them to move beyond the artefact itself to discover insights not just about the technology but also about the people and their interactions. Similarly, in this PhD the researcher used the two designs she made as a research tool to gather insights about the children's play.

E-textiles have increasingly allowed the maker and DIY communities to experiment with making fabric sensors from scratch (Perner-Wilson, & Buechley, 2010) and to create hand-crafted technologies (Perner-Wilson, Buechley, & Satomi, 2010). Therefore the TUIs designed for the three studies are inspired by technology probes (Hutchinson et al., 2003) which are often used as a tool to understand people and expand design's possibilities.

UCD on the other hand, as seen in chapter 2.8.1, is usually concerned with utilitarian aspects such as the usability of a system, the context of use, system efficiency, effectiveness, and its learnability (Norman and Draper, 1986), and less on aspects of user experience (surely not the shareability aspect of systems) (Norman, 2004). It often uses usability evaluation methods, more or less rigorous, employing techniques such as think-aloud (Baauw and Markopoulos, 2004), card sorting (Cassidy et al., 2013), questionnaires, interviews (Brederode, 2005), wizard of Oz (Jeong et al., 2018) etc. and is specifically concerned with certain elements related to the design of GUIs such as visibility, accessibilities, navigational elements, legibility, language and so on.

The TUIs developed in this PhD, designed for ludic entertainment, don't really fall into the UCD paradigm as such. In fact, from the utilitarian approach of the UCD process, this research moves to a more experiential and playful one where technologies are evaluated against criteria such as children's experiences and how these are affected by the artefacts. Nonetheless, the three studies developed for this PhD follow the four main UCD steps. As shown in table 3-1, the studies started with understanding the context of use to define the user requirements (the **formative phase**), a design phase where conceptual (alternative sketches and drawings) and detailed designs ideas (small scale and large scale prototypes) were developed, or improved and pilot-tested (**iterative prototyping phase**), and an evaluative phase were the technologies were tested with the children and the findings were analysed (**testing and analysis phases**).

3.3.1 Positionality

Throughout the studies the researcher found herself to be the **observer**, the **designer**, the **facilitato**r and the **evaluator**. Therefore, she positions herself both as an insider and an outsider to the culture being studied in this PhD and acknowledges the influence that this might have had on the research's process and its outcome. Mercer (2007) argued that "*The insider/outsider dichotomy is, in reality, a continuum with multiple dimensions and that all researchers constantly move back and forth along several axes*". Therefore, the researcher's positions overlap in different ways and at different stages of the process.

The researcher considers herself to be an **insider** due to a) her previous employment at the Garden school, hence her knowledge of some of the staff working there, some of the children and of the scholastic system, b) her previous experience working in playgrounds for SEN children aged 4 to 18, therefore her in-depth knowledge of autism and other conditions and play, and c) her role as facilitator during the testing sessions or that of an immerse observer during the data collection of the pre-testing phases. However, she also positions herself as an **outsider** as she no longer worked at the Garden, hence she was seen and treated as a researcher - an external professional and specialised figure, rather than as a member of the school personnel. Also, she no longer knew the children she worked with when she was a TA (two of which participated in the first study of this PhD) or those that she met during her employment, because one or more years had passed since then and people changed.

As an outsider, the researcher was helped by the OT working at the Garden (an insider) to steer the focus of the research project toward social play. However, she reinforced this choice by reflecting on her observations of children's play-time personally experienced as an insider when working at the Garden. Therefore, she wanted to focus on both play and self-regulation opportunities. This belief was reinforced by studies that demonstrate that children's participation in leisure activities is affected by sensory processing and anxiety levels (Hochhauser and Engel-Yeger, 2010). As anxiety is found to be higher for around 80% of autistic people when exposed to social contexts (Rodgers et al., 2016), and repetitive movements or sensory stimulations are used by autistic people as a strategy to lower anxiety (Case-Smith et al., 2015; Suarez, 2012), the researcher believed that to enable children to fully enjoy a socially engaged play activity they needed to feel safe and comfortable and this meant enabling them to be themselves.

The context in which the research took place also influenced the research process and the researcher's choices. Using SCERTS as a source of inspiration for the analysis and the design of the studies, is one example. The training that the researcher received at the Garden such as Attention Autism, Positive Behaviour Support and Intensive Interaction and her experience working with different children is another example.

As an **observer,** both during the formative and the testing phase, the researcher often found herself immersed in the children's activities and a part of it. Hence, she was both an outsider because of the way that she was considered by some TAs and perhaps some of the children (at least at the beginning), but also an insider, as she was still a person that knew the scholastic system and many of the children engaged with her while she was observing. When **designing** the TUIs instead, she first approached the conceptual design from an external observer's point of view (outsider), sketching and prototyping her vision of shareable toy. However, after collecting enough information about each child she started having an idea of what their needs and preferences were and tried to understand how some of the stimuli that the children sought the most could be replicated into one single design that catered to multiple preferences. This shifted her approach to a more insider perspective.

As a **facilitator** the researcher stepped into the insider shoes again by participating in the testing phases and blending in with the children and the adults. This could be seen as both a disadvantage as well as an advantage. It could be a disadvantage because one could think that the findings might have been influenced by her involvement in the activity and her personal investment in and interest toward it. Adults interventions however were limited in the studies and the researcher never prompted any child to the TUIs of her own initiative. The advantage instead is that the researcher was better equipped to understand the events that occurred, she had a feel of them as they unfolded because she was there, so she got an unfiltered feedback of what happened.

As an **evaluator** the analysis that the researcher carried out post-testing was based on the video recordings of the sessions, not on her personal memory of the experience. Although it is suggested that we can never objectively describe reality (Holmes, A., G., D., 2020), the researcher tried to provide a neutral analysis and discussion of the findings, clearly supported by evidence drawn from the videos. However, she acknowledges that few of the TAs that she interviewed and talked to, were once her colleagues, and there might be have been some bias in respect to how she asked the questions and or to the answer that she was given. However, the researcher didn't know most of the TAs that participated in the three studies (she previously worked with two of them who participated in study 1 and 2), she tried to construct questions objectively and approached all the TAs and teachers equally. In the first two studies the feedback given by the TAs in their observation sheets was general instead of being directly linked to each of the theme that they were asked to observe. Therefore, the researcher had to contextualise their notes with each theme. When quoting the TA's comments in the result sections of each study, especially study 1 and 2, the researcher used her own interpretation to contextualise the teacher's notes within each theme. However, she didn't just pick the comments that better suited the themes observed, but rather she used these comments to either confirm of contradict the quantitative data that she collected from the video analysis. Although the research started with an inductive approach, the analysis was not reduced to a small number of observations. On the contrary the researcher annotated every minute of all the video recordings by describing everything that the children did during the testing sessions.

3.4 Data Collection

The type of data collected in the three studies during both the formative phase and the analysis phase, are displayed in Table 3-2.

Types of Data Collected
Children's documentation (pre-test)
Researcher's notes and sketches (pre-test)
Teacher's interviews (pre-test)
Video recordings (during testing)
Video annotations (post-test)
Audio recordings of interviews taken pre-test and post test
Transcripts of audio recordings (post-test)
Dance teacher and TAs observation sheets (during and post-testing)
Questionnaires (post-test)

Table 3-2 Types of data collected in the three studies before testing, during testing and post-testing

3.4.1 Data collected in the formative phase

During the data gathering period that preceded the testing phase of each of the three studies conducted in this PhD, children's information was collated to form the children's profiles. These were similar to the child personas tool used by designers to define requirements (Antle, 2008) but were based on real people instead of fictional archetypes (see table 4-1, 5-1, and 6-1). This information included: P levels, SCERTS levels, Positive Behaviour Support Plans (PBS), the Individual Educational Plans (IEP), and information taken from the One Page Passport (OPP). The OPPs are one-page documents that summarise the most important things about a child and how to best support them in case of need and are usually displayed on the wall of each classroom. The PBS Plan instead is an assessment that provides the team of teachers with a plan to enable the child's participation in daily activities. It usually contained a summary of the child's likes, dislikes, triggers, and the strategies implemented to overcome challenges in specific circumstances. Finally, the IEPs are a tool used to review the progress of a child and offer strategies to help them learn. In this case they contained plans to achieve certain curricula targets.

Field notes and sketches about the children's were taken mainly during the observations carried out by the researcher in physical education (P.E.) and dance lessons due to the fact that the dance studio was the same environment where the study took place, while the P.E. hall was the only place where the children at the Garden were offered a choice of physical equipment. For the researcher, this was a chance to observe their preferences and use of tools and toys, and to find out what sensory stimuli they sought the most. During the observations the researcher occasionally interacted with children, or sat next to other TAs, while other times she moved around the room. Additionally, at times, she was approached and welcomed by some children, she was brought around the space or she was prompted by few to play with them. During this phase the researcher also carried out various interviews with class teachers, TAs, P.E. teacher, dance teacher, and in study 1 she also interviewed the OT and the parents. All the interviews were audio recorded to be used for later analysis. This information fed into the final designs of Mazi and Olly.

3.4.2 TUIs Designs: how data and theory influenced the designs

The main design principles that guided the development of the two systems were:

1) To build on children's past experiences, needs, and preferences, hence their strengths
2) To support self-regulation
3) To encourage social activities

The researcher tried to build two TUIs that supported stimuli that the children were seeking and went into the design phase with a lot of information collected from different channels (i.e. children's observations and documentations, class meetings, previous and personal knowledge of the school and children etc.). The information collected showed that children enjoyed playing with ball-shaped toys such as tennis balls, inflatable gym balls, volleyballs, basketballs, etc. and many enjoyed touching and manipulating fabrics. How this information fed into the design of Mazi and Olly is better explained in the formative phase of study 1 and 2. However, the children influenced the choice of the materials used to make the TUIs and the circular shape. For example, during the observation she did in P.E. and dance lessons she noted that children were invited to come together mainly by using a big multicoloured nylon parachute. This has a circular shape and children were invited to go either under it all together or to hold it by standing on the outside. The literature then reinforced the choice of designing two shareable, large-scale, semi-spherical objects.

The researcher went into the design phase with different designs in mind in both in study 1 and in study 2. Figure 3-1 shows few of the first sketches she made of Mazi while figure 3-3 displays the first conceptual design ideas for Olly.

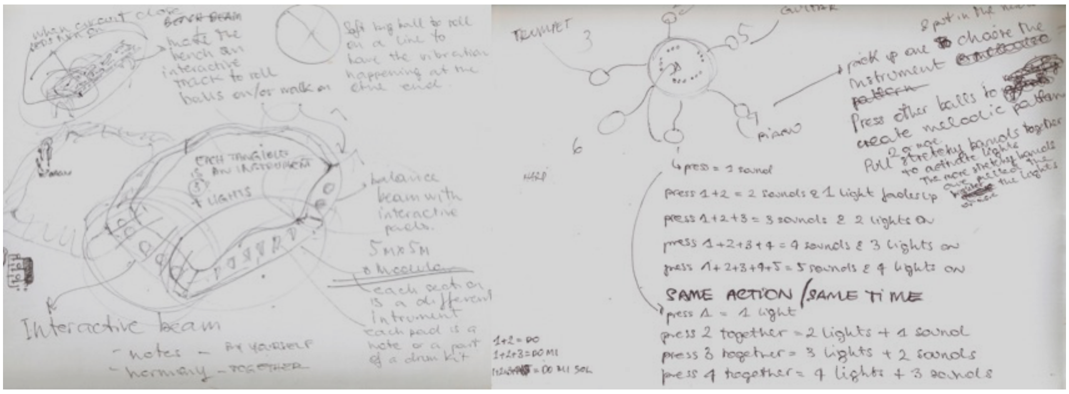

Figure 3-1 Mazi first conceptual designs

For example, for Olly, after she saw that children in study 2 still liked fabric materials and one child (Isaac) particularly liked playing in a group activity with a big stretchy band, she decided to use stretch sensors. However, as it can be seen from figure 3-2 on the right picture, initially she wanted to attach stretch fabric ribbons (with e-textile sensors embedded in them) on the ceiling of the dance studio. After having requested the idea to the Headteacher however she was told that the structure of the building would not support the children's weight. Therefore, she had to abandon that idea and went back to experimenting with a similar shape to that used for Mazi (figure 3-2 on the left side).

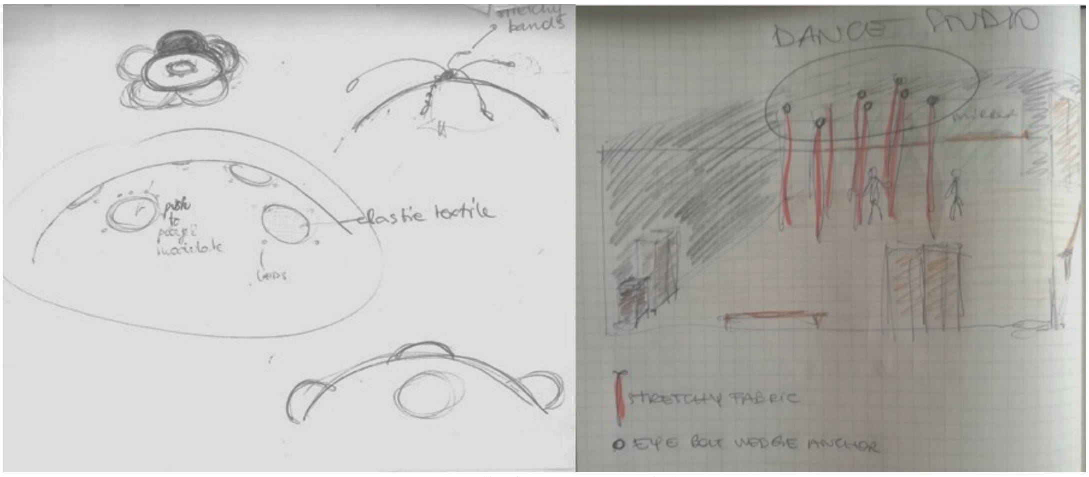

Figure 3-2 Olly first conceptual designs

After exploring different design options and getting to know the children, the researcher, showed the ideas to the dance teacher and then picked the two final designs (figure 3-3).

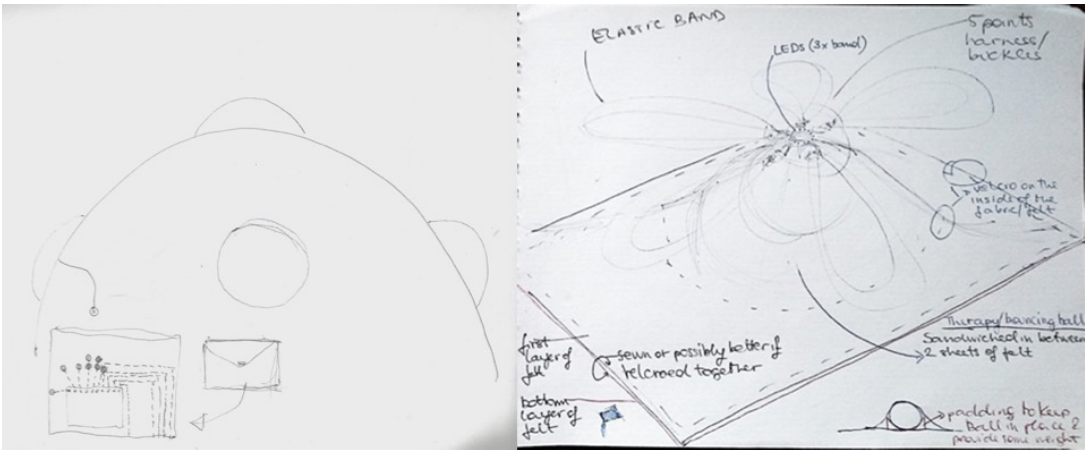

Figure 3-3 Sketches of final designs, Mazi left; Olly right side

Studies show that circular configurations facilitate natural communicative and collaborative mechanisms providing means for socialization (Luff et al., 2013). Larson et al. (2009) found that round shapes convey positive meanings whereas shapes formed by acute angles are perceived more as a threat. According to theories of embodied interactions (Kendon, 1990) body orientation and the configuration of space contribute to social interactions in different ways. In Kendon's F-formation, for instance, social interactions organize around an imaginary circular O-space maintained to grant the same access to all parties involved in the interaction (Kendon, 1990). The O-space is specific to Human-human communication. It may take a variety of configurations (facing each other; L-arrangement; side by side), which depend on different factors such as the numbers of participants, the arrangement and layout of physical space, and the type of activity. Therefore, Mazi and Olly (figure 3-4 and 3-5) were designed to recreate the illusion of an imaginary *O-space* around which interactions are often organized (Kendon, 1990) and where children could meet together and tolerate each other's proximity by having the same access and entry points. The position of the participants also pinpoints their speaking rights and their agency within the piece. For example, face-to-face interactions usually gives the same rights to speak to participants or can denote competitiveness, while a parallel alignment is usually an indicator of collaboration.

Figure 3-4 Mazi as exhibited at Ars Electronica 2018

Harris et al. (2009) noted that multi-touch systems enable equal rights of access and participation, therefore she opted to offer multi-touch interactions. The soft designs aimed to entice the children (as they liked fabrics and plush objects such as pillows – as better seen study 1 and 2), and to provide a feeling of security by reducing feelings of uncertainty (Van Horen and Mussweiler, 2014; Chang, Šabanovic, & Huber, 2013; Cascio et al., 2008; Jeong et al., 2017).

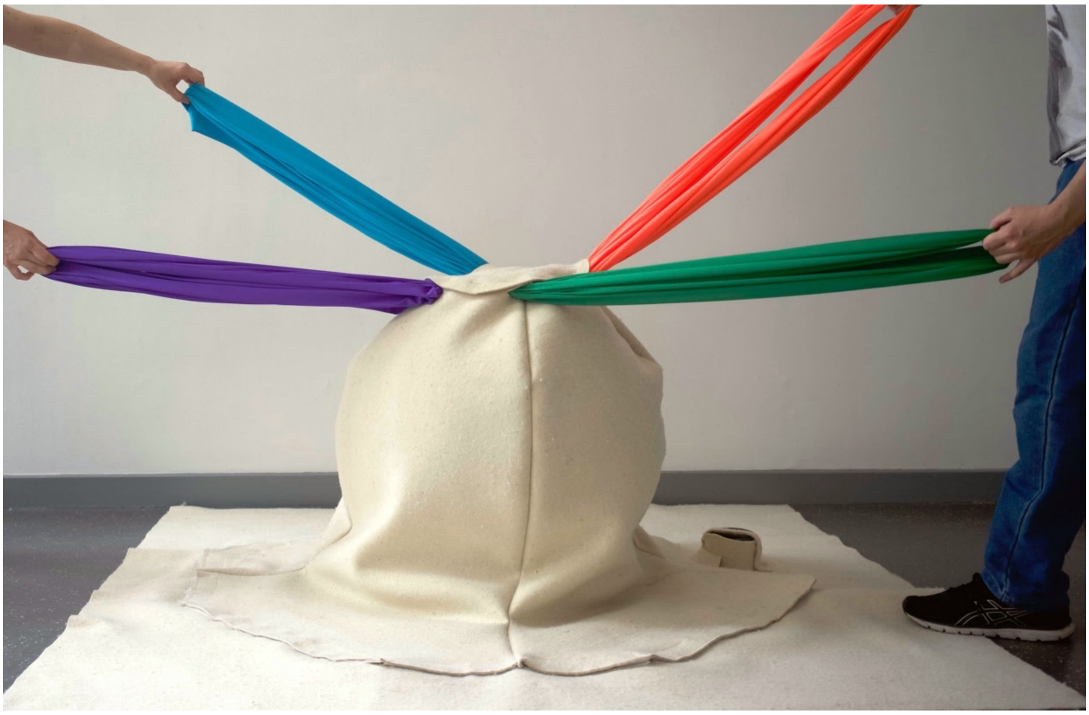

Figure 3-5 Olly as exhibited at Ars Electronica 2019

To enable social interactions to happen more effortlessly the principle of *shareability* was also implemented in the design of both Mazi and Olly. The designs reflect these principles by:

a. offering a clear overview of the technologies in their environment,
b. using colours, fabrics and sound outputs to create a honeypot effect, which together with their circular shapes and designs, aimed to promote social awareness and allow perceptual access;
c. aiding manipulative access and
d. fluidity of sharing through their size and shapes, including their access points, i.e. the sensors, and their materiality such as the elastic ribbons, the bubbles and the felt, used to minimize access barriers.

Each of the above criteria was applied to the design of Mazi and Olly and the rationale behind this approach is better explained in the formative phase of chapter 4 and 5. Rarely shareability has been applied to the development of technology for children (Marshall et al., 2009), and to the researcher's knowledge, no prior research has explored the use of these principles on TUI designs to support social play and self-regulation in groups of autistic children. Finally, as a mean to empowering the children, the designs aimed to facilitate appropriation of the artefacts, agency, and self-expression by borrowing the concept of *Opera Aperta* (Eco, 1997). This resonates with that of ambiguity and design for pleasure detailed by Gaver (Gaver, 2002; Gaver et al., 2003) in ludic design and allows the TUIs to become an unfinished work of art (in this case an interactive toy) that is open to interpretation and use, and enable freedom and agency through a process of completion of the art work (by interacting with it). TUIs in this thesis are therefore intended as toys in the way that Baudelaire defines them "*the child's earliest initiation into art, or rather it is the first concrete example of art*" because of their aesthetical qualities that enable them to address the "*childhood notions of beauty*" (Baudelaire, 1853). Therefore, following this principle, Mazi and Olly should enable a varied type of play and be "*meaningful even if the power is turned off*" because *"technology should add to a toy, without sacrificing the good qualities inherent to its class of toys*" (Raffle et al., 2004).

3.4.3 Data collected during and post-testing phase

The video recordings of the children's testing sessions were taken for all the three studies. Figure 3-6 shows the layout of the room and the floor map of the dance studio, and it indicates where the cameras and the TUIs were positioned in each study.

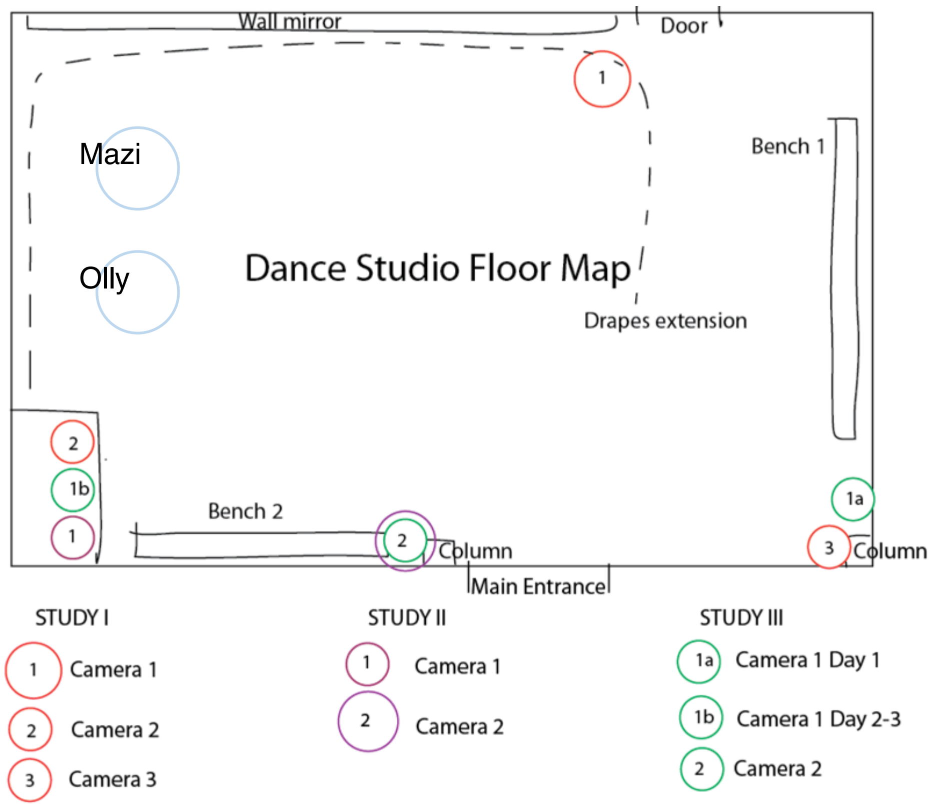

Figure 3-6 Dance Studio Cameras Floor Map

In Study 1 the testing sessions were video recorded using two mini cameras, and one iPad. In study 2 they were recorded with two mini cameras and one mobile-phone, the iPad was not used as children were distracted by it, and in Study 3 just the two mini-cameras were used as it was found that the mobile phone used in study 2, created a barrier between the children and the researcher. The cameras were set up in the space by the researcher 10 minutes before the children entered the dance studio and were removed as soon as all the children left the room. In Study 3 one of the cameras was moved after the first session as the view point did not cover the whole room as expected. In all the studies the teachers rated the children following 5 points rating system, which was an evaluation measure that they currently used at the Garden and that was based on the level of independence of the children (Figure 3-7). However, in study 1 and 2 most of the TAs feedback was based on the 5 points rating system rather than on their comments, because unfortunately, most TAs didn't feel confident with adding any descriptive text. For example, Joshua's TA reported after day two told the researcher that that she didn't not know what to write as *"Mazi is amazing and Joshua is reacting very well to it".*

from dependent *to* independent			**Prompting**	
Learners complete tasks independently				
Full/Total 100% 1	Substantial/A lot 75% 2	Some 50% 3	Minimal 25% 4	Independent/None 0% 5
Not achieved		Partly achieved	Achieved	

Figure 3-7 The 5 points rating system used at the Garden

The rating system however was not used by the researcher as it did not offer rich analytical data. Furthermore, when she compared those of the TAs with the points given by the dance teacher the ratings not always matched. The observations sheets contained a certain number of evaluation criteria, here called themes, that the researcher used as a probe to gain the teacher's insightful opinions on the children experiences (see analytical framework better explained in chapter 3.6), especially from study 3.

In study 1 and 2 the TAs and the dance teacher were asked to provide general qualitative information related to the themes observed and to use an extra sheet of paper for anything that they wanted to add. The researcher therefore used the fewer information that she gathered from the extra sheets of the TAs and the dance teacher and paraphrased their comments in the result sections of each themes, contextualising what they wrote within the themes. The quotes fitted the description of the themes but were not intended by the teachers to fall under these categories.

The researcher thought that it was a good idea to enable the teacher and TAs to use a measuring system they were comfortable with to start off the observations. However, she realised that this numerical information didn't contextualised what happened. Therefore, in study 2, after she noticed that the 5-points system used in study 1 didn't work, she asked the TAs to focus more on the qualitative notes rather than on the numbers. The qualitative feedback that they were asked to give in study 1 and 2 was in respect to the themes that they were asked to observe, but it was general; they were not specifically asked to leave a comment under each specific theme.

In study 3 however, the researcher explicitly asked the dance teacher and the TAs to leave qualitative feedback under each of the themes that they observed (T1 to T7) and used this information to map more easily their responses to the themes. These comments contradicted or confirmed what she found in the video analysis that she independently conducted in the analysis phase. In Study 1, the dance teacher and the TAs were asked to evaluate 5 themes (see Figure 3-8, left side) while in Study 2 and 3 their observation sheets were expanded to contain 7 themes for evaluation also called criteria (see Figure 3-8 right side). The framework for assessment is better explained in section 3.6 of this chapter.

child	Engagement with technology	Week 1	Week 2	Week 3	Week 4	Week 5
	Looks with interest at the presentation of Mazi' (Debby Attention Autism)					
	Approaches Mazi' with confidence					
	Touches notes to activate sounds					
	Plays notes together with peers or partner					
	Shows use of Mazi' for else than playing notes (e.g. deep pressure; patting; squeezing etc)					

Area of learning	Cycle 5		Year: 2019		
Social Interaction and collaborative Play	Week 1	Week 2	Week 3	Week 4	Week 5
Looks interested in the presentation of Olly (Debbie Attention Autism)					
Approaches Olly with confidence					
Pull to activate sounds					
Plays notes together with peers or partner					
Shows use of Olly for else than playing notes (e.g. deep pressure; patting; squeezing; climbing etc)					
Share emotions: express appropriate emotions (pleasure/calm) and he/she is able to self-regulate					
Share attention: When not in Olly's proximity, shows attention towards others interacting with Olly and follows what's going on					

Figure 3-8 Example of the observation sheet for TAs during study I (left); during study 2 and 3 (right)

After the testing sessions of study 2 and 3 ended, the teacher and TAs were asked further information e.g. their level of prompts, the children's engagement, if they noticed anything in particular, and so on. However, in study 1 this didn't happen because the researcher didn't think about it; in Study 3 instead, no face-to-face interviews were allowed due to the spread of COVID-19, thus the researcher sent them a questionnaire (see Appendix E for details on questionnaires).

3.5 Final evaluation framework

The framework for assessment also called framework for observation or evaluation, contained between 5 to 7 criteria or themes because the teacher and the TAs completed their sheets after each session, and the dance teacher advised that they would not have being able to keep track of more things. The dance teacher evaluated all the attending children individually while each TA observed the child or children that they worked with. Few examples of the completed observations sheets received in each study can be found in Appendix B, C, and D. The researcher, on the other hand, analysed all the video recordings by segmenting them first into 7 (study 1) then 8 themes for assessment (Study 2 and 2). In addition, she coded other behaviours that were driven by the data (see appendix G for a full description of the coding scheme used by the researcher). These are better explained in section 3.6.1. The results reported in each study therefore include a combination of the observations made by the teachers on the child or children they worked with during each session, the information collected in the post-testing interviews and questionnaires, and the analysis done by the researcher on the video recordings. The staff members were each given an observation sheet per session, before the studies commenced during a collective meeting organised by the researcher for each of the studies.

Theories of human interactions and social development were combined with the Garden school teacher's criteria for assessment and were used as a probe to extract data and create themes. This process is better explained in the analytic approach in section 3.5.1. As shown in (Table 3-3), the final framework is eventually made of 8 main criteria for evaluation (or themes). For example, **Theme 1 (T1)** captured whether the children exhibited any interest in the presentation of the TUIs, and **Theme 2 (T2)** captured the times that children spent approaching the TUIs. Hall (1966) in his description of interpersonal space, considered the space between two people to belong to a) the sphere of personal space - when two or more people are less than 1.2 m. apart; and b) the sphere of intimate space - when people are less than 0.45 m. apart. Thus, when looking at children's interactions it was considered an approach when children were not more than approximately 1.2 meters far from the TUI. **Theme 3 (T3)** reported whether the children touched the TUIs to actively play the sounds, while **Theme 4 (T4)** probed observations about whether the children played music together with their peers or with the adults, and **Theme 5 (T5)** showed how children used the TUIs.

Themes	Definitions	Analysis
Theme 1 (T1)	**Introduction to TUI**. Show interest in the presentation of the TUI (teacher Attention Autism)	Time each child spent: showing signs of interest towards the introduction of Olly by looking at it
Theme 2 (T2)	**Approach** the TUI	Time each child spent: approaching Olly independently (I), or receiving gestural/verbal (GP/VP) and/or physical prompts (PP)
Theme 3 (T3)	**Touch to activate sounds**	Time each child spent: playing sounds independently (I), receiving gestural/verbal (GP/VP) or physical prompts (PP)
Theme 4 (T4)	**Music making** together	Time each child spent: playing music together with peers, by themselves or with adults
Theme 5 (T5)	**Show unexpected use of TUI** (i.e. for else than playing notes such as deep-pressure, climbing, squeezing, patting etc.)	What types of unexpected uses, what parts of TUIs are of interest, and the rate of occurrences of different actions performed by the children when using Olly other than to trigger sounds
Theme 6 (T6)	**Share emotions**: express appropriate emotions, able to self-regulate	Time each child spent: displaying emotions i.e.: *positive, negative, giggles/over-excitement, vocalizations, running, jumping, playing around/hanging from curtain etc*.
Theme 7 (T7)	**Share attention:** Attentional focus towards other peers interacting with the TUI	Instances of common focus of attention.
Theme 8 (T8)	**Play Types**	Time each child spent: exhibiting different types of social play such as those in Table 3-2

Table 3-3 Final evaluation framework used to assess the TUIs

In **Theme 6 (T6)** the children's emotional responses were observed (positive or negative emotions, giggles/over-excitement, and instances of vocalizations), and **Theme 7 (T7)** captured whether the children's focus of attention was on the TUIs and peers, or if they sought adult's attention. The framework was expanded and refined throughout the studies. For example, in study 1 'Theme 6-Sharing emotions' and 'Theme 7-Sharing attention' were added by the researcher during the analysis of the videos because she found that those were important information that she didn't ask the teachers to evaluate. Therefore, in study 1, the comments of the teachers that are paraphrased by the researcher in the results sections under T6 and T7 quote things that fitted the description of these two themes but were not intended by the teachers to fall under these categories.

From study 2, the teachers' observations sheets included T6 and T7, but as already mentioned, the teacher and TAs were not asked yet to leave their comments under each of the themes. Hence, the teacher's quotes reported by the researcher under these two themes in study 2, were not originally given to each specific theme. By the time that study 2 finished **Theme 8 (T8)** called 'Play types' was added to the analysis carried out by the researcher on the video recordings. The definitions of the types of play observed by the researcher in theme 8 are described in Table 3-4. The researcher did not ask the teachers to evaluate T8 because of what they initially agreed about the numbers of themes to observe (5 to 7 and no more). In study 2, in the video analysis carried out by the researcher, T7-Share attention was changed to T7-Eye-contact because with the Onlooker play type in T8, it offered redundant information. In addition to Parten's stages of social play (Parten, 1932), the results reported under T8 include other types of social and non-social behaviours. These other types of play were observed because children were not always playing, but the researcher wanted to have a more holistic opinion of the children's experiences.

Categories of Play *(adapted from Parten 1932)*	**Definitions**
Unoccupied (U)	Child plays with own body/clothes, goes off/on bench, stands around, sits in corner, fiddles with string/symbols
Onlooker (O)	Child looks at other children but does not participate. This can be performed from beside people or from far away.
Solitary (S)	Child plays alone by doing imaginative play by vocalising on their own and running around/wiggling body, making funny body movements, spinning around the room, running around the space and or behind curtains. Child can also play alone with Olly.
Parallel (P)	Child is next to peers using Olly in different ways than that displayed by their peers i.e. touch felt and/or ribbons, speaker pouch, steps on speaker etc. Plays beside peers rather than with them.
Associative (A)	Child displays identical or similar activity (watching, copying). Children act as they wish, and the activity is not organised but there is a sense of togetherness and belonging
Cooperative (C)	Child actively engages in same activity. There are not spoken rules (child might sign to communicate to peer), but children influence or modify activity of others. There is a sense of belonging.
Child-initiated seeking of adults (CISA)	Child approaches adults to satisfy a sensory desire i.e. requesting legs massage, deep pressure on body parts, touching adult's ear lobes, armpits etc..
Child-initiated affectionate interaction with adults (CIAA)	Child approaches adults to request for comfort i.e. lays on adults laps, strokes adult face or body parts, leans with body on adults, hugs, caresses.
Pro-social interaction and positive response (ProS +)	Child initiates a social interaction and receives a positive response by peers or adults
Pro-social interaction and no response (ProS -)	Child initiates a social interaction and receives no response by peers or adults
Refuse to Join (RJ)	Child clearly avoids being prompted to Olly or offered a ribbon
Competitive (Cm)	Child clearly displays a competitive spirit i.e. by taking ribbons off adults' hands or pushing a peer away from Olly.
Turn-taking (TT)	Child clearly waits for his turn when other peers are on Olly.

Table 3-4 Theme 8 sub-themes

Child-initiated seeking of adults (**CISA**) was coded when a child-initiated interaction with an adult to satisfy a request; **child-initiated affectionate interaction with adults** (**CIAA**), was coded when a child-initiated interaction with an adult to give or receive affectionate interactions; **pro-social interaction**

and positive response (**ProS +**) when children exhibited reciprocated interactions, and **pro-social interaction with no response** (**ProS -**) when a child-initiated interaction with a peer but it was not reciprocated. R**efused to Join** (**RJ**) was coded when children refused to respond to an adult's prompt, and **competitive play** (**Cm**) happened when children exhibited conflicting behaviours. Lastly **turn-taking (TT)** behaviours were coded when children were waiting for their peers to either move away from the TUIs or to finish an action.

3.5.1 Analytic Approach: how theory influenced the themes analysed in the final framework

The mixed approach used for developing the framework was inspired by tenets of embodied interaction (Heath et al., 2010), principles of social interactions (shared use of technology, eye contact, shared attention, shared emotions, types of interactions, turn-taking, spontaneity), evidence-based assessment tools (SCERTS and teacher's assessments) and the children. The analysis of embodied interactions (Hall, 1966; Kendon, 1970; Lewis, 1998) helps researchers defining:

- the start and end point of an interaction
- the relation between members and their roles
- the shared focus of attention
- the level of participants' engagement.

Previous research on social bonding show that embodied interaction and nonverbal communication like gaze, posture, gestures, orientation, and facial expression can be valuable indicators of engagement as well as other communicative signs, both in dyadic and group interactions (Lewis, 1998; Kendon, 1970). Considering that children in the studies were minimally verbal and nonverbal these non-verbal interactions were observed in theme 1, theme 6 and theme 7 of the final framework for analysis. Kleinke (1986) and Webbink (1986) described the function of gaze as providing information such as (a) focus of attention, (b) regulate interactions such as managing turn-taking, (c) express intimacy, (d) facilitate task service and (e) express social control (Kleinke, 1986; Webbink, 1986).

These behaviours were therefore checked in theme 1, theme 6, theme 7 and theme 8. Following Kleinke's theory on gaze, Lewis proposes that the eyes are the most expressive tool of non-verbal communication that disclose what's inside our head and can "*signal intimacy, concern, naughtiness, joy, surprise, curiosity, need for* *approval, affection and love, pleading for mercy, attempts to fake, and so on*" (Lewis, 1998). Furthermore, smiling (observed in Theme 6) is a great indicator of pleasure, which in turn can help developing intimacy (Lewis, 1998). Recent studies on social development and autism indicate that eye-gaze, attentional engagement, joint attention, sharing experiences (i.e. proto-declarative pointing), objects and spaces, turn-taking and imitation are among the precursors of social development (Toth et al., 2006). It is reported throughout the literature that autistic children seem to show atypical social development, hence when evaluating the benefits of TUIs for social play and self-regulation it was important to look at the emergence of these basic skills. The dance and P.E. teacher's assessment measures (see Figure 3-9 for P.E. teacher's one) also inspired the final evaluation framework (table 3-3 and 3-4).

Fundamental Skills	Moving	Moves with confidence in various ways	Squats or sits on floor to rest or play and rises independently	Explores actively all space available	
	Objects	Shows curiosity about objects	Manipulates various objects	Uses equipment in unconventional ways	Uses equipment in conventional ways
	Attention	Initiates activities	Maintains focus for a short period	Maintains focus for a long period	Not easily distracted by environment
	Motivation	Engages in new experiences	Persists when challenges occur	Shows satisfaction in accomplishing goals	
	Understanding	Responds to simple commands	Collects objects on request	Follows simple instructions	Follows complex instructions
	Endurance	Endures during prolonged physical activity	Endures during "intense" physical activity		
Locomotor Skills	Running	Runs randomly	Runs rhythmically	Follows course	Evades stationary obstacles	Evades moving obstacles
	Jumping	Jumps up and down	Jumps forward	Jumps down form height	Jumps up to height
	Galloping	Moves forward using the same lead foot with trunk sideways	Moves forward using the same lead foot with trunk forward		
	Hopping	Hops on one foot with support	Hops on one foot independently	Hops forward	
	Skipping	Skips consistent pattern, irregular rhythm	Skips rhythmically		
Object Control Skills	Bouncing	Bounces ball away from self	Bounces and catches	Bounces continuously same hand	Bounces continuously alternating hands
	Kicking	Kicks stationary ball	Kicks slow rolling ball	Kicks fast rolling ball	Moves to kick ball
	Catching	Catches rolled ball	Catches ball slowly tossed to midline	Moves upper body to catch ball	Moves whole body to catch ball
	Throwing	Throws to stationary target	Throws to moving target	Throws with adequate force and direction	Adjusts throwing style to goal
	Combining skills	Combines two or more object control skills			
Body Control	Balance	Walks on a narrow path (ground level)	Walks on wide elevated surface	Walks on narrow elevated surface	Stands on one foot
	Tonicity	Sits on bench to relax	Lies down at request	Lies down still	Lies down, eyes closed, with no visible tension on face or limbs
Cooperative Skills	Partner	Plays with an adult	Plays with a peer	Plays reciprocal games (few exchanges)	Plays reciprocal games (many exchanges)
	Group games	Plays alongside others	Takes turns for same task (waiting and observing)	Plays in a group, for a common goal	
	Competitive games	Plays against partner	Plays in a team, against another team		
Sports Skills	Basketball	Bounces ball whilst moving	Shoots to hoop	Passes and receives ball whilst moving	Combines two or more previous skills
	Football	Kicks stationary ball to target	Passes to partner and receives in control	Controls the ball whilst moving	Combines two or more previous skills
	Badminton/Tennis	Hits moving ball, shuttlecock, balloon with racquet	Serves with appropriate strength and direction	Engages in exchanges with partner	
Analytical Skills	Self-assessment	Analyses own performance and compares it with previous ones	Recognises changes causes by exercise in own body: heart rate and temperature		

Figure 3-9 School assessment measures for P.E. that inspired the final evaluation framework

For example, ‘manipulates various objects’ and ‘uses equipment in unexpected ways’ under the **Fundamental Skills/Objects** of the P.E. assessment (Figure 3-9), is analysed in Theme 5-Unexpected uses (table 3-3). Whether the child ‘showed curiosity about objects’ (still under the Fundamental Skills criteria/Objects of the P.E. assessment) was observed in theme 1-Introduction to TUI and in T2-Approaches. In the ‘Group games category’ of the **Cooperative skills** domain in figure 3-9, the P.E. teacher looked at whether the child ‘played with adults or peers’, (observed in T8 and T4), took turns for the same task (T8), or played together for a common goal (T8 and T4).

Finally, ‘Share attention’ and ‘Share emotions’ were also part of the P.E. assessment criteria but are also key areas tracked within the Social Communication domain of the Joint Attention section of the SCERTS (Figure 3-10).

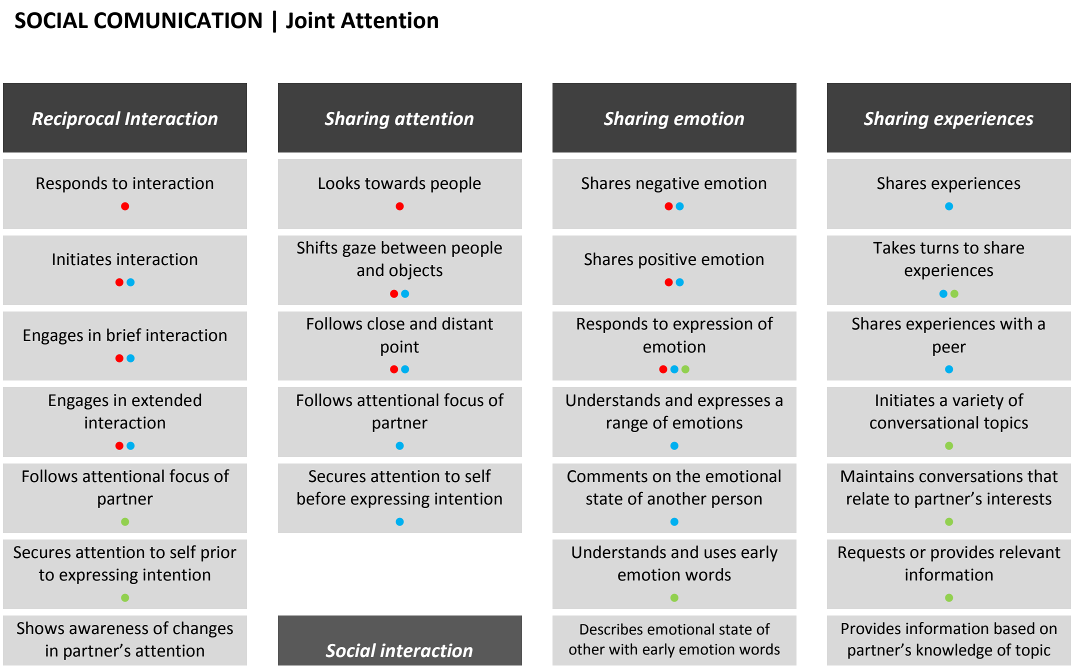

Figure 3-10 SCERTS assessment measures. Social Communication domain of the Joint Attention section of the SCERTS

3.6 Data analysis

Considering that the studies were aimed at minimally verbal to non-verbal children a behavioural analysis was preferred over an attitudinal one. As already mentioned, data analysis consisted of a mix of qualitative and quantitative data (see Table 3-5). This enabled the researcher to gather qualitative information (about what, how and when) and to combine them with quantitative information on (on frequency and time).

Types of Data Analysed
Audio recordings of pre-test and post-test interviews
Transcripts of audio recordings
Dance teacher and TAs observation sheets
Questionnaires
Video recordings
Video annotations

Table 3-5 Types of collected data for analysis

The quantitative parts of the results reported in each study display the percentages of time that the children were observed doing certain things. However, a frequency-based analysis was also carried out in T5 to evaluate how many types of unexpected uses of the TUIs were exhibited by the children. This helped understanding the different types of play that the TUIs encouraged and how applicable the technologies might be to different types of play. If two of the 7 or 8 criteria analysed by the researcher were conflicting, that is, if they happened at the same time, such as T6 and T7 which could happen together with any other themes, the results were all counted, and the overall percentage could exceed the 100% mark.

The qualitative inquiry on the other hand, was mostly based on the dance teacher and TAs' opinions gathered after each of the testing sessions in their observation sheets, and in the interviews and questionnaires post-testing sessions carried out in study 2 and 3 (see Appendix E for list of questions and examples of the returned questionnaires). As already mentioned the researcher used the comments left in the extra sheets of the observation sheets of the TAs and dance teacher, to confirm or discredit the results of the percentages analysed from the video annotations. Lastly, the observation sheets completed by the teachers were validated just by the researcher, that is, she was the arbiter of the assessments based on the analysis she carried out on the video recordings.

The video analysis of the video recordings was carried out using a flexible technique for the analysis of interactions in natural settings (Heat et al., 2010). To do this, a Codebook approach was used. Codebook encompasses approaches like Framework Analysis (Ritchie & Spencer, 1994; Smith & Frith, 2012) and Template Analysis (Brooks et al., 2015; King & Brooks, 2017). During the video analysis, this mixed approach enabled early themes development based on theory-driven concepts (literature) and data-driven ones (observed) and allowed the researcher to add some data-driven codes which were strongly linked to the data observed. Some examples are given in the following section.

3.6.1 Video Analysis

The evaluation carried out by the researcher on the video recordings, was expanded to include specific recurring sub-themes that contributed to a more in-depth quality of data, and which were in fact data-driven. These were also found in the literature to be important to social skills. For example, within **T2**, **T3**, and **T4**, the researcher looked at the levels of adult's prompts that children received - independent (I), gestural/verbally prompted (GP/VP), and/or physically prompted (PP). In **T5** she looked at the different uses that children exhibited of the TUIs, while in **T6** she noted down the various kind of emotions expressed by each child. In **T8** instead she looked at the types of play and other behaviours displayed by the children. An example of how the video analysis was carried out i.e. in study 3 for Theme 8 (Play Types) can be seen in Figure 3-11.

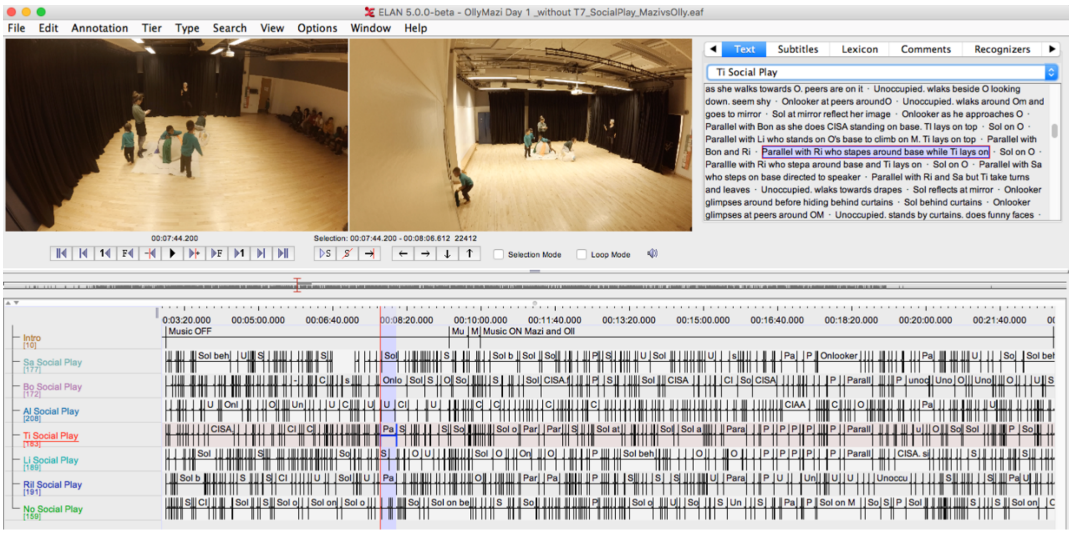

Figure 3-11 Illustrative example of video analysis annotations

The video analysis was done as it follows. The researcher watched all the video recordings once to first familiarise herself with the data. Then she carried out the video analysis over the entire duration of each video session. The analysis was done by creating content logs throughout the video timelines and was aided by the 7 or 8 themes presented in table 3-3, and their corresponding sub-themes discussed above and presented in (table 3-4). The transcripts of the annotations have been used to inform the analysis; the themes were used to contextualise the annotation's procedure. The transcriptions were mainly related to the visible conduct of the children and to their vocal expressions. An example of the extracted annotations is shown in Appendix F.

4 Design Study 1: Mazi

Note - Some of the content in this chapter has been published and presented at the *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, (Nonnis, and Bryan-Kinns, 2019a) and in *Proceedings of the 18th ACM International Conference on Interaction Design and Children* (*IDC '19*). (Nonnis, and Bryan-Kinns, 2019b).

This chapter reports on the first of three studies that investigated how haptic and auditory stimulation can be playfully implemented in school settings as an accessible and stimulating form of tangible interaction for autistic children. A shift in the interaction paradigm that sees design as a problem-solving activity is proposed, and the notion that autistic people should aspire to simulate neurotypical behaviours to adhere to societal norms is challenged by offering a methodological approach that embraces diversity and promotes designs that support repetitive movements and self-regulation. The aim was that of providing children with the most favourable environment and tools to socialize with peers. This was achieved by designing a system that was open, multimodal and multifunctional. This approach allowed to take a holistic view on the development of playful TUIs for autistic children, focusing on the broader context in which the technology is deployed, the ecology, not just the technology (Hourcade, 2015; Smith et al., 2013).

Five children of the Garden school aged between 6 to 9 participated to this first study. The testing phase happened for five weeks between April-May 2018 and was conducted in the dance studio of the school. The design of the first Tangible User Interface (TUI) developed for this study, named ‘Mazi’, is presented. Mazi is a sonic e-textile playful TUI designed, developed and programmed by the researcher, to explore the potentials of TUIs development as a channel to facilitate social interaction between autistic children, and as a way to provide self-regulation opportunities during play time in indoor spaces.

The study offers four contributions: 1) it presents an exploration of an e-textile sonic TUI called Mazi developed to support collaborative play in a group of autistic children; 2) it provides evidence of its impact on a group of five non-verbal autistic children with high support needs; 3) it presents an evaluation framework inspired by curriculum and evidence-based assessment, further developed for study 2 and 3; 4) and lastly it provides design considerations for developing TUIs to support social interaction among children with high support needs. The study presents a freshly grounded methodological approach in which methods intended particularly for

Special Education Needs contexts have been applied to the research methodology behind the technology. As explained below in section 4.1, these contributions helped addressing the main research questions.

This chapter presents the motivations behind doing the study, the study's procedure already introduced in chapter 3, which consisted of the formative phase, the iterative prototyping phase, the testing phase and the data analysis. This information is followed by, a reflexive discussion about the findings, the methodology used and the built system, an overview of the study's limitations and a final conclusion.

4.1 Motivations

The main idea behind this study was to explore the potentials of using tangible interactive technologies as a channel for encouraging social open-ended play during a scholastic activity. The questions that this study aimed to explore were the same as those reported in chapter 1.1.

1. How do groups of minimal to non-verbal autistic children respond to playful e-textile sonic TUIs? (mRQ1)
2. Can we design and evaluate playful e-textile sonic TUIs to provide sensory regulation and to encourage social interaction in nonverbal autistic children? (mRQ2)
3. Which design features of the playful e-textile sonic TUIs presented in this PhD are supportive of social play and sensory regulation? (mRQ3)
4. What are the challenges and opportunities created by playful e-textile sonic TUI designs when working with autistic children that have a high level of support needs? (mRQ4)

By developing a technology that was inspired by the children's likes and their sensory needs, it was hoped that the design would inspire an intrinsically motivating and socially engaged play while still being able to offer sensory stimuli that could contribute to the children's participation. As sensory processing abilities are correlated to participation in leisure activity among autistic children, it was important for the researcher to address this challenge.

4.2

4.2 Procedure

As shown in table 3-1, and mentioned above, this study was structured as it follows. It started with an initial **formative phase** and the **recruitment** of the children. This phase allowed a rich collection of information about each child through observations, field notes, teacher's interviews, Occupational Therapist's meetings, a parent's meeting, and the children's documentation, which enabled the creation of their profiles. The researcher worked closely with the school's therapists and the teachers, whose in-depth knowledge of children, alongside the researcher's previous experience at the school, facilitated the rich collection of children's data during the formative phase and offered some lateral co-design approaches, especially when designing for the space. This was followed by the **iterative prototyping** phase which describes the iterative process of the prototyped design, Mazi. This was piloted by colleagues at QMUL to avoid children's frustration caused by i.e. the inaccurate calibration of the sensor sensitivity or the instable interaction design. The **testing phase,** which took place every Thursday afternoon in the dance studio of the Garden in North East London, UK, explains in detail the set-up of the study's sessions and it is followed by the final **analysis,** where the researcher explains what types of data were collected and how the analysis was conducted.

The design process was constructed to align with the curriculum and practices of the school with sessions semi-structured to allow children to do what they liked most and to leave the sessions when/if they wished.

4.3 Formative Phase

In order to inform the design of Mazi, the researcher started the formative phase of this study in October 2017. This ended at the end of February 2018.

4.3.1 Participant recruitment

Children were recruited for the study under the advice of the Headteacher following these selection criteria:

a. diagnosis for autism
b. aged between 4-10
c. children with higher support needs/minimally to nonverbal
d. children challenged by sensory processing
e. children that respond well to music

Queen Mary University's Ethics of Research Panel fully approved the research and the parents of the participating children signed and returned their consent forms by the beginning of January 2019. Because children were young and mostly non-verbal, it was decided that parents should give their consent for the children. Children were also free to leave if they expressed so by showing signs of dislikes or dysregulation. This study refers to the children as Alice, Pete, Joshua, Tom and Leroy. Alice was a girl and the other four participants were boys.

4.3.2 Participants insights and data collection

For two to three weeks each child was observed during dance and P.E. and field notes were taken for each child (Figure 3-4). Class and dance teachers, Teaching Assistants (TAs), and one Occupational Therapist were interviewed to acquire more information about the children. During this phase, the researcher talked with the dance teacher to understand how to setup the space and to define a plan for the sessions. As discussed in chapter 1.3., the Occupational Therapist (OT) helped finesse the plans, and under her direction, attention was given to build a TUI that would scaffold social play.

To gain a deeper understating of each child, each class teacher and the TAs that worked with each child were interviewed on separate occasions. Most of the children and TAs came from different classrooms - apart from Alice and Leroy who were in the same class. The school's Occupational Therapist has been met twice. A meeting with all the parents was organised by the Headteacher in the formative phase and it was attended by four of the five children's mothers. This lasted roughly 1.5 hrs and was a chance for the researcher to explain the purpose of the research and to have the parent's feedback on potential designs that she had thought of during the first two weeks of observations. When she worked as a TA at the Garden the researcher worked 1:1 with Alice and with Tom as they were in the class that she was TAing in. Furthermore, Alice and the researcher were very close when they worked together. As shown in table 4-1 each pupil's profile, was made by collecting different sources of information about the children. Their pseudonyms have been abbreviated by using the first two letters of the pseudonyms i.e. Al stands for Alice.

From each child's Individual Education Plan (IEP) the children's current SCERTS stages were ascertained. Two of the children were at the Social Partner stage SP

(Joshua and Tom) and the other three (Alice, Pete, Leroy) were at the Language Partner stage LP (see Table 4-1).

Child	Likes	Dislikes	Support strategies	Age	Gender	SCERTS	1:1	P Levels
Al	Tidy, quiet, calm spaces; listening to songs; singing; edible messy play; drawing; mirror's reflection; blow bubbles, dancing; tickles; animals, dressing up	Crowded spaces; noisy environments; unexpected sounds; fast movements;	Encourage to use symbols or say no if she doesn't want something; give her space/time	8	F	LP		3; 4
Pe	Deep-pressure; puzzles; reading; familiar routine; being independent; quiet and calm environments; gymball; TV characters; shapes; joking; numbers letters; fiddling with fabric	Sit still; changes of routine; noisy environments; find hard to focus	Use individual timetable; wait symbol; offer to play with train set and/or reading; use PECS; use keywords, visual prompts, verbal communication and modelling; give big hug or offer walking; give him time/space	9	M	LP	x	6; 8
Jo	Manipulates fabric/ribbon; physical contact and deep massage; time in corner to self-regulate; dry textures; time at the corner, mirror, rocking; cover with a blanket; fine motor skills activities (i.e. threading, screws, torches etc); blankets	Waiting long; noisy environments; wet clothes; new people and textures; transitions	Touch lightly when I rock intensely; use OoR during transitions from one activity to another; use Makaton and simple language; encourage to make choice; show toilet picture and take me regularly	8	M	SP	x	4
To	Hula hoops; trampoline; therapy ball; deep pressure; denim jeans; nursery rhymes; vibrations; dry food; climbing	Messy play; wet textures; shoes and trousers on; loud noises; changes in routines; not having space	Use PECS; give me time before transitioning; offer encouragement; help with toileting; be aware that when I'm dysregulated I inch, scratch and pull hair; offer support to remain seated	6	M	SP	x	2
Le	Shows, people; movements; things happening; chewy tube; soft toys; running; music; dancing; chasing; straws; eating tiny things	Fans; Waiting, sharing toys and adult attention, sitting for long; transitions if not ready	Use a timer to count down when an activity is about to finish; give alternative options to satisfy sensory need (e.g. soft ball, stretchy dragon); help with toileting; give time to accept changes and transitions; Use keywords and visual support	6	M	LP		4; 5

Table 4-1 Summary of the children's profiles of Study 1

The pupils' Performance levels, already introduced in chapter 3.1, were varied. Alice was mainly at P-level 3 and 4; Pete ranged between P-level 6 and 8; Joshua was at

P-level 4; Tom corresponded to P-level 2, and lastly Leroy ranged between P-level 4 and 5 (see Table 4-1). The children's individual Positive Behaviour Support Plans and further discussions in various meetings with teachers and TAs enabled the researcher to determine each child's current likes, dislikes, triggers, and responses to triggers/events which were subsequently categorised and condensed in table format (table 4-1). Alice and Leroy were both accompanied by one TA, while every other child was assisted on a 1:1 basis. Pete attended the first lesson alongside his class teacher, instead of his usual TA, and arrived unaccompanied in week 4. It was agreed between the teachers that there was enough staff to keep an eye on all children. Alice and Leroy, who were both in the same classroom, attended the sessions with their class teacher on week 2, and with their TA every other time. The other two children always attended the sessions with their respective TAs. Attendance of the first session included the P.E. teacher - as she was curious to see the children's reactions.

From an interview Tom's class teacher said that: *"[Tom] Doesn't like much; in fact he doesn't interact much...He responds much better to structured environments. In unstructured activities he's either in the corner on a chair with fisher-price toy or he's in the pile of soft cubes"* and confirmed that he would really benefit from *"motor skills, engagement, social interactions and also extended interactions*". She added that he "*responds much better to sounds*" than any other type of toy. Joshua's class teachers instead said that he "*is over-responsive to sensory environments…He often overreacts because the environment is very stimulating for him"*. On the other hand, teachers said that Pete was "*a very visual child...loves pictures*". In addition they said that in class during attention autism Pete "*is the one that doesn't look, […] he's the one that most seeks your, your, the tapping, or sucking his thumb or he has one of those sensory cushions..but Attention Autism he's the one*".

During this phase, in a collective meeting with all the TAs and the dancer teacher, the researcher gave to each of them a folder with a copy of the lesson plan, pen, tracking sheet, 5-points rating scale guidelines, extra notes sheets, extra symbols, and Objects of References (OoR) (Figure 4-1).

Figure 4-1 Object of Reference OoR, prototype used for transitions and timetables

The OoR was hand made by the researcher out of a half tennis ball which she hand-felted to resemble the shapes of Mazi's interactive bubbles (Figure 4-2). The final design (Figure 4-6) was inspired by the children's observations and from previous works on playful TUIs, social interaction and e-textile found in the literature.

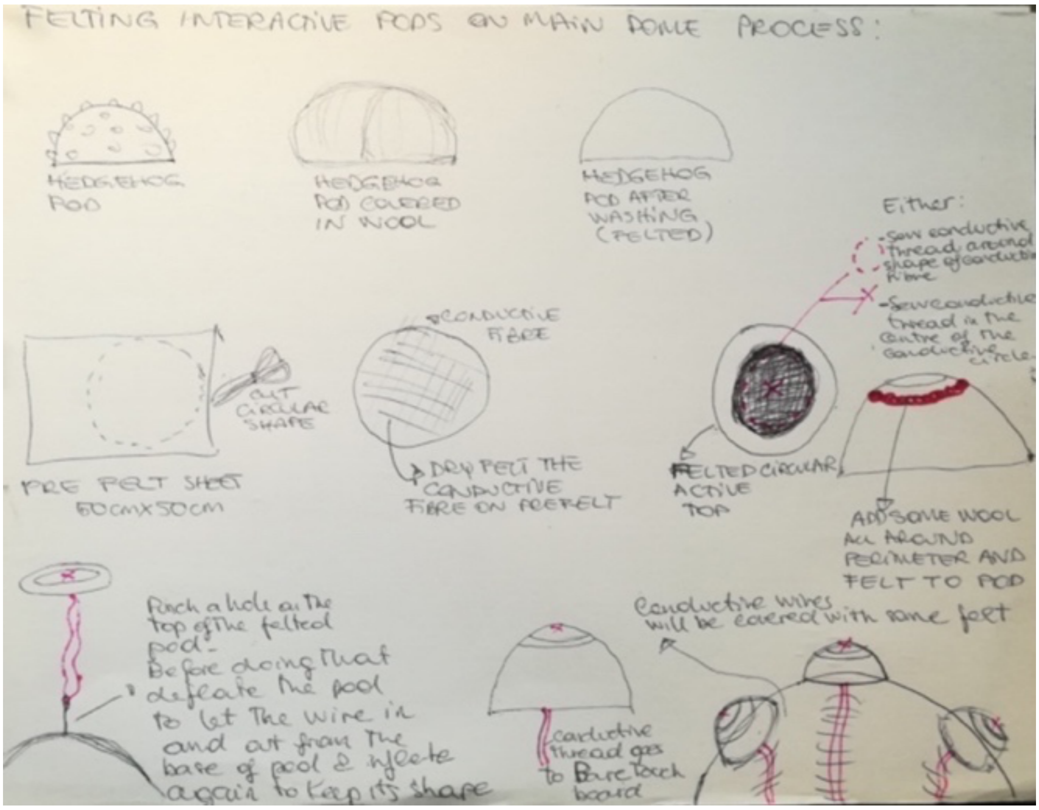

Figure 4-2 First sketches of Mazi; 3D sketches of the initial idea

For example, as previously mentioned in (pg. 88), while she observed the children in P.E. and dance lessons, she noted that the teachers used a big multicoloured nylon parachute to invited them to a group activity. The parachute is circular in shape and the children interacted with it either by holding its handles on the perimeter, or by standing/sitting under it. This influenced the first idea of wanting to build a large shareable and round TUI (Figure 4-2).

As shown in figure 4-3, some of the children liked to be rolled over an inflatable ball while they laid on it on their back or on their belly, others liked to bounce on an inflatable ball while sitting on it, some liked to balance on it, and few pressed their hands on the ball or squeezed smaller balls or malleable toys. Alice loved dressing up, and Joshua liked twisting textiles materials and fiddling with soft textures. Tom liked interactive musical toys and also loved rolling on the inflatable ball.

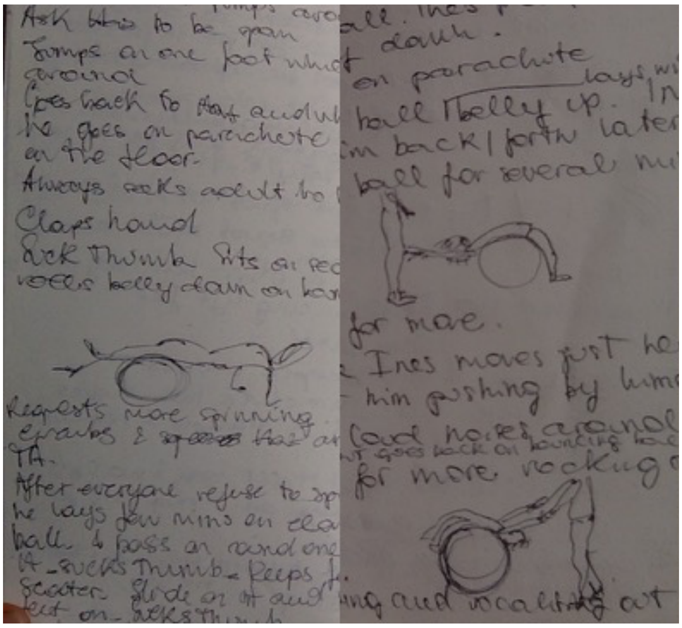

Figure 4-3 Field notes sketches of children's observations

This information influenced the choice of using e-textiles and a soft body that could reproduce the sensation given by the inflatable ball. By experimenting with different materials then the researcher opted to work with felt. The HCI literature lacked works that looked at stimulating social skills while also catering to the children's sensory needs. Considering the relation between sensory processing abilities, participation in play, social interactions and anxiety in autism, it was important for the researcher to address these challenges. In order to tackle this gap found in the literature, the TUI was designed as a big semi-spherical interactive toy that allowed the children to gather all around it and share it by having the same **access** and **entry points** (Hornecker et al., 2007) (Figure 4-2), thus facilitating social interactions. These were well defined by the physical and spatial affordances of the TUI. In Mazi **access** points were defined by characteristics such as the size and the number of inputs (*manipulative access*), the flow of interaction allowed with the

TUI (*fluidity of sharing*) - defined by the types of sensors, their disposition, colour, output, and around the TUI (*perceptual access*). The qualities of the mediums used such as the felt, the colours used, and the sonic interaction design, but also the overall shape of Mazi, worked as points of attraction or *honey pot effects* that stimulated children's curiosity. These defined the TUI **entry** points.

Mazi allows people to play up to five sounds polyphonically and it was designed with the children at heart. It was developed following shareability principles such as that of entry and access points. The former represented by the shape of the piece, the type of interaction it offers, and the colours used, and the latter denoted by characteristics such as the disposition of the coloured bubbles, the polyphony of the instrument, and its affordance. People can press, sit, climb, lay on the main body and touch the tops of the coloured bubbles to activate the sonic outputs but they can also use it in different ways.

4.4 Iterative prototyping phase

Given the exploratory nature of the study the development of one TUI was prioritised. The physical materials were chosen to be resilient and to provide means for deep-pressure through the soft yet quite rough texture. A mix of bright primary and secondary colours, in keeping with colours used in the school, were chosen to help attract attention to the active sensors' areas and as already mentioned, to define entry points. To develop the digital aspects of Mazi, the researcher bought a Bare Touch Board which she used in MIDI mode. The Bare Touch Board is a circuit board that uses capacitive sensing to detect proximity and touch, and it allows to play up to 64 sounds polyphonically. The circuit board was sewn onto a felted A4 green sheet of wool and was connected to five pieces of silver jersey fabric sewn by the researcher on top of the coloured bubbles by using some conductive thread. The wool onto which the circuit was sewn was green because it was left over from a sample of felt sheets that she bought. To make the interactive bubbles, the researcher enclosed five inflated balance hedgehogs (figure 4-3) in two layers of 5 mm thick polyester wadding, which was then covered by several layers of merino wool fibres. These were felted using both wet and dry felting techniques. The hedgehogs were spikey round balls made of PVC often used for yoga, massage or balancing exercises (see Figure 4-4).

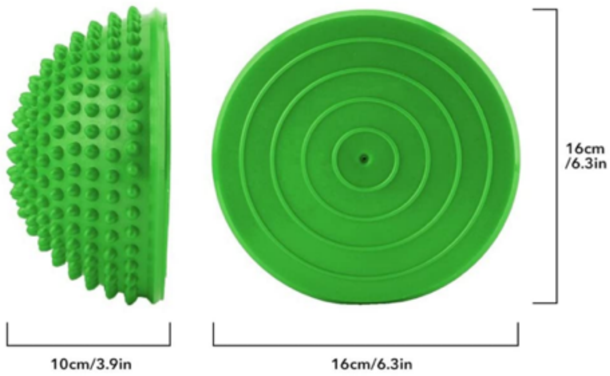

Figure 4-4 PVC hedgehogs used as the base for the interactive bubbles of Mazi

Here the researcher repurposed them to become the base of the interactive bubbles which she felted onto Mazi's body. Lastly, patches of conductive jerseys were sewn on top of the padded and felted hedgehogs to make them interactive (Figure 4-5).

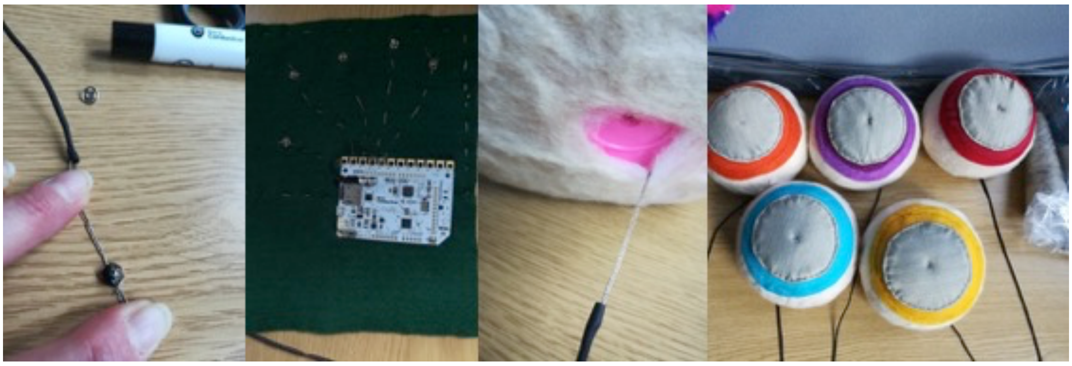

Figure 4-5 Mazi: bubbles and circuit under construction

The main frame of the installation was a soft-play piece of equipment, bought from a UK manufacturer of soft-play structures and products[17] and it can be seen in (Figure 4-6 on the right side).

Figure 4-6 Mazi: body under construction

[17] https://www.softbrick.co.uk/products/soft-play-roundabout#

This was covered in wool roving which fibres were felted onto it by the researcher through a process of wet and needle felting conducted in the home of the researcher which took about two weeks. Cables and circuitry had all been covered by strips of felted wool and, in order to make the installation stand-alone, Mazi was battery-powered (3.7 V 1.200 mAh Lipo battery cell) (Figure 4-7 left).

Figure 4-7 Mazi: finished design

The Lipo battery was chosen as it is smaller and more powerful than typical NiMH batteries. The Lipo battery has a flat design and was securely hidden within Mazi, inaccessible to children who were always supervised when using the technology. No sharp objects were present during the activity that could have damaged the battery, and the battery had an onboard circuit to prevent the risk of damage. Alongside being fire retardant and self-extinguishing, felt is also a chemical retardant and has thermal insulating properties.

For the first 3 weeks each of the five bubbles when they were touched triggered a note of a pentatonic scale of an acoustic piano based on C major (specifically the 1st, 3rd and 6th grades of the C major Scale). This generally allows for harmonic series of notes to be played without dissonant intervals - even by untrained musicians therefore this approach was preferred.

Also, in dance and or P.E. lessons, the teacher played melodic and/or rhythmic music and children responded well to them. Following the teacher's suggestions however, from week 4 the notes were changed with a combination of sound FX, as she believed that these could be "*funnier*". Appendix A shows Mazi wiring diagram and schematics. The process of prototyping continued throughout the testing phase following the teacher's suggestion i.e. an extra speaker was added to the TUI as they advised that the sound should be louder.

4.5 Testing phase

As the prototyping phase finished on the 26th of April 2018 the testing phase began. This section explains in detail how the sessions were set-up and how they took place. As illustrated in table 4-2 each session's length varied. Children are represented by a coloured star in table 4-2 to indicate whether they attended the session. All the sessions were video recorded.

MAZI	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5
Total duration of each session displayed in minutes: seconds (includes Introduction's times)	**** 22:42	***** 20:31	***** 21:10	*** 26:36	***** 27:02
Duration of the Introductions times only, displayed in seconds per session	114	93	64	114	113
Children representative colour: Alice*; Pete*; Joshua*; Tom*; Leroy*					

Table 4-2 Sessions' length and visual representation of daily children attendance

As shown in chapter 3 (figure 3-6) the video footage was captured using three video recording devices; two mini cameras (Xiaomi Yi), one attached to a wall via Velcro®, and the other attached on top of a cupboard already in the room. One iPad was positioned on a stand next to one of the walls of the room, mainly to provide a more close-up view. These recordings offered three different points of view. Unfortunately, the iPad was switched off a few times during the sessions, leaving just two points of view for the video analysis of those days.

For the first two weeks the activity started by having the tangible on the floor of the dance studio covered by a cloth, so that as the children were coming into the room they could see the installation. Due to the fact that the children were arriving at different times, from week 3, it was decided to put the technology in a storage room adjacent to the dance studio, and to take it out just before the Attention Autism inspired song, 'under the cloth', started. When all the children had taken their shoes and socks off, the dance teacher, with the support of PECS sequenced on a timeline attached to the wall, started the session by saying hello to everyone, and introduced the technology to the children "*It's time for Mazi*" she said. Then, she usually sat on the floor, on her knees, in front of the covered tangible, and started singing a song "*I 've got something under my cloth, under my cloth, under my* *cloth, I've got something under my cloth, I wonder what it is*". This was used to capture the attention of the children.

Following Attention Autism practices, every TAs, including the researcher, started singing along with the teacher and made surprised faces and very exaggerated vocal expressions when the technology was uncovered. After this introductory moment, it was up to the children to come and play spontaneously, but if they didn't, the dance teacher invited first the adults, to model the interaction, and then the children to try out the technology (Figure 4-8). The invitation was verbal or by using or gestural prompts, but if a child was seen by the teachers or TAs to needing direct support due to being too shy or not confident the TAs then used physical prompts to accompany them to the Mazi. Children however where not forced to approach, so if the provided resisted the prompts they were left free.

To signal that the session was finished and to give enough time to each child to process what came next, the teacher usually started a count-down from 5 and then covered the technology using the same big cloth used at the beginning. As two of the children knew the researcher (Alice and Tom) from the previous years that she worked at the school, it was decided by the dance teacher that she had to be part of the experience. Therefore, she was introduced to all of the children (the first day) and invited to take the lead in congratulating each of the pupils for the good play they did that day. Eventually, the Dance Teacher closed the session inviting the pupils to put socks and shoes back on and waved goodbye to all of them.

Figure 4-8 Children playing with Mazi

The parents were given some pictures extracted from the video recordings alongside written feedback every Friday afternoon. This information was exchanged between the parents and the researcher by using each child's bags and it was a way to share with the families what was observed during each gathering (testing day).

4.6 Data Analysis

As discussed in chapter 3, the children's observations were completed weekly by the dance teacher and the TAs working with each child with respect to the five criteria, also called themes. An example of the observation sheets can be seen in (Figure 4-9).

Class:	**Area of learning**	**Cycle 5**		**Year 2018**		
Name of child	**Engagement with technology**	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
	Looks with interest at the presentation of Mazi' (Debby Attention Autism)					
	Approaches Mazi' with confidence					
	Touches notes to activate sounds					
	Plays notes together with peers or partner					
	Shows use of Mazi' for else than playing notes (e.g. deep pressure; patting; squeezing etc)					

Figure 4-9 observation sheet given to TAs and dance teacher

Furthermore, they were given an extra sheet of paper to write any additional information they thought were important. The dance teacher observed all the five participating children, whilst each TA evaluated the child(ren) they worked with. The TAs were told that they could use the 5-points rating system as a prompt to their evaluations, and as already explained, unfortunately the majority of them based their feedback on that. Few examples of dance teacher and the TAs feedback can be found in Appendix B. As a reminder, the TAs and the dance teacher were asked to give an overall assessment of how the children's responded following 5 themes for observations:

T1. Introduction to TUI (teacher Attention Autism)

T2. Approach the TUI

T3. Touch to activate sounds

T4. Music making together

T5. Show unexpected use of the TUI

In the analysis conducted on the video recordings by the researcher, the frequency of three types of behaviours such as independent (I), gestural/verbally prompted (GP/VP), and/or physically prompted (PP) have been checked for each of the pupils against T2-Approaches, T3-Touch to activate sounds and T4-Music making together. The TAs and the dance teacher rated the children's independence following the 5-points system introduced in chapter 3, but the ratings given by the them did not match for some of children therefore they were not considered in the final analysis. Also, they lacked any particular descriptive information, therefore the researcher decided not to use them.

In T4 the researcher further looked at if the children played together with their peers or with the adults, while in T5-Unexpected use, the rate of occurrences of the children using Mazi unexpectedly was checked alongside the time that children displayed this use. As explained in chapter 3, T6-Share emotions and T7-Share attention were added to the video analysis done by the researcher post-sessions and were not part of the teacher's observation sheets. Within T6, the researcher observed four data-driven behaviours: positive and negative emotions, giggles/over-excitement, and lastly instances of vocalizations. Finally, the quantitative analysis of T7 captured if a child showed attention towards Mazi or sought adult attention/did Intensive Interaction with adult.

The researcher was always present throughout the five sessions. After each session, the dance teacher and the researcher exchanged feedback about the activity, and notes were taken to help to improve the experience along the way. For example, because some children arrived late in the first sessions it was decided to move Mazi in a room adjacent to the dance studio until all children were in the space.

Lastly, the video analysis was carried out by the researcher using the ELAN software and, as explained in chapter 3.6 she applied a mix of theory driven and data-driven framework analysis following a qualitative inquiry approach inspired by Heath et al. (2010).

The qualitative analysis is mainly made of quotes taken by the dance teacher and the TAs observation sheets after any of the testing sessions in the extra sheet that they were given. The quantitative results instead were provided by the annotations of the video recordings done by the researcher. Annotations with logs of timings enabled her to calculate the amount of time that certain behaviours and emotions were exhibited by a child and to understand the level of children's engagement in performing different play and behaviours. Inside each annotation, the researcher noted a brief description of what happened within that time and used it to drive her analysis. The annotations were then exported and analysed using MS Excel, which was also used to produce the following graphs.

4.7 Findings

As mentioned above the ratings given in the 5-points system by the TAs and dance teacher presented some practical challenges and these results were not taken into consideration or reported due to the low level of agreement between the teachers (68.18%), the inconsistent completion of the TAs, and the lack of details provided by such numerical information. As seen in Table 4-2 the length of each session changed over time. The total amount of time of all the five sessions from start to end was of 118:02 minutes. The duration of the introduction to the TUIs (T1), which indicated the start of the testing, was calculated over the sum of the total sessions and is equal to 08:18 minutes. Percentages were calculated as proportions based on the individual attendance of each child and on the amount of time that they spent displaying what was observed. Minutes were converted into seconds and then percentages. For those children who were not present at all the sessions, their evaluations have been done over the sum of the times they attended. The following sections present the results for each of the seven themes.

When adding together the overall results of T3 and T5 the overall percentage of time that the children interacted with the TUIs is obtained. The remaining percentage refers to the children being in the near proximity of the TUI, often sat around the TUI but not necessarily directly interacting with it.

4.7.1 T1. Introduction to Mazi

To check children's attention, their gaze, postures, body orientations and behaviours, were coded during the 'introduction's times'. T1 was calculated from when the dance teacher welcomed the children by saying hello, to the end of the 'under the cloth' song. Generally, if a child was oriented toward the TUI (and dance teacher) and was looking at it (or the dance teacher), that was annotated as an interest toward the introduction. However, children might have been looking at the immediately adjacent environment around Olly, and not directly at the TUI, or at the people around it. Therefore, the researcher could potentially have misinterpreted the children's intentions. The results as shown in figure 4-10 suggest that the Attention Autism inspired introduction captured the children's attention and overall worked well to introduce Mazi to the group.

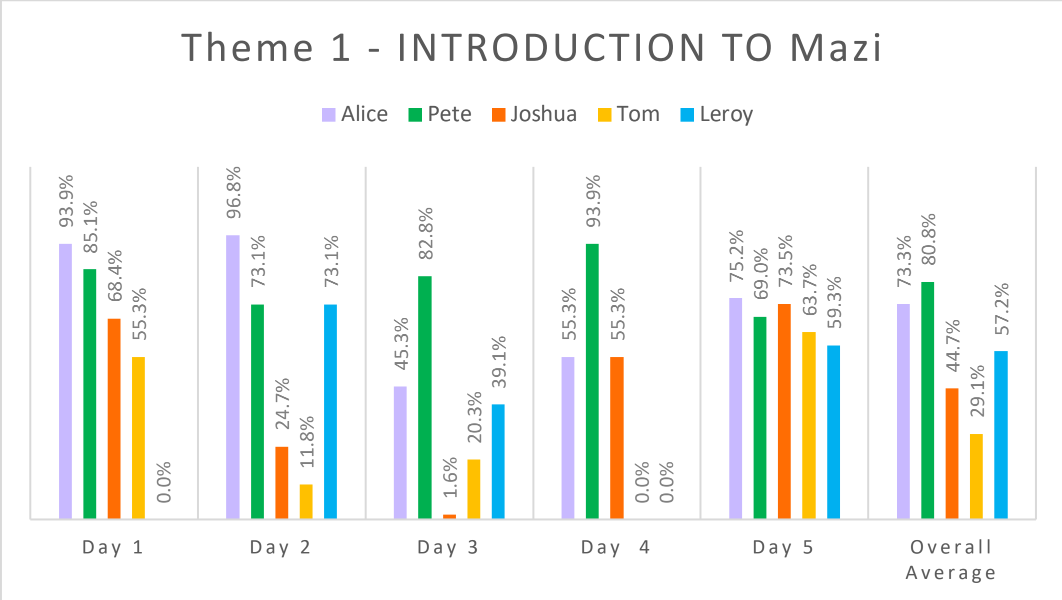

Figure 4-10 Daily displays of interest by child shown in percentages

This is demonstrated by the percentage of time that the children have looked toward this part of the activity, which in the case of Alice, who attended every session, happened for an average of 73.3%. In day 5 Alice was happy and smiled while looking at i.e. the door opening to slide Mazi in the room, and at Mazi being positioned in front of them. Then she kept looking at Mazi and the dance teacher for almost all the duration of the song and finally looked at the peers that were approaching Mazi. Pete also attended all the sessions and showed the highest percentage of interest toward this part of the activity (80.8%) which was quite impressive as it was reported by his teacher that in class he didn't pay attention to it (see section 4.3 above). As soon as the song started in session 5, Pete looked at Mazi and the dance teacher with interest and kept looking for several seconds (36). Joshua throughout the five weeks demonstrated an interest equal to 44.7% of the time. Although not the highest score, this was a positive result for him especially when considering what's been reported in the pre-testing class interview (see formative phase, section 4.3). Again, in session 5, Joshua looked at Mazi getting out of the storage and into the room, then kept looking for few more second after the song started but lost interest and looked at his fingers and started fiddling.

Tom instead, turned around from the back of the room and spontaneously looked at Mazi still covered, then he approached it. He sat on Mazi's, but as it was still covered by the cloth, the dance teacher prompted him to help her to uncover it, then played some of the sounds to show him how Mazi worked. He attentively watched, smiled and went to sit back on the bench. Tom was absent on day 4 and left after 17 minutes on day 3. It's worth noticing that on day 1 his class teacher and TA reported that he was already distressed before coming to the session, and this might have affected his initial ability and willingness to focus on the events. Although Tom is the child that exhibited less interest in this part of the activity (29.1%), on day 3 and day 5 he went towards Mazi as soon as the song ended. On day 3 he helped the dance teacher uncovering Mazi and leaned on it while smiling and making eye contact with the dance teacher, and on day 5 he climbed on Mazi as soon as the dance teacher removed the cover. The dance teacher wrote after day 5 that "*Tom Entered the room - looked around and smiled...During the Attention Autism -under the cloth he approached independently - looked and touched.*" Although he was not looking toward Mazi or the dance teacher during AA, Tom was paying attention to what was happening within the presented activity. In day 2 his participation might have been affected by the fact that he arrived late as the dance teacher said that "*The delay in the start of the lesson affected C4. I span with him which distracted him".*

That day the dance teacher said the same of Leroy "*arrived late…this affected his initial engagement".* Leroy attended just three sessions and exhibited an interest toward the introduction that corresponds to 57.2% of the time. From the information gathered about Leroy the researcher knew that he was a very curious boy, and this showed throughout the weeks and also during the introductions, as he sometimes looked at people passing by the corridor or moving around the room and turned back his attention to Mazi after few seconds. In day 5 for example, he looked at the timetable and at Mazi getting moved into the room. Then he looked at the door and around the room but looked again at Mazi and the dance teacher as soon as she started playing the new samples. Leroy was off in day 4 and didn't have the chance to hear them yet so he looked quite curious about the new sounds.

4.7.2 T2. Approach Mazi

If the child was in near proximity of Mazi even though they were not necessarily interacting with it, it was coded within Theme 2. T2 was calculated over the times that a child attended minus the introductions, therefore from when the TUI was uncovered to when the teacher started the count down. If a child went to the toilet, or left the room, the time that they were out of the studio was detracted from their overall attendance time of that day and the reported percentages reflect that. The daily approaches of children can be seen in figure 4-11.

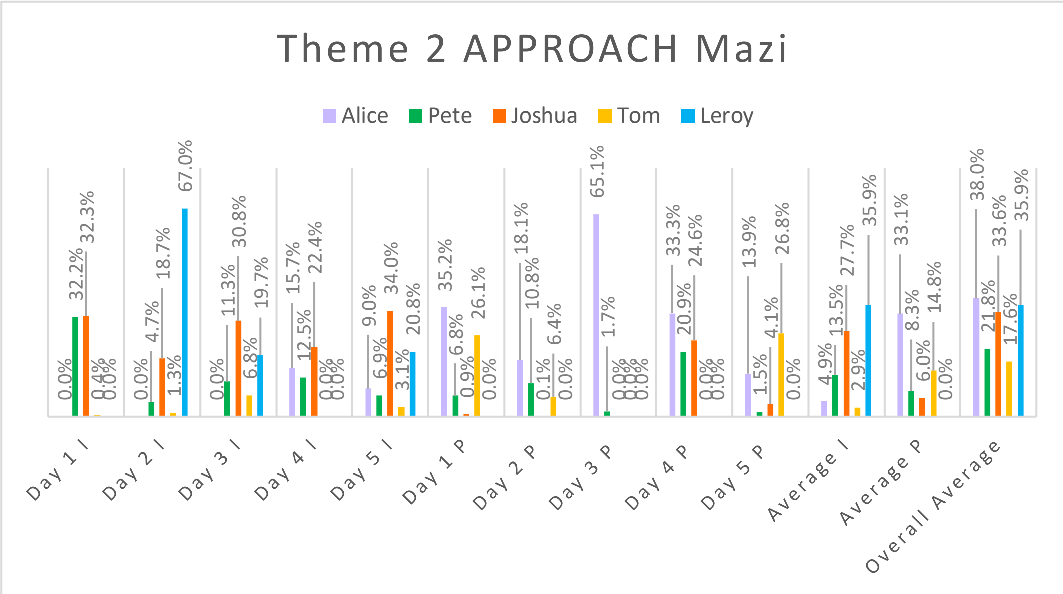

Figure 4-11 Daily independent and prompted approaches by child shown in percentages

The graph shows the daily approaches of children and those where they needed some sort of prompts (either verbal, gestural or physical). The overall time that Alice spent approaching Mazi corresponds to 38%. Most of that time she was physically prompted, but over time, especially after week 3, her confidence increased, and she started to approach and play independently. For example, in day 5 at a point she was directed to Mazi by a TA. She looked actively engaged and independently played the top bubble after the TA modelled the interaction, then she laid on Mazi's top and slid it across floor pushing it with her knees in front of the mirror where she looked at herself leaning on Mazi.

Pete approached the TUI mostly independently (average of 13.5%). The overall time he spent approaching Mazi is equivalent to 21.8%, and day 4 was the session where he received more physical prompts (PP). Pete was the only child that over time showed diminished interest towards the tangible. However, on day 2 for example, he hopped towards Mazi as he entered the studio, but two pupils were late, so he was prevented from interacting with it by the teacher and was span around as a diversion. As it can be read from the dance teacher and TA's extra notes of that day, the spinning distracted him: "*[Pete] wanted to play with it immediately trying to move Mazi to a different part of the studio. I had to prevent this as I was waiting for other pupils who were late. To distract [him] I did spinning which distracted him*".

Also, on day 3 the extra notes of his TA read: "*He was distracted because of the symbols. He also listened to one song very exciting for him before Mazi time. He could have been over-excited because of that*" and the dance teacher said, "*not focussed today - he was distracted by everything, symbols, me*". However, she also said that Pete was *"happy in the environment"*.

As seen in section 4.3 his teacher, she said that Pete "*is a very visual child...loves pictures*" and this passion was displayed on day 3, when throughout the session he took two or three symbols off the timetable and observed them. This was interpreted as a way for him to get used to the new environment and activity. However, as confirmed by the video recordings, throughout the sessions he preferred to play in solitary mode, by sliding Mazi across the floor away from the other children and found unexpected uses for the TUI, such as climbing and laying on it. In day 5, he sat on Mazi and played repeatedly all the different sounds making few exchanges with a TA, he looked excited, then he pushed Mazi towards the curtains and climbed on it to pull his body up with his hands on the curtains.

With regard to Joshua, it was reported that he did not like soft toys, playing with objects, or interact with the environment. When compared against these claims, Mazi was a successful tool that promoted both collaborative (see T4), and independent play (average of 27.7%). Joshua also required some PP 0.5%, and VP (average of 14.3%) to approach Mazi. After day 2 the dance teacher observed that he moved "*in the space with his ribbon he independently approached Mazi requiring no prompts*". Joshua, half way through the session, stopped playing with the curtains and independently went to play with Mazi while other TAs and peers were around it.

On the contrary, Tom spent 17.7% of the time he attended in Mazi's proximity, of which a total of 14.8% was done with PP, while 2.9% was independent. Although he was absent one day and left earlier on day 3, his confidence and his tolerance toward sharing places and other people appeared to increase over time. His TA confirmed that the environment was "*Possibly too intense; lots of adults and children interacting with Tom and making noise...* [..] *Appeared to increase in confidence with Mazi as weeks progressed.*" After 10 minutes into session 5, Tom was held by the dance teacher and prompted to Mazi, but many peers and TAs were around it and he refused to stay. He calmly walked back on the bench. Interestingly, Leroy, who's among the youngest of the group, always approached Mazi independently (average of 35.9% of the three sessions he attended). He spontaneously approached Mazi after having wrapped himself in the curtains for less than a minute and tried out the different notes. He was very attentive, and he was focused on his actions. Then he laid on Mazi and stayed there for several seconds.

4.7.3 T3. Touch to activate sounds

Within the times that the pupils approached Mazi, Theme 3 (T3) captured how long each child spent playing with it by touching the different bubbles to activate sounds. T3 was calculated over the time displayed by each child's daily approaches and indicates when a child played music. The daily musical activities of children shown in figure 4-12 are displayed when children triggered sounds both independently and by receiving prompts. For example, Alice activated the sonic outputs for an average of 5.7% of the time, of which 4.9% was done playing independently, 0.6% with physical prompts (PP), and 0.2% with verbal (VP) or gestural prompts (GP). On day 4, she played independently for longer, but she still received some prompting, while on day 5, even if she played just for few seconds, she played just independently.

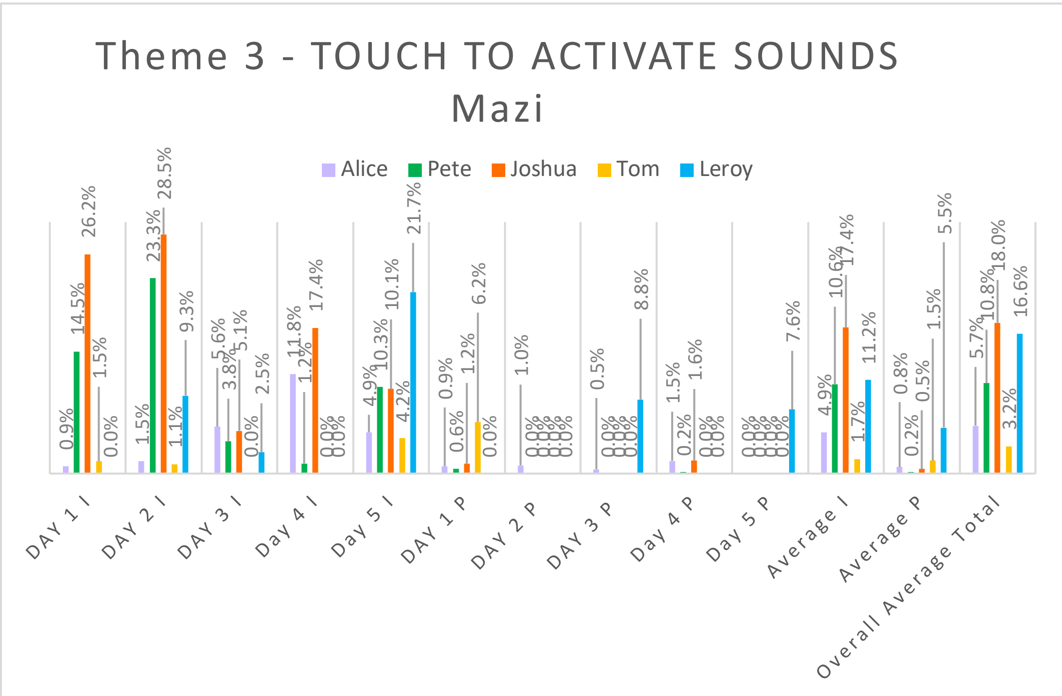

Figure 4-12 Theme 3. Graph showing percentages of daily sounds activations counted per child with prompts and independently in study 1

She often touched the blue bubble (after the audio samples had been changed), possibly indicating a preference for the sound assigned to that sensor. She also smiled as a reaction to the sounds played by her. Prompts were diminished throughout the five weeks, and the last day, although for a very short amount of time, she played with Mazi just spontaneously. On the other hand, Pete played for an average of 10.8% of the time including 10.6% of the time independently, and 0.2% by receiving prompts. When playing sounds, he usually patted the bubbles to receive some sort of deep pressure, which he usually satisfied by holding and patting/pressing a TA's hand. Especially on day 1, he also smiled after touching the bubbles.

Joshua instead was the pupil that engaged the most with the sonic feature of Mazi. He spent an average of 18% of the time activating sounds, of which 17.4% were independent actions. Joshua did not show any preference toward any specific sound but smiled several times throughout the sessions after playing the bubbles. He was also the first one that on day 1, after the song finished, independently sat on Mazi and started playing all the bubbles with one hand while sucking his thumb with the other and laughed as a consequence of his actions. Throughout the sessions, he sometimes played the sounds while his TA was singing in the background. From day 1, the dance teacher noticed that he: "*Engaged immediately with Mazi. Created sounds using his hands, body and feet…*". After day 3 his TA reported that Joshua is *"very familiar with Mazi. He enjoys playing the different notes"* and after the last session she wrote that "*Joshua again did amazing today with Mazi, he waited patiently (whilst doing other things) to approach Mazi with confidence and played the different notes"*. When the sounds were changed, from day 4, the dance teacher observed that he "*was fascinated by the new sounds - gained his attention*".

Tom on the other hand, played with Mazi for the least amount of time (average of 3.2 %), of which 1.7% was done independently and 1.5% receiving prompts. Although it was reported by the TAs working in his classroom that Tom responds well to sounds, the TA that accompanied him to the sessions wrote: "*Tom enjoyed climbing on Mazi, not sure how much he responded to sounds"*. Possibly, to fully enjoy the sonic features, Tom needed more time. Lastly, Leroy spent an average of 16.6% of the time playing sounds, and the majority of this was done independently (11.2%), but he also received prompts (5.5%). Particularly on day 1, Leroy tried and played all the different notes. The last day he attended (day 3), he initiated instances of explorative and collaborative play with two TAs, which are better discussed in the following section.

4.7.4 T4. Music making together

As shown in graph 4-13, in Theme 4 (T4) it was observed if a child played with other children, with the adults, or if they played competitively. T4 was also calculated over the children's approaches. The amount of time that a child spent playing the TUI solitarily, that is, when nobody else then them was playing music with it, can be obtained by subtracting the overall results of T4 by T3.

Generally, the dance teacher stated that "*there's [sic] lovely 2-3 ways interactions happening [sic] and children are enjoying it*" and that the researcher "*should be happy already about the spontaneity and independence that's happening*", as children generally received a big amount of prompting. When combining the percentages of playing together with adults (2.3%), with peers (1.3%), and competitively (0.7%), Alice spent an overall time playing with others equal to 4.3%. The analysis shown in figure 4-12 reveals that the child played notes several times independently and sometimes collaboratively.

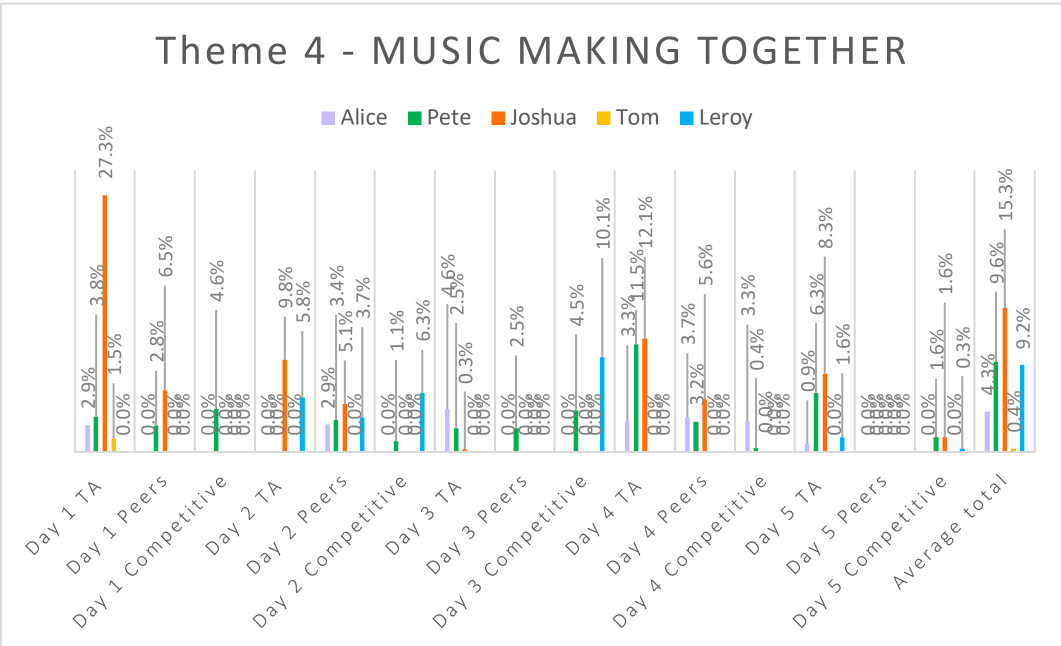

Figure 4-13 Theme 4. Graph showing percentages of children playing music together shown daily per child in study 1

Alice really started expressing herself and initiating interactions with Mazi from day 3, and with the adults from day 4, suggesting that Mazi was a positive social stimulus for her. Pete instead played sounds for an average of 9.6% of time and played with peers and competitively for the same amount of time (2.4%). When displaying competitive behaviours, he slid Mazi across the floor away from the rest of the group. He also played with the adults for an average of 4.8% of the time demonstrating some sharing abilities and awareness toward the concept of working together by saying the word "*together*" as he went toward Mazi and exchanged few notes with an adult.

Joshua played music with others for an average time of 15.3%. In day one the dance teacher reported that he exhibited "*3 way interaction with Alice and Pete creating music*". This was particularly impressive because it was said by his teacher that it was difficult to engage him in unstructured activities. The dance teacher reported in the extra notes after day 2 that "*he was smiling. [..] Joshua joined whoever was exploring Mazi touching and looking".* Like the previous two children, he played sounds together mostly with adults (11.6%), then with peers (3.5%) and lastly competitively (0.3%). Joshua played competitively (just once) by sliding Mazi across the floor and to the corner where he sometimes stood. Contrarily to the rest of the group, Tom played sounds together with an adult just once (total of 1.5% displayed in day 1, corresponding to an average of 0.4% of the time he attended). The researcher was informed by his class teacher that, Tom would "*not initiate interaction with peers*". The dance teacher confirmed that it would take some time for Tom to get used to the new situation and people.

Leroy on the other hand, performed several sonic exchanges while playing with adults, and generally spent 2.5% of the time playing with the TAs, and 1.2% played alongside peers. He also did some competitive play (5.6%), especially with Pete. During the last day, while two of the TAs were keeping the rhythm, one by clapping and the other by patting on Mazi, Leroy activated two sounds simultaneously for a prolonged period of time (more than few seconds). The dance teacher and Leroy's TA interpreted this as the child wanting them to play his game on his own rules. The TA observed in the extra notes that Leroy "*is aware of Mazi. He can touch and create sounds. He's more interested in adult interaction. He is not interested in playing as a group. He tries to encourage the adult away from the group to play his game*". By contrast, in the video analysis, it appeared that Leroy was exercising his coordination and motor skills and the researcher thought that certain dynamics, such as one of the TAs moving Mazi away from Leroy and toward another child, might have accidentally interrupted what was potentially a collaborative moment between the Leroy and the adults playing along.

4.7.5 T5. Show unexpected uses of Mazi

Within the approach times, theme 5 describes how long a child spent interacting with Mazi unexpectedly, shown in figure 4-14.

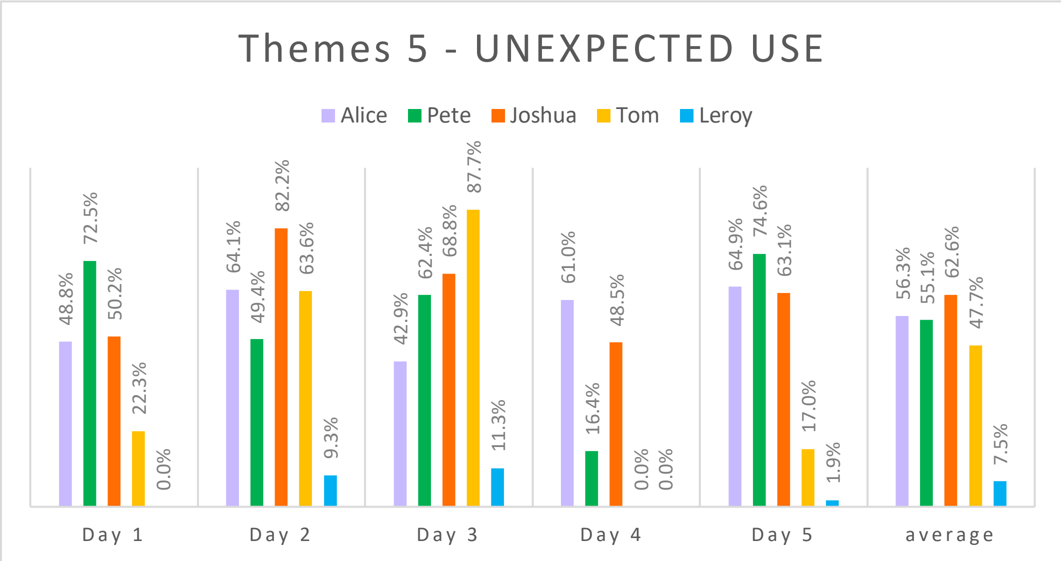

Figure 4-14 Theme 5. Graph showing percentages of unexpected uses of Mazi per child in study 1

Theme 5 was calculated again over the times that the children approached the TUI. A frequency-based analysis has also been carried out to evaluate how many types of behaviours and activities children exhibited, as this enabled a better understanding of the different types of interactions that the TUI encouraged. It also helped identify how applicable the technology might be to different types of play and to offering opportunities for self-regulation. The rates of occurrences of the main nine actions displayed by the children was counted. These actions are listed below in descending order (xNumber of times displayed):

1. Lays on it: x53
2. Sits on it or next to it: x48
3. Slides across the floor: x29
4. Presses: x27
5. Climbs/Jumps on it: x24
6. Using with feet: x23
7. Shows interest in speaker: x23
8. Strokes: x9

9. Pats: x6

Alice spent an average of 56.3% of her approach time interacting with Mazi in unexpected ways. Her TA after day one noticed that she spent time "*exploring material with feet*". The actions she performed the most were: lay on it (x14); using with feet (x11); press (x6); sit on it, stroke, interest in the speaker and slide across floor (x5 instances each); pat (x3); and lastly jump or climb (x1). She often laid against Mazi and looked at herself and Mazi in the mirror. Pete instead used Mazi unexpectedly for most of his approach time (11.2%.). After session 5 his TA noticed that that day he *"used it for climbs to the curtains".* The actions he performed the most were: lays (x14); jumps or climbs on it and slides across the floor (x13); sits (x4); presses, pats and shows interest towards the speaker (x1 instance each). Pete never displayed touching with feet and stroking.

Joshua used Mazi unexpectedly for an average of 55.1% of his approach time and he mostly exhibited: laying on it (x19 instances); interest in the speaker and pressing (x16); sitting on it (x14); using with feet (x10); jumping or climbing on it (x6); sliding across the floor (x4); stroking (x2) and he never exhibited patting. Joshua patted just when playing music on the bubbles. After session 1 the dance teacher observed that Pete "*engaged with Mazi immediately. Sliding across the floor, manouvering [sic] Mazi' to different parts of the studio. (laying-sitting-standing on Mazi')"*. After session 5 instead Joshua's TAs wrote that "*When he's not playing with Mazi you can see that he was listening attentively. He also requested deep pressure from Mazi and lifted Mazi onto his legs, as though to attain deep pressure and to create a blanket/ a form of comfort. Thanks to Antonella! He really enjoys it!"*.

Tom used Mazi unexpectedly for an average of 47.7% of the times of the combined sessions he attended and displayed the following actions: sitting on it (x6); climbing/jumping on it (x4); pressing (x3); patting and using with feet (x2 each); stroking and laying on it (x1). He never performed sliding Mazi across the floor and touching the speaker. His TA said that "*Tom enjoyed climbing on Mazi*" and she was "*not sure how much he responded to sounds*". Leroy on the other hand spent an average of 7.5% of his approach times using Mazi in unexpected ways. He would usually sit on it and stay sat on it throughout the duration of the whole sessions or until he would fall off or someone else wanted to play with it. He mainly performed:

sliding across floor (x7); laying on it (x6); pressing, stroking and sitting on it (x1 each). He also showed interested in the speaker (x1).

4.7.6 T6. Share emotions

Theme 6 captures children's emotional states during the five sessions. The main types of emotions coded by the researcher were: positive/negative, giggles/over-excitement, and vocalizations and are shown in figure 4-15. T6 and T7 were calculated over the length of the overall sessions, including the introduction's times, that is from when the teacher said hello and Mazi was covered to when the dance teacher started the countdown at the end. The graph in figure 4-14 shows the daily overall emotional responses per child and the average percentages of positive, negative, vocal and other emotions displayed per child. It's worth noticing that only instances of clearly visible emotions, such as positive or negative, or vocalising or doing something in particular were coded. That means that for the rest of the sessions, children were in a regulated energy state, that is they could be doing something like interacting with the curtains or with the mirror, or something that was in the space but because they didn't particularly smile, shout, show boredom, or vocalise this time was not coded.

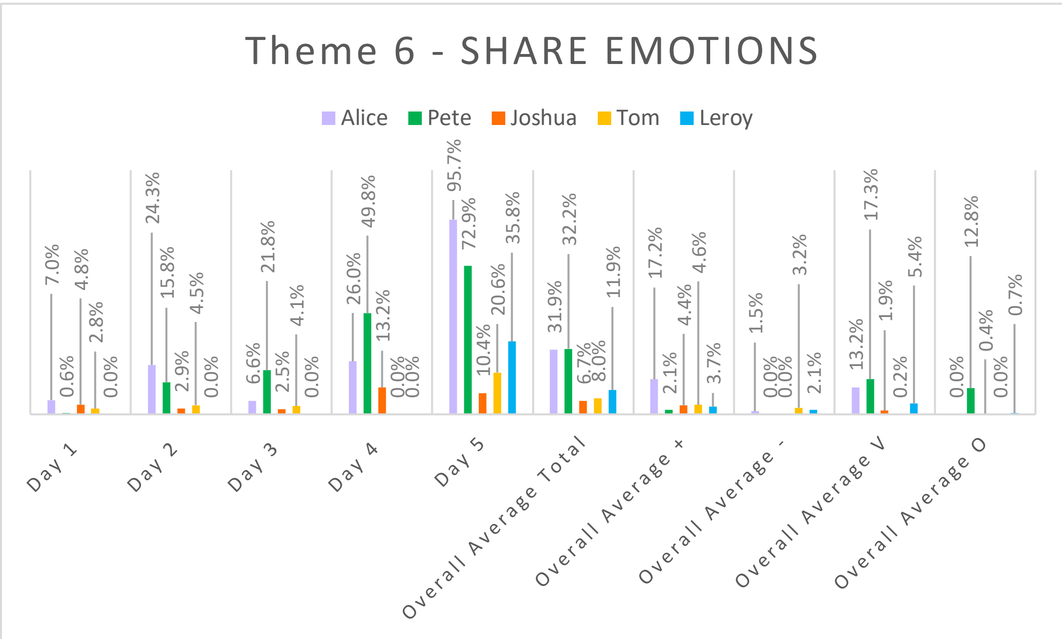

Figure 4-15 Theme 6. Graph showing percentages of daily emotions exhibited by child in study 1

For example, Alice exhibited more positive emotions than any other child (average of 17.2%) and vocalised often throughout the sessions (average of 13.2%), but she also expressed an average of negative emotions (average of 1.5%). The negative emotions were always displayed when she was physically prompted (PP) to interact with Mazi, by vocals moans (accompanied by smiles). It was observed even during dance and P.E., that Alice needed lots of prompting to participate during structured and unstructured activities. However, on day 5 the dance teacher observed that Alice was "*motivated. switched on. Vocal. Happy. Engaged. Alice was enriched by Mazi…Alice is able to express herself in this session enabling her to develop confidently*".

Pete expressed an overall average of emotion of 32.2%, among which the researcher observed some vocalizations (average of 17.3%), signs of giggles/excitement (average of 12.8%), and self-regulated positive emotions like smiles and laughs (average of 2.1%). The feedbacks of the dance teacher after session 4 read that "*Pete required close supervision by all adults to enable him to engage with Mazi. (he was prevented from looking and touching the symbols) [as asked by his class teacher]. He still require [sic] physical guidance to engage - Halfway through session he needed the toilet*". Preventing Pete to look at the symbols, might have increased the instances of over-excitement exhibited that day, which the researcher noted being particularly high. However, he also came unaccompanied that same day and needed the toilet halfway through the activity. Therefore, it was difficult to isolate one single cause. Joshua, on the other hand, expressed positive emotions for an average of 4.4%, and halfway through the sessions he started vocalizing (1.9%). He is non-verbal, and when vocalizing he always produced abstract sounds. The dance teacher after the last session noted that Joshua was "*at ease in the situation. He has formed a relationship with Mazi and he's able to touch engaged naturally- organically. …Joshua did not have an object (as he always requests) so what he achieved today was amazing*". After day 3 she observed that Joshua was "*extremely happy with interactions with peers and adults*". The TA instead said that "*Joshua was amazing today. He enjoyed the change of music notes and the small number of people that attended. Again, he listened attentively and really enjoyed the interactions*". Potentially Joshua might have felt more confident to join in the activity if the group was made of less people as in session 3 just three pupils attended.

Tom and Leroy were the only pupils that expressed negative emotions, which were usually represented by distress. Possibly this was due to the fact that they were the younger members of the group, and perhaps experienced more challenges to fully self-regulate their emotional states. In the case of Tom, dysregulation was once related to physical illness, another time it was thought to have been triggered by the group playing together too loudly around Mazi, and lastly, it was due to over-stimulation by interacting with one particular TA. The dance teacher reported that "*moments in the session he was 'SWITCHED ON' and confident in the space*". The amount of time that Tom expressed his emotions is described as follows: positive for an average of 4.6%, negative for an average of 3.2%, vocalization 0.2%. Peculiarly, Leroy did not exhibit any particular reaction to the environment or peers during the first sessions he attended. However, he displayed a hint of a smile and made a surprised face after he sat on Mazi for the first time. On day 5, he was more expressive and displayed a range of emotions. Leroy negative emotions were triggered by being prevented to play with his TA. Nonetheless, he easily returned to a calm state and managed to self-regulate independently, and in a short period of time. The TA after the study commented that Leroy "*interacted with Mazi with the children and the adults*".

4.7.7 T7. Share attention

The last aspect observed in this analysis was theme 7 and it describes whether the children looked toward Mazi and the peers interacting with it, or if they sought the attention of the adults when not in Mazi's proximity. The daily percentages of the amount of attention that children gave to Mazi and to the adults are shown in figure 4-16.

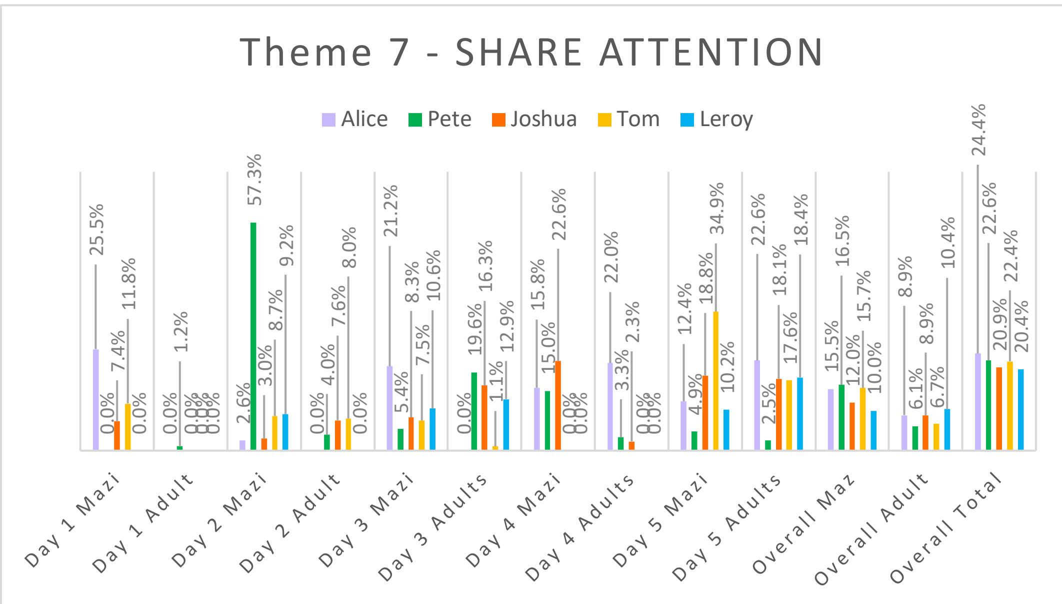

Figure 4-16 Theme 7. Graph showing the frequency of sharing attention behaviours per child in study 1

For example, Alice shared her attention for an average of 24.4% of the time of which 8.9% were spent doing Intensive Interaction (II) with adults. On days 4 and 5, for a total of 44.6% of the 8.9% spent doing 2 with adults, Alice initiated II with the researcher. After session 5 ended, the TA working with Alice told the researcher that "*it was amazing to see her eyes wide open and active* [..] *it was very good"*. Pete, on the other hand spent an average of 16.5% of the time he attended displaying attention towards Mazi, while for 6.1% he sought the attention of adults. During the first day, Pete did not show any interest toward Mazi when not in its proximity (see Figure 13). Contrarily, on day 2 he showed increased attention but also spent less time approaching Mazi. After day 2, and especially on day 3, he sought adult attention and insisted on being span by the dance teacher. The teachers and the researcher thought that spinning contributed to lower his overall interest in approaching Mazi for the days that followed. Joshua, on the other hand shared attention for an overall time of 20.9% of which 8.9% of the time was spent seeking adult's attention. On day 4, Joshua engaged in Intensive Interaction with the researcher for 2.3% of the time that he spent seeking adult's attention. After the last day, the dance teacher wrote that "*he required some deep pressure at the beginning which showed he was relaxed- was bouncing around the space observing the others touching Mazi - joining the group leaning- returning*". The TA instead said that "*When he's not playing with Mazi you can see that he was listening attentively".* After day 3 the dance teacher also observed that Joshua's *"Eye contact very good before touching Mazi".*

Tom spent an average of 22.4% of the time sharing his attention, of which 6.7% he sought adult's attention. He sought the attention of the dance teacher particularly on day 2 after he had been spun around alongside Pete, whilst on day 5, the time he spent with an adult was mostly due to doing Intensive Interaction with one particular TA that was not usually working with him. During the sessions the researcher also noticed one instance of eye-contact between Pete and Tom. This pupil had been described as being generally very solitary, so Intensive Interaction was good practice for his social engagement. It could also be noticed by the footage, that on several occasions Tom stopped whatever he was doing and appeared to listen to the sounds being played by others. The dance teacher also wrote that he was looking *"at Mazi from a distance. He stood several times and listened to the music being played. (I think it will be more responsive if the music is louder)".* She also reported that there were "*moments in the session he was 'SWITCHED ON' and confident in the space*". During the sessions, there were several instances where Tom made eye contact with some people. The adults noticed that he smiled while looking at them on two occasions. In the pre-testing phase parents meeting his mom commented that he started making and sustaining eye contact with her just recently, so this result was valued.

Finally, Leroy shared his attention for an average of 20.4 % of the time and, unlike the others, he mostly sought adult's attention (10.4% vs 10%). During one of the three sessions he attended, he was holding a straw, which, it was observed by the TA, distracted him for the whole activity. The TA observed that "*Leroy had a straw with him at the Mazi project so that might [have] had an effect on his interaction with Mazi*". During one of the meetings before the study started, it emerged that at playtime he "*demanded*" two adults to play hide and seek with him and he liked to guide the TA's actions and "*to feel in control*". Also, in the playground, he would not interact with any equipment. However, during the study, Leroy explored Mazi's sonic features and interacted with them on several occasions, independently, collaboratively and competitively.

4.8 Discussion

This study explored the main research questions of this PhD. In particular, it explored how a group of 5 children responded to a custom built playful e-textile sonic tangible use interface designed to be shared playfully (related to mRQ1); whether designers can build TUIs to provide opportunities for autistic children to be self-regulated and to enjoy social interactions within a safe environment (mRQ2); which design features are supportive of social play and regulation (mRQ3); and what are the challenges and opportunities created by playful e-textile sonic TUIs when working with autistic children (mRQ4). The discussion below provides an overview of children's engagement, sensory and emotional regulation, sonic interactions and social activities. It also offers some insights about the design and the methodology used.

4.8.1 Children's responses

Throughout the sessions, it was reported that children responded positively to Mazi i.e. as reported in T3-Touch to activate sound by a TA *"Joshua again did amazing today with Mazi"*, or "*Alice is able to express herself in this session enabling her to* *develop confidently"* as reported in T6-Share emotions by the dance teacher. The TAs and dance teacher facilitated the activity and encouraged children's joint attention and exploration. However, teachers' reported children's level of engagement with Mazi beyond their facilitation, as in i.e. T2-Approach "[Joshua was] *moving in the space with his ribbon he independently approached Mazi requiring no prompts"*. In T6 the dance teacher said that "*...Joshua is at ease in the situation. He has formed a relationship with Mazi and he's able to touch engaged naturally-organically"* and *"Alice was enriched by Mazi - enhancing her journey of discovery*". However, the dance teacher also said that Pete, for instance, "*still require[sic] physical guidance to engage"* (T6) but his TA said (in T2) that he was "*happy in the environment*". The majority of the children seem to have benefitted from the sessions, and even Leroy was reported to have been actively involved with *"Mazi, with the children and the adults"* (T6). In theme 2 Tom was also described by his TA as "*to increase in confidence with Mazi as weeks progressed*" indicating that, maybe with more sessions his active participation could have increased.

Instances of eye contacts were shown by Joshua (in T7-Share attention) and Tom (in T1-Introduction and T7) indicating that Mazi might have been beneficial in facilitating this kind of social interaction. Children's engagement was promoted through various channels and the TUI multifunctionality and versatility provided various stimuli that attracted children in different ways. For example, as shown by Joshua, children were able to lift Mazi and keep it on their thighs while sitting on the floor, which was evidence of the fact that some children benefitted from different forms of deep-pressure. Also, Mazi's physical affordances and its large circular configuration (Luff et al., 2013; Kendon 1990) supported instances of parallel and associative play by providing a focal point for collaboration and togetherness (Turkle, 2011). The various bubbles acted as areas of access points for each child, allowing for sharing opportunities and socialization around the artefact (Hornecker et al., 2007). The size of the tangible provided also turn-taking and sharing opportunities allowing people to appreciate and acknowledge each other's presence (Andrews et al., 2010, Zagermann et al., 2016) i.e. as confirmed by Joshua's TA who after the last session said that "*Joshua again did amazing today with Mazi, he waited patiently (whilst doing other things) to approach Mazi with confidence and played the different notes"*.

4.8.2 Sensory and emotional regulation

It's worth noticing that in session five i.e. the dance teacher was very happy about Joshua because he *"did not have an object (as he always requests) so what he achieved today was amazing"* (T6). This suggests that Mazi and the context provided some sort of regulatory opportunities that enabled the child to feel regulated without needing a ribbon as he did in i.e. the classroom, P.E. and dance lessons. Whether the music contributed to children's emotional regulation is still unclear but the physical affordances of Mazi intuitively prompted a variety of actions and play i.e. laying on it, use it to apply pressure on body parts, sliding it on the floor, move it across the space or lifting it from the floor. For example, the dance teacher reported that Pete "*engaged with Mazi immediately. Sliding across the floor, manouvering [sic] Mazi' to different parts of the studio. (laying-sitting-standing on Mazi')"* (T5-Use unexpectedly).

These actions suggest that among the design features that might have been more beneficial and attractive for this group of children is its versatility and possibly its mobility. Children were free to move around the environment and to move Mazi with them if they felt it necessary. As demonstrated by the children's behaviours, the mobility aspect of the tangible might have been crucial for encouraging socialization and collaborative or competitive activities (Laurie et al., 2019). For example, Joshua's TA said that "*He also requested deep pressure from Mazi and lifted Mazi onto his legs, as though to attain deep pressure and to create a blanket/ a form of comfort"* (reported in T7). Mazi not just was versatile and mobile, but it provided children with a weight-bearing activity and with opportunities to self-apply deep pressure onto their bodies, which is a stimulus that they often sought during the observations carried out in the formative phase. Deep pressure, also known as swaddle therapy, has been proved to reduce anxiety and to contribute to self-regulation (Field et al., 2005). This might explain why Joshua, as reported by the dance teacher during the last session, was for the first time able to go through the whole length of the activity without holding a ribbon. Sensory stimulation, alongside rewarding the children with something they like and need to balance their arousal and energy levels (in this case achieved through the use of textile, sounds, and a soft structure), which as suggested by Baker (1998) might increase children's participation in play, it's also an important feature for developing effective TUIs because it could encourage the children to interact with the artefact while autonomously regulate their sensory and emotional states (Harris, 2005).

The open nature of the design (Eco, 1997) and its ambiguity (Gaver, 2003) yet familiarity enable children's appropriation of the artefact. The children explored the textures and feel of Mazi for longer than they explored the sonic outputs (average of 45.8% vs 10.9%) but it's not known exactly how much and in what particular ways the use of felt, for instance, or of the PVC hedgehogs used for the bubbles, the semi-spherical dome, or the e-textile sensors, influenced the children's behaviours. However, children were regulated i.e. as reported in T6 by the dance teacher about Alice "*motivated. switched on. Vocal. Happy. Engaged. Alice was enriched by Mazi…Alice is able to express herself in this session enabling her to develop confidently*" or about Joshua "*at ease in the situation. He has formed a relationship with Mazi and he's able to touch engaged naturally- organically".*

The use of felt might have contributed to create a more organic interactions, and like a plush toy, the use of soft materials and e-textile could potentially reduce stress and anxiety levels, and it could help children overcome social exclusion (Casio et al., 2008; Jeong et al., 2018).

4.8.3 Sonic interaction

The simple auditory affordances were intended to support children's understanding of the cause-effect interaction, while the polyphony of Mazi was intended to make it possible for multiple children to act at the same time, thus reinforcing opportunities for collaborative play. This was supported by the observations of the children's smiles after the sounds were played as an effect of their own actions, and e.g. as quoted in T3-Touch to activate sound by Joshua TA's "*enjoys playing the different notes*" or by the dance teacher in T7-Share attention about Tom *"He stood several times and listened to the music being played".* Children displayed their appreciation for the musical element i.e. as reported by the dance teacher in T3 "*Engaged immediately with Mazi. Created sounds using his hands, body and feet…*". Generally, all the children that approached Mazi at first played at least one of the sounds, and then explored other uses. When a different set of sample sounds were proposed in day 4, as described under theme 3, the dance teacher observed that Joshua "*was fascinated by the new sounds"* and that this *"gained his attention*". Alice also exhibited a high curiosity toward the new sounds by exploring them independently, but it cannot be pinpointed if her interaction has been affected by the change in the samples used, hence was related to a high level of curiosity, or if the child gained more confidence as the time passed. The feedback received by Joshua's TA in T6-Share emotion after day 3, reads: "*Joshua was amazing today. He enjoyed the change of music notes and the small number of people that attended. Again, he listened attentively and really enjoyed the interactions.*" The novelty of the samples therefore, might have (re)gained children's attention. It's not known if the children preferred the harmonious or the sound FXs but he researcher believes that the harmonic notes allowed for greater musical expression. Tom's TA however said that he "*enjoyed climbing on Mazi, not sure how much he responded to sounds".*

When not in direct proximity of Mazi, sharing attention behaviours were also supported by the sonic feature of the TUI. For example, the dance teacher noted Tom that was "*looking at Mazi from a distance. He stood several times and listened to the music being played*" (reported in T7), and Joshua *"was listening attentively*" (T7).

4.8.4 What was learned about the design

Through enabling children to play by their strengths and doing so by reflecting their preferences into the design of the TUI, Mazi created opportunities that facilitated children's intrinsic play. The designed artefact helped in this regard as it offered stimuli that children sought and liked (pressure, touching or playing with fabric materials and plush objects, music). This choice of materials empowered them to use their preferred regulatory strategy or stimuli to interact with the TUI. In this study the researcher found that TUIs should:

- Reflect children's preferences and offer opportunities to employ favourite regulatory strategies as and interaction modality, so that an uncomfortable situation such as social play could feel more comfortable
- Be multifunctional, versatile and possibly mobile. They should be open (Eco, 1997), hence ambiguous (Gaver, 2003). In this study the TUI's digital interaction was dictated by sounds because all children liked music, fabric materials as children liked to dress up or to touch or fiddle with textile materials such as blanket, clothes, and pillows, and deep-pressure used as a probe for interaction. This is because this group of children sought these stimuli. In other studies, these modalities of interaction could take a different form depending on what children like the most.

- Be soft to offer increased opportunity for various types of tactile interactions and to provide soothing experiences.
- Be shareable and multi-user, to enable children's participation. In this case the polyphony of the musical interaction also provided opportunities for social music making.

Mobility as well as an advantage could also be considered a disadvantage as it might create opportunity for disagreement. However, nurturing disagreement could be an asset for designing TUIs as it might provide opportunities for solving conflicts constructively, which Hochhauser et al. (2015) said is challenging for autistic children. Another design challenge regarded the sound and is better discussed in limitations and future work – section 4.9.

A challenge that instead focussed more on design's features, was noticed on day 1 with the sound. Having just one little speaker was problematic as one child from secondary was crying in the corridors during the session, and the noise coming from outside was so loud that the sounds inside were merely perceivable at times. The problem was solved by adding a second speaker from the second day onward, allowing for better sound quality. However, Mazi still used two small speakers and more powerful devices should be used next time. For future studies, it would also be interesting to modify the characteristic of the sounds when touch is detected such as tonality, pitch, or volume to allow for longer and more complex interactions. Future research could also be conducted on the shape and size to investigate if the design provides better social opportunities than different shapes or sizes. From the findings presented here, it's believed that this shape delivered a wide range of equal and social opportunities for this group of children.

4.8.5 What was learned about the methodology used

The open-ended nature of the testing activity and the design of the space, including how the study was (semi-) structured, enabled children to express themselves freely and to become active participants in a socially demanding space. The TUI did not require children to follow any particular rules, or to play with it in any specific way, and it was not something that children could take apart and play with in solitary mode. Although instances of play in solitary mode happened with one particular child (Pete), the adults were eliciting a shared use of Mazi. The inclusive and supported setting promoted children's participation more than common unstructured playtime formats. When confronted with other tangibles for play from the literature, Mazi offers a novel approach to the design space of TUIs for playful activities, which other researchers could adopt in their practice to design forms of play that are friendly to neurodivergent children (Spiel and Gerling, 2020). The attention autism inspired song that the researcher invented, worked well to introduce Mazi to this group of children. Considering that 3 out of 5 children looked at the introductions for more than half of their overall duration, as reported in theme 1, and that the TUIs were covered for this period, the children displayed signs of interest toward the way that Mazi was introduced to them.

The data collection approach used here however, didn't work that well. The researcher found that some TAs didn't complete the observation sheets when they were asked to. For example, Alice and Leroy's TA filled in the tracking of the children the day after the study took place (as the researcher reminded her to do so) on both days 3 and 5. Joshua's TA also completed the observation sheets the day after sessions 1 and session 2. Tom's evaluation of day 4, was written a week after the session by one of the TAs that was present in day 4. Furthermore, the 5-points rating system they used was highly inefficient in providing any useful descriptive information on the reasons behind their ratings. As some of the TAs didn't add any descriptive text to back-up the number that they associated with each of the five themes observed, this meant that the researcher had less qualitative data to use in the analysis. The children were also distracted by having the iPad on a tripod in the room and at times they switched it off involuntarily while interacting with it. Thus, the use of this device to record the testing sessions is inadvisable, especially if it's within children's reach, as they know and often use this type of technology.

Another methodological challenge, was identified with having the TUI in the room before the session started. Two children arrived late in day 2 (roughly 7 mins later), and those who were in the studio on time didn't understand what they were waiting for. This ended up with the children needing support to avoid getting dysregulated as they wanted to interact with Mazi or move around the space. For this reason, from session three, Mazi was then moved to an adjacent room until all the children were in the room.

The study's timescale instead, did not allow to develop a baseline assessment which may have strengthen the results. By baseline assessment is meant having had the opportunity to observe the children using the TUI switched off first and then with the music on. Testing the TUI with the power switched off was not possible as the dance teacher was against this idea because she thought that children would have not appreciated. For future studies, the plan is to start the analysis by recording the children for few minutes before the technology is in the room (or with the technology in the room but with the power switched off) and compare those with few minutes of footage with the technology powered on. This can be achieved just if the teacher agrees to it and finding compromise of this nature might limit the development of a more accurate analysis even in future studies. To conclude, the length of the study was too short to confirm scientific validity and the group was small, thus it is hard to isolate the confounding variables that might have affected certain actions.

4.9 Conclusions

This study found that autistic children who like music respond well to sonic e-textile playful TUIs. Key factors for effective tangibles included but were not limited to: the robustness of the design, its versatility, ambiguity, openness, the sensory stimulation provided, its configuration, size, and possibly its mobility. This exploration suggests that TUIs can be used to provide both self-regulation and social play opportunities. Further studies are needed to discern whether the sonic element influenced the children's experience. It seems that children used the TUI more for unexpected purposes and to satisfy their deep-pressure touch seeking behaviours, rather than to play sounds together. However, it was reported that all of them played and listened attentively. Children also showed active participation when playing sounds. Furthermore, the open-ended nature of the design allowed the children to appropriate aspects of the TUI and the open-ended nature of the study structure left freedom to the children and enabled them to be themselves and act as they wished. It should be noted that just behaviours displayed within sessions were compared and there is uncertainty about the transferability of these performances to other contexts and of the long-lasting effects. Nonetheless, this holistic approach to TUI design and evaluation could be used to encourage playful activities among children also in other educational contexts, such as i.e. play-time. It could also inspire designers for SEN spaces to create more inclusive spaces that encourage socialization.

5 Design study 2: Olly

Note – Some of the work presented in this chapter has been published at *International Journal of Human-Computer Studies*, Volume 153, (Nonnis, and Bryan-Kinns, 2021) and presented at the *New Interfaces for Musical Expression* Conference in 2020 (Nonnis, and Bryan-Kinns, 2020).

This chapter presents the second explorative study done with a group of five children aged between 5-10, three of whom participated in Study 1. Similarly, this second study was carried out at the Garden school for five weeks, between December 2018 to May 2019. It proposes a second TUI design with similar aspects to those proposed with and found to be interesting in Mazi, such as the multi-user circular large-scale design and the use of e-textile. However, it investigates further other aspects that the researcher thought could have been improved, such as the modality of interaction to evoke longer interactions. Therefore, the design of Olly, the second tangible developed for this second study, resembles Mazi in its size, the use of similar materials and its shape, but it offers a different interaction style than that offered by Mazi. In study 1, the researcher noticed that the simple touch-and-play interaction paradigm was too simple for some children, hence, this time, she aimed to offer an interaction style that evoked longer interactions, such as that of i.e. pulling. The methodology used for the data collection of the testing phase is also different from that of study 1. As previously mentioned, in this study the themes observed by the teachers during the testing phase, contained two more criteria than those collected in the previous study. These were theme 6-Share emotions and theme 7-Share attention. Hence the analysis provided in the results of this second study, gives a qualitative description of the teacher's general opinions that included also considerations on children emotions and focus of attention. The researcher however, asked all the TAs to provide qualitative general feedback but still allowed them to use the 5-points rating system because they felt comfortable using it.

As already explained in chapter 3.6.1, during the video analysis however, the researcher added a further theme to her analysis of the video recordings, theme 8-Play types (T8). Also, she changed T7 from 'share attention' to 'eye-contact', because information on sharing attention were redundant with one of the play's types she observed in T8, the 'onlooker play' type. In theme 4, the researcher also analysed when children played music with Olly in solo mode, rather than just when they played with peers, adults or competitively. This was considered important as it helped to understand who were the children that tried the TUI on their own and perhaps had more opportunities to understand the cause-effect interaction. Competitive play, which in study 1 was observed within T4-Music making together is here reported within T8-Play types. The way that the TUI was introduced to the children at the beginning of the sessions was also different as it was revealed to the children in two steps.

The study offers several contributions. It contributes to the field of HCI, particularly Child-Computer Interaction (CCI), by presenting a second exploration carried out over five weeks within a semi-structured ludic setting in a specialised school, where another e-textile sonic TUI, called Olly, was assessed in terms of its support for social activities, and self-regulation, in a somehow different group of minimally verbal autistic children. This helped identifying which further features of design could be beneficial toward scaffolding social play and self-regulation, as it unveiled how another group of children responded to a similar playful TUI that offered a different interaction style but was designed with the same aims. The study validates and expands a novel evaluation approach developed in study 1 by the researcher, which uses a framework for analysis that incorporates educational constructs, such as those from the Social Communication, Emotional Regulation, Transactional Support (SCERTS), with an HCI lens on future design implications for TUIs. The study proposes a holistic approach to designing and evaluating TUIs for social activities between peers, coupled with a positive attitude towards the sensory needs and strengths of this population (Brulé et al., 2019). This provides information on how to design and evaluate playful TUIs with nonverbal autistic children and helped addressing some of the main research questions.

5.1 Motivations

The idea behind Olly was to make an interactive toy, that offered opportunities for longer interactions than a simple touch and play toy like Mazi. This was thought to be achieved by changing the interaction required to use the TUI e.g. pulling instead of touching. As in study 1, because children's sensory processing abilities are correlated to their participation in leisure activities (Hochhauser and Engel-Yeger, 2010) it was important to focus on providing opportunities for self-regulation. The pulling interaction therefore was chosen because during the formative phase the researcher observed that in the dance lessons one of the children showed interest in this kind of interaction. The study therefore tried to understand:

- How do groups of minimal to non-verbal autistic children respond to a different playful e-textile sonic TUI? In particular, how do the children respond to TUIs that require an overt style of interaction?
- What are the opportunities and challenges created by this new design i.e. stretch materials, with respect to the sensory and emotional regulation and engagement of the children (mRQ4)?

The first set of questions feeds directly into mRQ1, as they provide information as to how a different group of children responded to a similar TUI design that offered different affordances, and into mRQ3 as they provide information as to whether a different interaction style and design can support social play and self-regulation in another group of children, and if this design features (i.e. pulling) and affordances are supportive of play and sensory regulation. Lastly, the study helped understanding whether it is possible to design and evaluate playful TUIs that encourage social play and self-regulation in groups of minimally verbal autistic children, addressing also mRQ2.

5.2 Procedure

In January 2019, the formative phase of the study began. The formative phase was the first of the three design stages followed, as in study 1, by the iterative prototyping phase, the testing phase and the analysis. The testing phase ran every Thursday afternoon for 5 weeks, at the cross between April-May 2019, from 2:15 pm to 2:45 pm, and it was carried out in the dance studio of the Garden school. Parents of the children participating in the study were contacted and informed of the proposed study at the beginning of January 2019, when information sheets and consent forms were given out to them through the school. as in the previous study, the documents were exchanged between the parents and the researcher through the children's bags. All the parents returned the signed documents in their child's bag by the end of January.

The mix-method approach developed for study 1, was applied again to inform the final design of Olly, a new TUI designed, developed and programmed by the researcher for another group of 5 children, some of whom took part in the previous study. This process is described in the iterative prototyping phase. As per the previous study, this study fitted within the children's scholastic routines. The initial date for testing the technology was agreed for the w/c 25 February 2019, matching the start of the scholastic winter Half-Term. However, it was subsequently decided to reschedule the beginning of the testing phase for the w/c/ 26 April 2019 (after Easter break), because the initial phase of the design had gone slower than previously thought, and unfortunately, the technology would not have been ready by February.

5.3 Formative Phase

The formative phase of study 2started in December 2018 and ended in mid-February 2019. The first months of fieldwork were carried out to inform the design of Olly.

5.3.1 Participants' recruitment

In December 2018, the Headteacher of the Garden school, alongside the dance teacher, selected the participating five children. For this second investigation, three of the children that participated in Study 1 were re-selected (Alice, Pete, Joshua), but two new boys were added to the group (Isaac, Ben). To maintain children's anonymity this study refers to the children as Alice, Pete, Joshua, Isaac, Ben. As summarized in table 5-1 these pseudonyms have been shortened e.g. Alice is Al, Pete is marked as Pe, and so on. Although the researcher knew Alice well, she never met Isaac and Ben before this study, whereas Pete and Joshua were familiar to both the researcher and the research format because they participated to the previous study. Queen Mary University's Ethics of Research Panel fully approved the research, and the parents of the participating children signed the informed consent forms. As per study 1, children were also free to leave the space if they expressed so by showing signs of dislikes or dysregulation during the sessions.

5.3.2 Participants' insights and data collection

A summary of the collected information about each child is provided in Table 5-1. The children's Performance levels - P levels (see section ..) ranged between P2 to P8, while their communication stages, were ascertained, as in study 1, from the Social Communication Emotional Regulation Transactional Support (SCERTS) (Prizant et al., 2006). Ben came from a disadvantaged background, and he was handled by social services, hence the dance teacher and the Headteacher thought that he would have benefitted from such activity. As shown in Table 5-1, the children's current SCERTS stages were: Social Partner stage (or SP) (Joshua and Isaac), Language Partner stage (or LP) (Alice, Ben), and Conversational Partner stage (CP) (Pete). The researcher was unable to assess Pete's Performance level due to missing information in some of the documents photocopied for collection and the class teachers did not reply to the researcher's later email requests.

Child	Likes	Dislikes/ Triggers	Support strategies	Age	Gender	SCERTS	P Levels	1:1
Al	Tidy, quiet, calm spaces; listening to songs; dance; singing; drawing; mirror; bubbles, dressing up	Crowded spaces; unexpected sounds; fast movements; noisy environments	Encourage to use symbols or say no if doesn't want something; give space/time	9	F	LP	3; 4	x
Pe	Deep-pressure; hugs; soft blanket; familiar routine; being independent; quiet and calm environments; gym ball; scooter; trampoline; spinning; swimming; splashing; shapes; magnet letters; looking and reading books; listening to favourite songs; interactive board; tickles; squeezes	Waiting; changes of routine; cold weather; stop something I'm enjoying; too many changes; not being prepared for new activity; not knowing whereabout of familiar people	Use individual timetable; wait symbol; give big hug; magnet letter and/or reading books for play; use keywords; visual prompts with verbal communication; model communication; walking; give time/space	10	M	LP	6; 8	x
Jo	Manipulates fabric/ribbon; physical contact and deep massage; time in corner to self-regulate; fine motor skills activities; sand and dry messy play; holding adult's arms in transitions, dancing, playing with water and soap; regular play time; independent transitions	Waiting long; noisy environments; communicating without objects; wet clothes and shoes; new people around my routine; working at the table; others to touch my food	Encourage breathing; clap hands together; give a pillow; allow to rock; provide deep pressure; give a ribbon/string; give time; tap fingers, allow independence; follow actions and be playful	9	M	SP	4	x
Is	Ribbons; running; sensory activities; outdoors activities; playdough; light-up toys; puzzle, interact with adults; foam; music; singing; swimming; being independent; routines; chasing games with adults; messy play; spinners; bubbles; blanket or comfort object; wind-up toys	Being rushed; waiting and taking turns; playing with peers; people touching my feet	Offer symbols to communicate; give choices; ask what Isaac wants; give some deep pressure	5	M	SP	2	x
Be	Bouncing on gym ball; running, chasing, dance lesson, dry food; make choices, bubbles, snacks, facial emotions/reactions, splash pool, swimming, scooter board, receive attention of peers	PP by adults; not being given space/time; small spaces; lights on in empty rooms; too much stimuli; lights	Structure a turn-taking activity; model; praise; offer support; offer chasing games/bouncing on gym ball; give time; redirect him; allow to lay down and rock	5	M	LP	4; 5	x

Table 5-1 Summary of the children's collected profiles Study 2

Isaac on the other hand was not assessed on the P levels, but with, what the teachers called, the Developmental Matter, as the P levels start from Year 1 and Isaac was 5 years old. However, as seen in table 5-1 his teacher identified him as in between P2 and P3s.

The children have been observed during Dance and P.E. Alice was once also observed during music therapy lessons. Isaac required a social story to facilitate his introduction to the new activity and this was prepared by the class teacher and given to the family before the formative phase of the commenced, during the Easter break. Social stories are pictures-based stories that tell about events that happen, or are about to happen, in a child's life. These usually help some children that have anxiety issues to process, and accept, new information and breaks in routines. At first, there was some concern with Ben's behaviours due to a developed habit of hitting other children either to get their attention or to look at their reactions. However, there were plenty of opportunities to monitor the children closely and to avoid any discrepancy rising from challenging reactions. Therefore, Ben was welcomed in the group.

Although it was reported by the teachers that Isaac and Ben shared the same playground space, they never approached one another before this study, and they never met any of the other children. From the data gathered, it was apparent that four out of the five children liked to bounce on the big therapy balls offered during P.E., and one child (Alice) liked ball games activities. Most of them, liked manipulating fabric materials, and four of them liked music. Ben just transitioned to a new classroom, and it was not known what his preferences were at that time, but he attended drumming sessions which were conducted in the same period as the testing sessions. All children followed regular music lessons in school, Alice participated in her first music therapy lesson in the term preceding the study. Lastly, Isaac usually attended the dance lessons of several other classrooms.

A symbol with a picture of 'Olly' was made at beginning of April 2019 to use in the timetables of the children and as a transactional tool (Figure 5-1 bottom), and, on the collective timetable of the dance studio. Object of Reference (Figure 5-1 top), were also made before the study commenced for the children's timetables and their transitional cards. Some of the symbols used to break down the testing sessions were re-used from study 1. In this study it was decided to avoid meeting with the children's parents/carers. This decision was taken because one of the new boys would not have had anyone coming for him. Ben's mother had learning difficulties and was unable to read. Thus, it was simply decided not to meet with any of the parents this time.

Figure 5-1 Objects of Reference made with left-over stretch lycra (top) and Symbols made with inPrint software

Inspired by similar design principles than those used to make Mazi, it was decided to re-design one semi-spherical shareable multi-users sonic e-textile tangible interface aimed at offering opportunities to practice social interactions while enabling children to self-regulate. The interaction's type implemented in the design of Olly however, aspired to scaffold longer interactions. This was achieved by using elastic ribbons instead of capacitive touch, as it was thought that pulling takes longer than patting. However, it was important that the interaction design still afforded a concrete mapping between the cause-effect interaction of the auditory feature (i.e. the children's pulling actions intuitively mapped to the different instruments triggered by each ribbon and the higher pitch notes). The design principles that this study aspired to address are described in chapter 3.4.2. To recap these were:

1) build on children's past experiences, needs, and preferences, hence their strengths
2) support self-regulation
3) encourage social activities

As in the previous study, Olly's design was inspired by the children's observations during the data gathering period and by principles of shareability and theories of embodied interactions, social configurations of people and spaces. For example, the children's observations in this phase of the study revealed that most of the children liked, or needed access to, a blanket or to any type of textile material, either to cuddle up to, to receive comfort from, to dress up with, or to fiddle up with. Some of the children made often use of soft blankets or cloths as a way to comforting and regulating themselves. For instance, in Dance lessons, Alice liked to dress up and play with plush toys and the mirror, while Pete, used to take some fabrics and pillows inside a big box of cardboard and hide himself (figure 5-2).

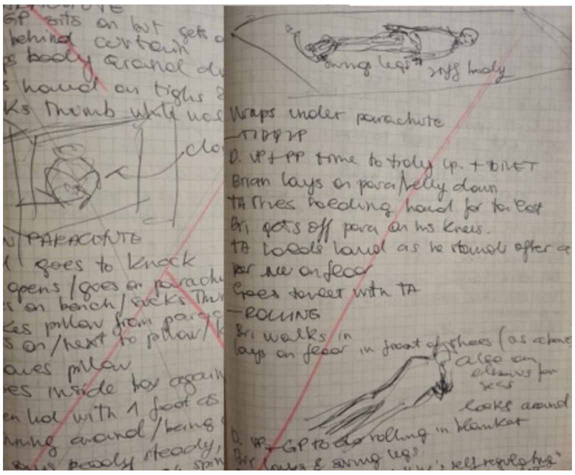

Figure 5-2 Fieldnotes and sketches of Pete and Ben during the observations in dance lesson

Together with Joshua and Ben, they really enjoyed receiving deep-pressure either through patting their hands, feet massage, and hugs. Joshua also usually fiddled with a string of fabric, or a ribbon and he liked to twist it and make sticks out it, and Isaac was found to really enjoy participating in dance lessons where the teacher proposed a group activity with a stretchy band. Therefore, as better explained in the prototyping phase, the final design tries to replicate some of these features (fabric, deep-pressure, ribbons, elastic materials etc..) to entice the children.

Figure 5-3 shows the initial sketch of Olly's final design (on the left) and a high-fi version which contains just four ribbons instead of five. The researcher thought that although the children were five, five ribbons would have not facilitated the children's manipulative access, and fluidity of sharing, which are important to fulfil the access points of shareability. Therefore, Olly has just four digital inputs. The principle of shareability is reflected in its clear *overview*; its visual, tactile, and auditory stimuli that aimed to create a *honeypot effect* to capture children's attention, and its shape and circular design, which aimed at fostering social awareness and enabled *perceptual access* (Figure 5-3). Its large size and affordances including its *access points* e.g. the sensors and their materiality, such as the elastic ribbons and the felt, aimed at enabling *manipulative access* and *fluidity of sharing* and allowed to *minimize barriers* to access.

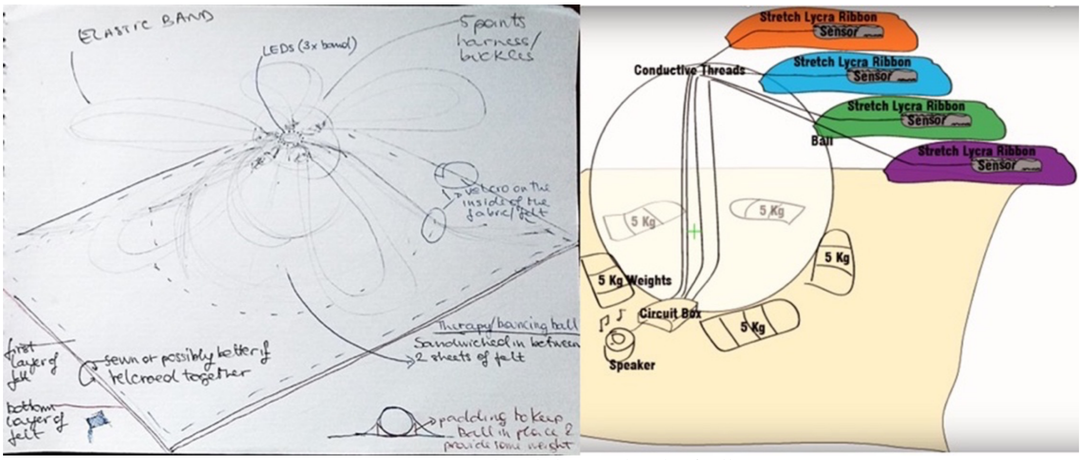

Figure 5-3 First hand-drawn sketch of Olly

The concept of *Opera Aperta* (Eco, 1997) was again borrowed in the design of Olly to facilitate children’s appropriation of the artefact. Therefore the design was ambiguous but used familiar textures (Gaver et al., 2002; 2003), it was malleable and it was soft but still capable of providing deep somatic feedback, and it could be used to make music with but also for other purposes. This design strategy was re-employed to enable children to use regulatory strategies that they found comforting, while participating to a social activity with they might find demanding.

5.4 Iterative prototyping phase

During the initial brainstorming period, a taxonomy of cause-effect interaction was created in order to understand what type of interaction could be best implemented in the design of Olly. The more complex the interaction, the more coordination, and cooperation were required of the children. Frustration and anxiety may arise, and negative emotions and responses needed to be accounted for. To facilitate the children’s joint actions, some types of interactions that could take longer than a touch-and-play action, were defined, such as squeeze, press, stroke, pull, push, pinch, rotate, twist.

The taxonomy included five different types of possible cause-effect interaction described as follow:

1. **simple cause-effect** = 1 action equal 1 output (require no joint action)

2. **quantity-based** = 2 or more actions equal 2 or more outputs (require not social intent but promotes them)
3. **time-dependent** = 2 actions at the same time equal 1 output (require coordination + notion of shared goal)
4. **action-dependent** = 2 different actions equal 1 output (require cooperation + notion of shared goal + notion of planning and sequencing)
5. **sequence-based** = first 1 action equal 1 output; followed by another action that affects output 1 (more complex interaction)

The decision to design for a quantity-based and time-dependent interaction came from wanting to give the children a more interesting and creative type of interaction that was still simple. The idea to use an inflated therapy ball as the main body of Olly, and also the e-textile stretch sensors, came from the observations of the children and it was eventually informed by their likes. For example, it was clear that all children liked soft textures and the inflatable balls that they used mainly in P.E. Isaac on the other hand, liked participating in a group activity done in one of the extra dance lessons he attended where children were invited to stand inside a large stretchy band positioned behind their waist, hold the band with their hands and then move back and forth while forming a circular shape. Figure 5-4 shows the final design of Olly and some of the children that played with it throughout the testing phase.

Figure 5-4 Three children gathered around Olly in the Dance studio of the Garden school

As previously mentioned, for practical reasons related to the size of the ball, and the interpersonal space that the researcher wanted to leave to the children even when interacting with the TUI, she decided to make just four ribbons instead of five. The researcher replaced the soft-play dome used to make the main body of Mazi with an inflated therapy ball, as she found this to be a cheaper and easier option that allowed Olly to be moved around more easily than Mazi by deflating it. However, this choice made the TUI much lighter hence at the base of the ball, she positioned five x5 kg. legs-weights to help to stabilise the TUI (Figure 5-3 right). Instead of felting Olly's cover from scratch (i.e. starting from merino wool), the researcher used sheets of industrial felt which she thought would speed up the process and also make the surface smoother than that of Mazi (figure 5-5).

Figure 5-5 Pattern template on felt sheet. It was cut, stitched together to form a sphere; Ball wrapped by the felt

It is important to note, however, that because of the thickness of the felt sheets (3 mm), the researcher found sewing the pieces together very challenging, especially when the pieces of fabric were doubled up (Figure 5-6).

Figure 5-6 Olly in the making. Using my sewing machine to stitch the Velcro at the base of Olly

The sawing machines at Queen Mary University were not working with this type of material, hence the researcher's personal sewing machine was brought and kept at the Maker Space of the Engineering building at QMUL until design completion. Many needles have been broken in the process, and achieving a clean line was challenging (Figure 5-6). The inflated ball was secured in between two thick layers of felt (the one used for the base and the one used to cover the ball) using strips of Velcro® (hard to the bottom; soft to the top) (Figure 5-7 top). An inflated stability ring was secured to the bottom of the base of the ball (Figure 5-7 bottom left) to prevent it from rolling around the base when the ribbons were pulled.

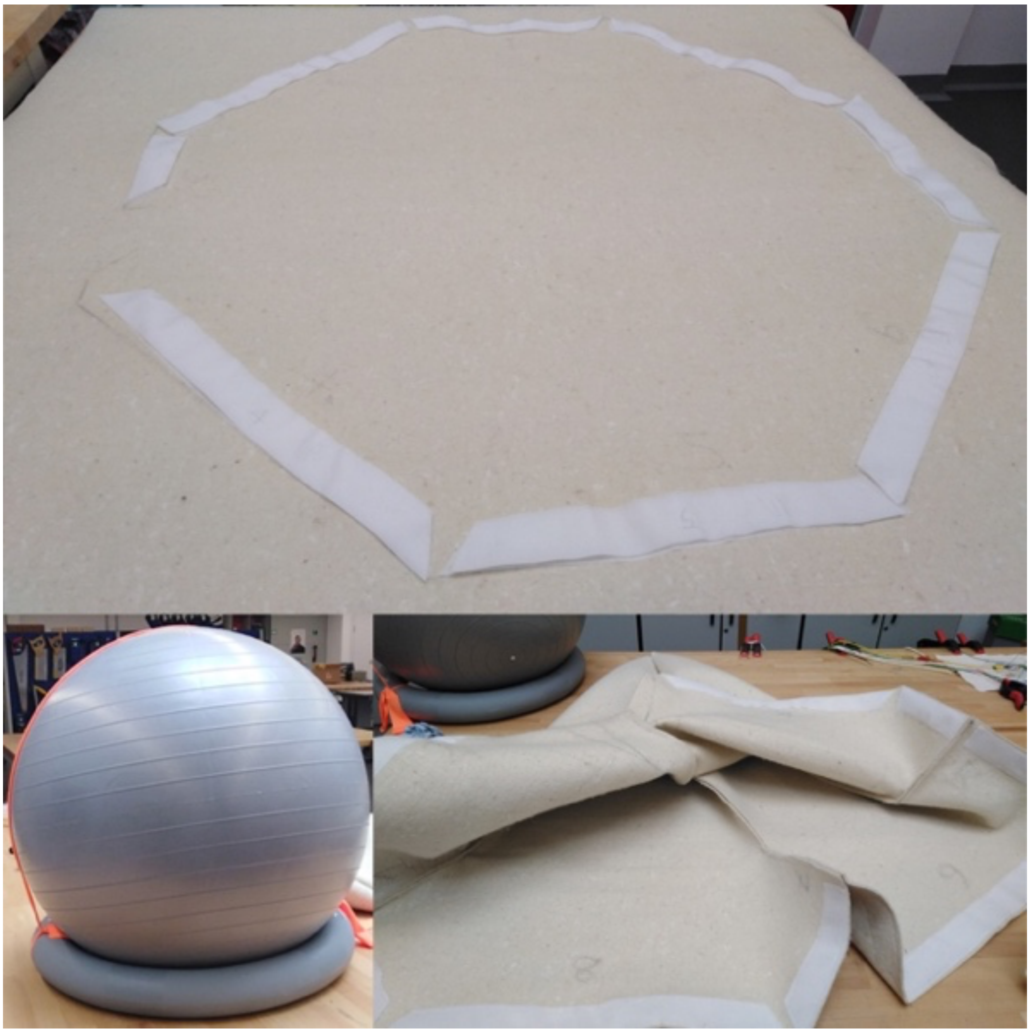

Figure 5-7 Base with felt attachments (top); bouncing ball (bottom left); felt ball cover

The electronic circuit uses 4 analogue inputs of the Bare Touch Board, which runs in Midi mode with a 3.7 V lithium battery (Figure 5-8). This was enclosed in a wooden box placed at the base of the installation in between the two layers of felt. The wooden box, displayed in figure 5-8 top right, sat in between the two weights and shown in the sketch in figure 5-3.

Figure 5-8 Olly's circuit box and detail of content

The sensors were embedded in the main body of the tangible by being sewn on the inside of the four coloured lycra loops, which are placed on the top of the installation, and are connected to the circuit board via hard wires (Figure 5-9).

Figure 5-9 Sensors embedded inside the lycra ribbons

The conductive threads pass from the inside of the lycra loops, to the top of the ball and then they are squashed in between the diameter of the ball and the felt 'til they get down to the bottom where they are soldered to wires and then connected to the circuit. The ribbons triggered different chords (triads) based on the C major scale; as they get pulled they each activate a progression of 8 notes, enabling the creation of melodies when playing in solo mode, and harmonies when playing together. Each of the different ribbons represented a different instrument. The purple ribbon played Dmin, the green plays Gmaj, the blue plays Fmaj and the orange played Cmaj. Another picture of Olly's finished design is shown in picture 5-10.

Figure 5-10 Olly finished design

Choosing sounds that would play well together was also another challenge. To do this the researcher asked the opinion of two musicians doing a PhD in the Centre for Digital Music at QMUL. The researcher therefore chose the chords combinations after having discussed the options with them. Olly wiring diagram and schematic can be found in Appendix A.

5.5 Testing phase

On the 25th of April 2019 the testing phase began. Two mini cameras (Xiaomi-Yi) and one hand-held mobile were used to capture the video recordings of the five sessions. The map of how these were positioned around the space can be seen in figure 3-6. The decision of having just two fixed cameras came mainly from the availability of the equipment that the researcher could borough from QMUL at the time of the study, and by the fact that the iPad used in study 1 was switched off in few sessions by few children, so the researcher avoided using the iPad. A third hand-held mobile was used instead to record the children from when they entered the studio until the end of the welcoming hello, as the view of the cameras was obstructed by the curtain being pulled in front of the children (Figure 5-10). However, the researcher ended up using it for longer sometimes. With Olly, it was decided to set up the environment so that the tangible was kept in the room since the beginning of each session and the TA were recommended to arrive on time. Apart from Ben, who attended just the first three sessions, all children attended all five sessions (see Table 5-2).

OLLY	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5
Duration of sessions in minutes: seconds (includes Introduction's times)	***** 21:10	***** 24:38	***** 23:56	**** 23:11	**** 25:09
Duration of Introductions times in seconds per session	47	54	63	57	52
Children representative colour: Alice*; Pete*; Joshua*; Isaac*; Ben*					

Table 5-2 Sessions' length and visual representation of daily children attendance

Upon entering the dance studio, children were encouraged to sit on the bench placed against one of the walls and to take shoes and socks off (as per dance lessons). A black drape was pulled in front of the bench to divide the room into two places, 1) to welcome the children, 2) to play with Olly (Figure 5-11).

5-11 Olly set-up in the Dance studio

The tangible was on the opposite side of the curtains, in the middle of the room and it was covered by a cloth laid over it. The black drapes, referred to as curtains, were already part of the setting of the room as this was a multipurpose space used for Drama, Dance, and Yoga Afterschool activities, but usually, were not pulled closed during Dance. It was revealed to the children over two times 1) by opening the black drapes after the children said hello and 2) by uncovering Olly from under the cloth at the end of a song inspired by the Attention Autism practices used in school. The dance teacher though that creating more expectations for this group would have work better. Usually the sessions started with the teacher saying hello after children removed their shoes, and this indicated the start of the testing session, then she pulled the black curtains to reveal Olly, which was still covered by a cloth. She positioned herself behind the TUI and started to sing the 'under the cloth' song, as she did for Mazi. Then she uncovered Olly and play with it to demonstrate how to use it to play music and waited for the children's responses (Figure 5-12). If they showed spontaneous interest and approaches, the TA's did not offer any support, whereas if it was considered that the children needed support the adults would offer some prompts.

Figure 5-12 Olly about to be uncovered after the Attention Autism inspired song

As in Study 1, it was decided by the dance teacher that the researcher had to be part of the experience, as three of the children knew her from the previous study (Alice, Pete, Joshua) and her previous employment at the Garden (Alice). Hence, the first day she was introduced to the children and at the end of the session she was invited to congratulate each child for the good play they did that day (as per study 1). Eventually, the Dance Teacher closed the session inviting the pupils to put socks and shoes back on and waved goodbye. The parents were given some pictures, extracted from the video recordings every Friday afternoon , alongside some written feedback. However, as Ben's mother was unable to autonomously read, her feedback was mainly based on pictures. Unfortunately, on day 4 Olly was not working, therefore it was left in the room for the children to explore even though the power was switched off and the TUI did not play any sounds. The dance teacher was worried that this would have upset some children and was seen as a challenge, but it was decided to carry on the activity as normal, just to avoid disrupting the routines. However, for the researcher it was a chance to observe how the children reacted to the TUI when the power was turned off, enabling her to explore whether the sound impacted children's experiences.

5.6 Data Analysis

The evaluation was carried out using the framework developed in the previous study (table 3-3). As per study 1, the dance teacher and the Teaching Assistants (TAs), were each given an observation sheet per child where they were asked to independently leave comments on the children's experiences in relation 7 themes. An example of the TAs and dance teacher's observations sheets is presented in figure 5-13. Some other examples of the completed sheets can be found in Appendix C.

Class: Snapdragon **Name of child: NP**	**Area of learning**	**Cycle 5**		**Year: 2019**		
Extra notes:	**Social Interaction and collaborative Play**	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
	Looks interested in the presentation of Olly (Debbie Attention Autism)					
	Approaches Olly with confidence					
	Pull to activate sounds					
	Plays notes together with peers or partner					
	Shows use of Olly for else than playing notes (e.g. deep pressure; patting; squeezing; climbing etc)					
	Share emotions: express appropriate emotions (pleasure/calm) and he/she is able to self-regulate					
	Share attention: When not in Olly's proximity, shows attention towards others interacting with Olly and follows what's going on					

Figure 5-13 Weekly running record/tracking/evaluation sheet for Teacher and TAs

This was combined with theme 8, which included an adapted version of the six stages of play defined by Parten (1932). The results reported in the findings are based on the 8 themes shown in table 5-3 and its subthemes shown in table 5-4. T8 was analysed after the testing sessions just by the researcher, when she annotated the video recordings, as per the previous study. As already explained in chapter 3.5, the researcher also changed T7-Share attention to T7-Eye contact because the annotations she took under 'Share attention' gave the same information as the one under 'Onlooker'. Looking at instances of eye-contact helped her to determine the social play behaviours that happened around Olly. Theme 7 (T7) therefore, identifies moments of eye contact between peers, and Theme 8 (T8) demonstrates what types of play children exhibited the most (from Unoccupied to Cooperative and Other types).

Themes	Definitions	Analysis
Theme 1 (T1)	**Look interested** in the presentation of the TUI (teacher Attention Autism)	Time each child spent: showing signs of interest towards the introduction of TUI by looking at it
Theme 2 (T2)	**Approach** the TUI	Time each child spent: approaching TUI independently (I), or receiving gestural/verbal (GP/VP) and/or physical prompts (PP)
Theme 3 (T3)	**Pull to activate sounds**	Time each child spent: playing sounds independently (I), receiving gestural/verbal (GP/VP) or physical prompts (PP)
Theme 4 (T4)	**Music making** together	Time each child spent: playing music together with peers, by themselves or with adults
Theme 5 (T5)	**Unexpected uses of the TUI *i.e. for else than playing notes*** (deep-pressure, climbing, squeezing, patting etc.)	Rate of occurrences of different actions performed by the children when using the TUI other than to trigger sounds
Theme 6 (T6)	**Share emotions**: express appropriate emotions, able to self-regulate	Time each child spent: displaying emotions i.e.: *positive, negative, giggles/over-excitement, vocalizations, running, jumping, playing around/hanging from curtain etc*.
Theme 7 (T7)	**Eye-contact**	Instances of eye contact between peers and child-adult.
Theme 8 (T8)	**Play Types**	Time each child spent: exhibiting different types of social play such as those in Table 5-4

Table 5-3 TUIs Framework Assessment for Social Play and Self-Regulation

The analysis was conducted in the same way of study 1; the results in the findings below report on the comments left by the dance teacher and the TAs in their observation sheets and the more quantitative analysis done on the video recordings. The time logs of each activity were recorded and converted into seconds, and the percentage of times was then calculated as proportions. A mix of data was gathered including pre and post-sessions interviews with the dance teacher, the class teacher, and the TAs, observations and extra sheets, and the annotations of the video analysis. The researcher was always present throughout the testing sessions as this helped to addressing practical issues such as limited camera angles during the hello part.

Categories of Play *(adapted from Parten 1932)*	Definitions
Unoccupied (U)	Child plays with own body/clothes, goes off/on bench, stands around, sits in corner, fiddles with string/symbols
Onlooker (O)	Child looks at other children but does not participate. This can be performed from beside people or from far away.
Solitary (S)	Child plays alone by doing imaginative play by vocalising on their own and running around/wiggling body, making funny body movements, spinning around the room, running around the space and or behind curtains. Child can also play alone with Olly.
Parallel (P)	Child is next to peers using Olly in different ways than that displayed by their peers i.e. touch felt and/or ribbons, speaker pouch, steps on speaker etc. Plays beside peers rather than with them.
Associative (A)	Child displays identical or similar activity (watching, copying). Children act as they wish, and the activity is not organised but there is a sense of togetherness and belonging
Cooperative ©	Child actively engages in same activity. There are not spoken rules (child might sign to communicate to peer), but children influence or modify activity of others. There is a sense of belonging.
Child-initiated seeking of adults (CISA)	Child approaches adults to satisfy a sensory desire i.e. requesting legs massage, deep pressure on body parts, touching adult's ear lobes, armpits etc..
Child-initiated affectionate interaction with adults (CIAA)	Child approaches adults to request for comfort i.e. lays on adults laps, strokes adult face or body parts, leans with body on adults, hugs, caresses.
Pro-social interaction and positive response (ProS +)	Child initiates a social interaction and receives a positive response by peers or adults
Pro-social interaction and no response (ProS -)	Child initiates a social interaction and receives no response by peers or adults
Refuse to Join (RJ)	Child clearly avoids being prompted to Olly or offered a ribbon
Competitive (Cm)	Child clearly displays a competitive spirit i.e. by taking ribbons off adults' hands or pushing a peer away from Olly.
Turn-taking (TT)	Child clearly waits for his turn when other peers are on Olly.

Table 5-4 Theme 8 Types of play

5.7 Findings

The average session's length was of 23 minutes and 58 seconds (Table 5-2). Within this time, an average of 54.6 seconds was spent introducing Olly to the children. As previously mentioned, due to a technical fault, on the fourth day, Olly was tested for a period of 23.11 minutes with the power off. The teacher started the session, as usual, using the same methods and excitements as per the previous sessions. Nevertheless, at the entrance of the dance room, there was a message attached to the door to inform the TAs that the technology was broken, and some children might have read that message, or possibly heard their TAs when reading it before entering. Ben left after 15 minutes during the first session, as he "*became distracted*", so to prevent him getting dysregulated he was brought back to class, whereas on day 2 he was brought out of the activity after more than 20 minutes into the session because he hit Alice on the back. Apparently, he did that after Alice acted out a baby type of scream because Isaac was running towards her. It was unclear whether the action of hitting was an unpleasant reaction to the brief and high pitch screams of Alice, or if it was due to the fact that she screamed while looking at Isaac, which might have been misinterpreted by Ben. The dance teacher said that it was "*a communication issue*". However, Ben stayed for the entire duration of the third session – the last he attended. In an interview post-session, the teacher said that "*you have to have a clear structure for our children to be able to have that moment to explore because they know that when it's starting and they do know when it's finishing and in the middle it can be that freedom*".

Instead of being accompanied by a TAs, Joshua came accompanied by his class teacher as she was very enthusiastic about the research and wanted to participate; but was unaccompanied in the 4th session. Every other child came with their TA. The researcher and dance teacher asked for Alice to be unaccompanied for the last session, and Ben was only present over the first three sessions.

The results, presented in the following sections (T1 to T8), offer an analysis of the findings using the same approaches as those applied to study 1. Theme 1 to Theme 7 paraphrase the general notes left by the teachers in their observation/extra sheets and contextualise them within each theme. T8 presents the researcher's interpretation of each type of play displayed by the children and offers factual observations on what the children did. Each theme also displays graphs showing the percentages of the time that each child spent doing the observed criteria. Alice's TA was asked not to come in session 5 as both the dance teacher and the researcher thought that she was working against the children at times e.g. as noted by the dance teacher "*she didn't make a relationship with anybody"* and again *"I think at the beginning she overpowered Alice*".

5.7.1 T1. Introduction to Olly

To understand the level of children's engagement at the beginning of the sessions, the researcher observed their behaviours during the introductions of each session. The graph shown in figure 5-14 displays the percentage of times that children showed interest in this part of the sessions, calculated per each child over the introductions they attended. As per study 1, the length of T1 was calculated from when the teacher said hello to the children, to the end of the song inspired by Attention Autism when the teacher unveiled the TUI. Children were expected to sit down during this part of the activity, and the teaching assistants (TAs) often prompted them to wait until Olly was uncovered. However, it was known from the class interviews, that some of the children found it difficult to follow common Attention Autism activities in their regular classrooms e.g. Pete class teacher said that *"He does have concentration issues"* and *"you need to grab his attention"*.

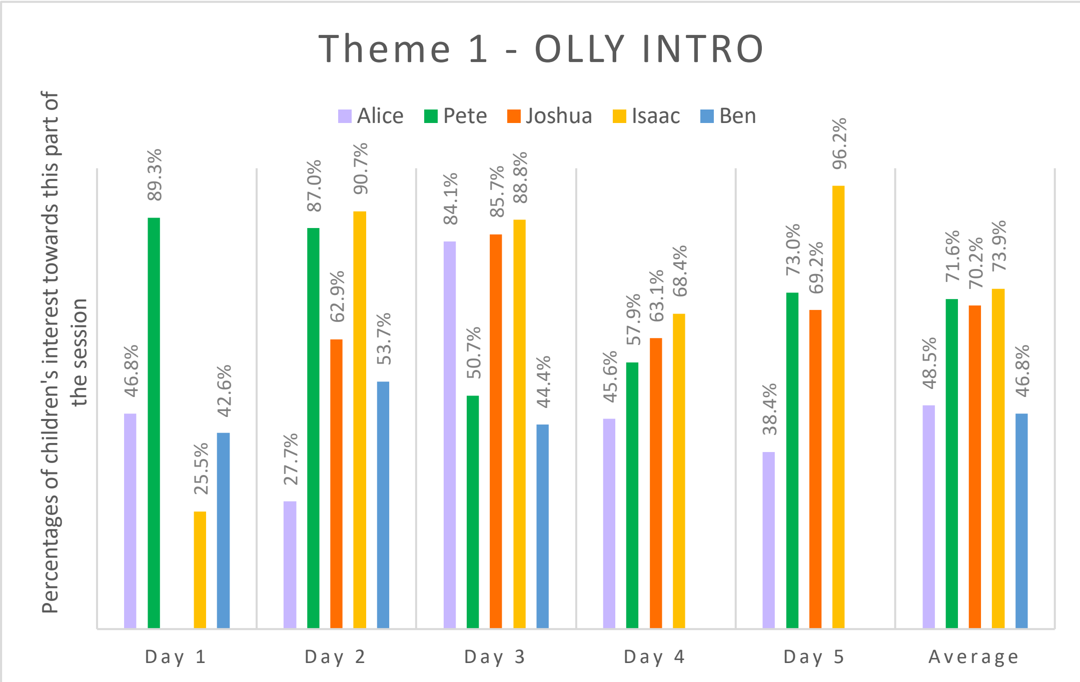

Figure 5-14 Theme 1. Graph showing percentages of daily interest toward the Intro per each child

In the post-study interview the dance teacher said that "*over the weeks I think the hello sitting on the bench with and the transition was excellent. [..] people don't really understand how difficult transition into a new activity is for our children. Is massive. Sometimes if you know add something new to the timetable you only had [..] to encourage that kind of engagement and focus and motivation in five weeks is normally unheard of"*. On day 1, Joshua arrived later and missed the introduction. At the beginning of the study, Isaac was unable to sit and wait during the introduction, and most of the time he needed a physical prompt. As the sessions progressed, however, he was able to sit for longer for this part of the session. After day 4 Isaac's TA on wrote that *"after a slightly difficult day (changes in routine, little accident, less outside play) he was able to wait more on the bench for "Hello"*.

5.7.2 T2. Approach Olly

To recap, following theories of proxemics (Hall 1966), an approach was annotated when a child was less than around 120 cm far from Olly. The approach times are shown in figure 5-15 and have been calculated over the daily times of the sessions that children attended, minus the introduction times, as children were asked to sit down for that part. Children exhibited a high overall average of approaches, and in general, it seems that Olly was enticing to the children. For example, the dance teacher wrote *"The cloth was perfect for Alice to interact with pulling with 2 hands wrapping the cloth around her waist"*.

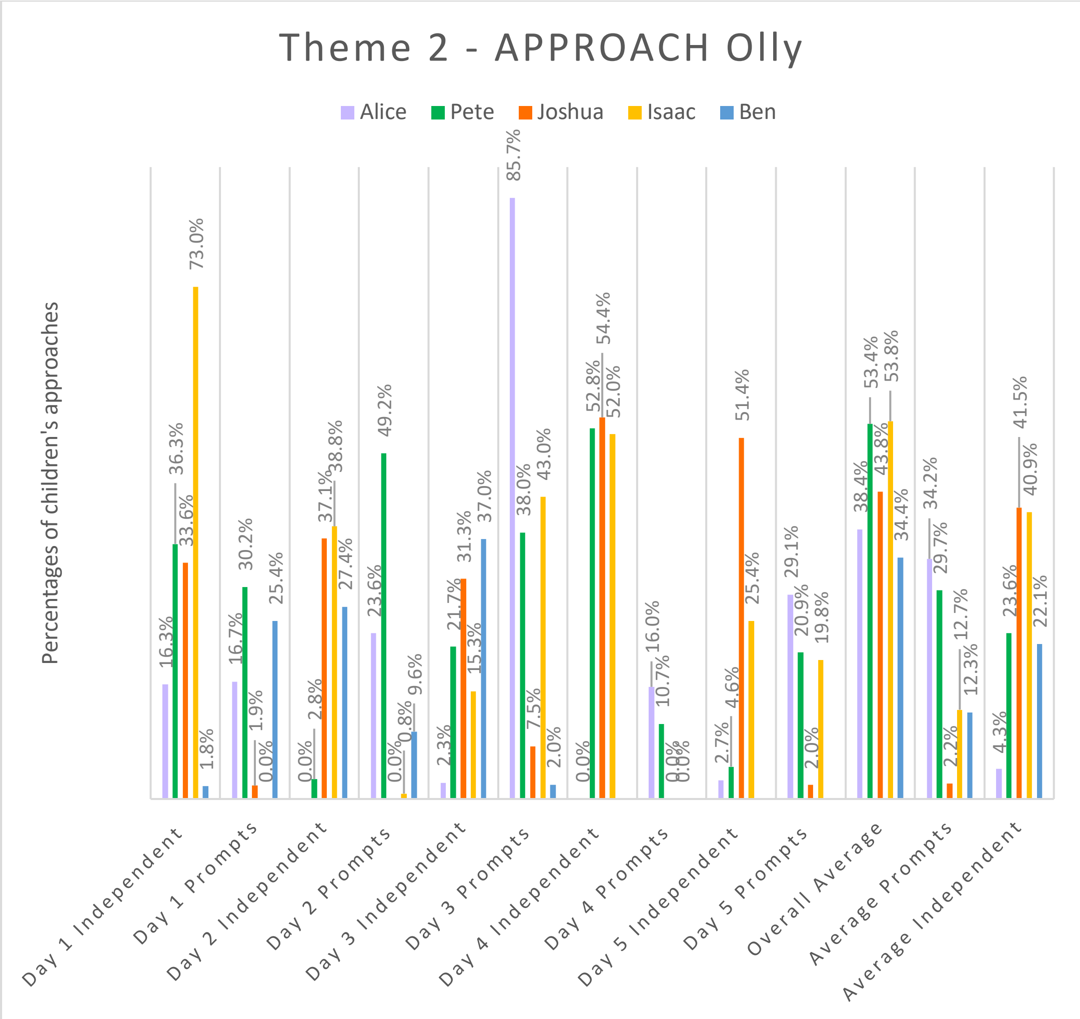

Figure 5-15 Theme 2. Graph showing percentages of daily approaches demonstrated by each child in study 2

It was confirmed by the class teacher, and TAs, that Alice "*needs physical prompts to participate and lots of encouragement*". In fact she sought adult's attention for an average of 7.3% of her approach's time (average of 38.4%). The dance teacher reported that she "*used a lot of physical prompts with Alice to encourage her into it but she will only stay as long as she can tolerate or she wants to be. I don't think she's* *ever moving away because she doesn't want to do it. She has to go away and process it because she gets so I think it just becomes so much*".

Interestingly, Pete approached less on the last day. However, it's important to notice that he was very excited about the holiday half-term starting the following day. He also sought adult's attention during his approach times (average of 26.4%), particularly in sessions four and five. Joshua on the other hand, is the child that approached more independently. However, after the testing sessions his class teacher noted that "*Pete was on top of Olly, Joshua wasn't feeling comfortable and was waiting. When Pete moved from Olly, then he was approaching with confidence you know, he was like, okay, it's not my turn now and he was waiting, he was in the corner*". Joshua also sought adult's attention when approached Olly (average of 6.7%) mainly in the form of requesting hand massages on their legs. In the post-sessions interview with Joshua's class teacher she said that *"he likes to stretch. He liked the feeling. He was also really interested in the vibration of the speaker because he was putting always his feet on top".*

After day one, the TA working with Isaac reported that he "*was eager to interact with Olly. [..]He amazed me with his brave initiation to go and explore Olly first of all kids in the middle of the room*". Isaac also sought adult's attention during their approach (average of 10.4%), mainly in the form of cuddles when it seemed he needed reassurance (i.e. when Ben tried to hit him), or to touch the TA's ear-lobe, which the researcher knew it was something that Isaac liked doing. Day 4 is the session that Isaac sought most adult's attention when around Olly, which interestingly, is the day that the TUI was powered off. However, after day three, Isaac's TA said that he "*spent a balanced time with playing with peer and came back to Olly pulling string*". Importantly, Isaac played with Ben for an average of 50.6% of their approach times (in day two, and day three) i.e. by running after each other around Olly. After the testing sessions ended, in an interview with Isaac's TA she said that *"[Olly] was good because it was round. So, there were no edges, and there was access to everyone. And it was soft, so it's really welcoming. It made sound, like song. As a shape, as a something, there was no gender of this. There was no very harsh colors [sic]. It was just like a nest. It was accessible. It was really good".*

Finally, Ben spent most of his independent approach times (when not playing with Isaac), seeking their TA's attention, and this was exhibited through lovely interactions of affection towards her, especially when he was, perhaps, getting overloaded by playing with Isaac. However, Ben spent an average of 66.7% running with Isaac around Olly from day 1, when even the dance teacher wrote "*running around Olly with Isaac quite fast*". After day 2 Ben's TA reported that "*he played with Olly in short bursts […]* and after day 3 she wrote *"he stayed for the whole lesson. Mainly ran around with another child [..] and interaction with Olly on and off*".

5.7.3 T3. Touch to activate sounds

Within the time that children spent approaching Olly the analysis captured how long each child played with it to trigger the sounds. Figure 5-16 shows the daily percentages of sounds triggered by the children, for each day, calculated over the daily approaches of each child. The dance teacher before the testing sessions started wrote in a Tweet that "*Olly sounded so peaceful*".

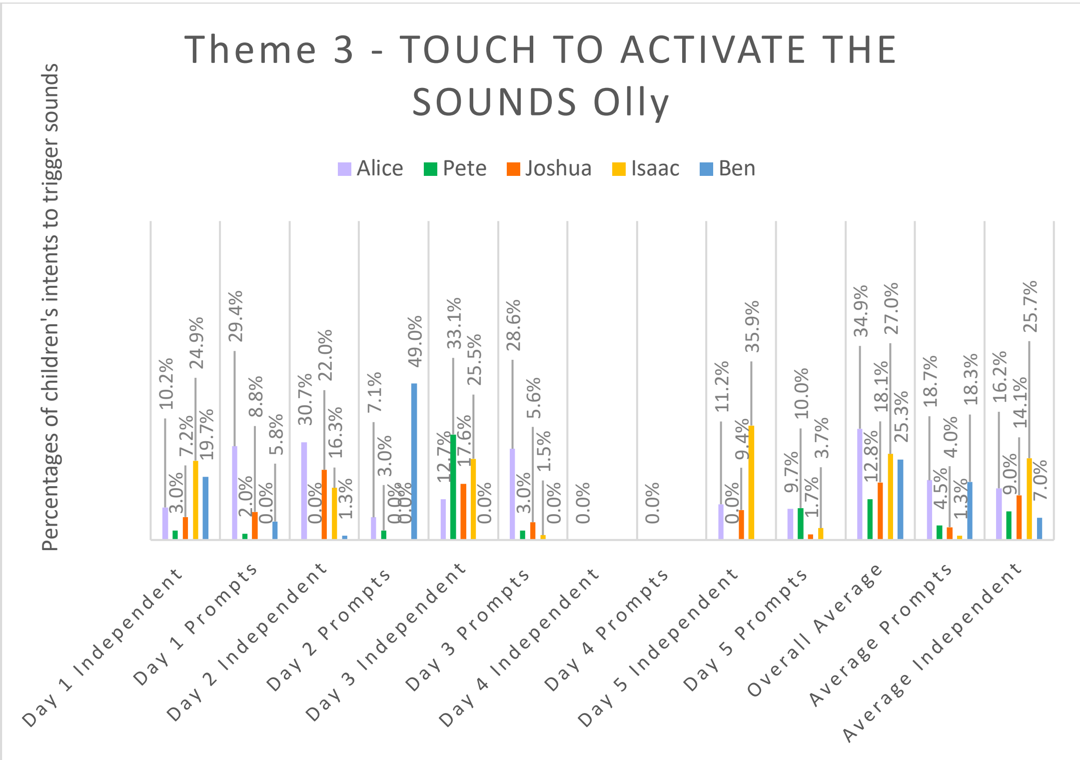

Figure 5-16 Theme 3. Graph showing percentages of daily sounds activations counted per child in study 2

It was assumed that if a child would play with Olly by themselves, or with others, by pulling the ribbons and creating music, and did so repeatedly, perhaps smiling after their actions, the purpose was that of creating music. If they triggered the sounds just sporadically, it was not considered as a purposeful music playing endeavour, but rather, as an appreciation of the elastic properties of the materials used (T5).

For example, after week 3 the dance teacher wrote "*Alice independently wrapped the Lycra around her waist touching back and forwards*". In week 4, she reported that "*Alice was very engaged and calm on arrival-ready to play with Olly",* but added that *"Once she realized there was no music [...] she became unhappy*". Alice left the room after crying very loudly as it seemed that the absence of sound upset her. After session 2 he TA's wrote "*with an adult support (full prompting) she sat close to the Olly and started pulling the clothes*". Pete's TA instead reported that "*Pete was very curious about Olly and explored well. Pete enjoyed laying over the top and rocking*". In fact, it was noticed by the researcher that Pete rarely grabbed the ribbon to activate sounds, but he was able to trigger sounds by rocking on Olly, as the fabrics got caught between its base and the ball. After day 2 his TA wrote that Pete *"was a little dysregulated as he was aware that his classmates were going out. However, without prompting Pete was able to enjoy Olly for a time today".* Joshua's teacher, however, thought that he still did not understand cause-effect and was not sure if the child pulled the ribbons to trigger the sounds *"I think he was stack in the point of, oh I can pull this, it wasn't like cause and consequence because his development. [...] it was a sensory experience."* Conversely, the dance teacher reported at the end of the testing phase that all the children understood the cause-effect interaction "*I believed that they had worked out that the music came when you manipulated the cloth."*

On day four, Isaac created sounds by patting on Olly's body alongside a TA and communicated vocally when they wanted her to stop patting on it (see T8 results in the following section T8. Play types). This result was taken as an indication of Isaac missing the music as he was the child that played the most independently. However, Isaac might have also liked the sensation of pulling and manipulating, as the TA's feedback after day one read "*He pulled the cloth. Placed his body inside the cloth. Isaac explored the cloth with Ben running around Olly*". Finally, Ben explored all the ribbons and spun around Olly holding the elastic and making music with two peers (Isaac and Pete), especially on day 1. After that day the dance teacher wrote that Ben "*Lays on Pete's back listening to the speaker. – v calm"* while after the second day, she stated that he "*was eager to touch Olly* [...] *Ben and Isaac laid at the speaker touching and listening*". In the three sessions that Ben attended, the child never had the chance to play solo and this might have impacted his understanding of the cause-effect interaction.

5.7.4 T4. Music making together

Among the times that children played music, the researcher analysed how much of it was spent playing together with peers, with adults, and/or solo. This helped identify which children had the chance to understand that the sounds were created by their own actions. Ben was the only child who did not play music with Olly in solo mode. Figure 5-17 shows the daily combined percentages of the different modes of music making together that the children exhibited.

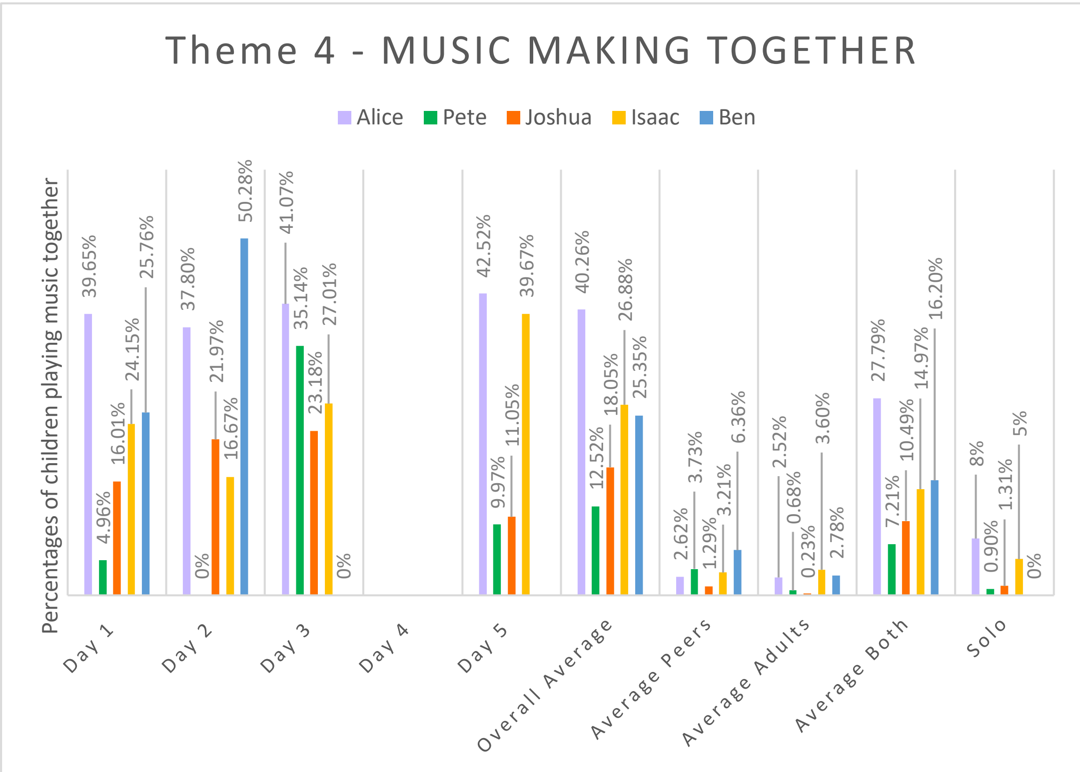

Figure 5-17 Theme 4. Graph showing percentages of children playing together shown daily per child in study 2

In the post sessions interview the dance teacher stated that with Olly the "*collaborative play was much more than with than with Mazi. In a different way. The fact that how it sounded it was different [] it was like they were creating music. Whereas with Mazi um the creative. Creating music was something. Well like with Joshua with Mazi. Once he got the hang of it he would come back and do it. But it was more like cause and effect*".

Alice played the most with both peers and adults in day 3, which is the same day she received most physical prompts (PP), while in the last session she played mostly independently, indicating that with more time she could have mastered the use of Olly. During a pre-testing phase class meeting, it was reported that *"Alice would not share spontaneously"* and that she would not initiate interactions. As Alice shared

Olly with several peers more than playing solo, this result was appreciated because she showed sharing skills perhaps not exhibited in other school contexts.

Similarly, the dance teacher explained that "*to share space is very new ideas for Pete*". In the last week he "*wrapped the Lycra around his feet the same time as Joshua"* and for the dance teachers *"watching this brief interaction was wonderful".* She added that "*I think that Pete was much better than he'd ever been [...] You never really get him in that close proximity with others. He's always on the perimeter, but he did that a lot.*". As reported by his class teacher also Joshua was not used to play with peers or sharing a toy *"he really, really liked Olly, because he's always by his own, you know, he's not really sharing with anyone at least here in the school.".* After session 4 she wrote that "*Joshua was more confident with less [sic] students in the room*". In day 3 Joshua joined the game of Isaac and Ben by pulling the ribbons and coordinatively releasing it when Isaac and Ben were passing by to chase each other around Olly. His teacher noted that he "*enjoy[ed] the other children's games*".

Isaac and Ben on the other hand, developed a sort of friendship while playing chase around Olly. Isaac's TA wrote after day 3 that *"in early years playground he found it difficult to play with peers*", hence this was considered a positive. Ben was absent for the last two sessions missing the day that Olly was not working and making it harder to evaluate if he would have reacted differently without the sounds.

5.7.5 T5. Unexpected uses of Olly

Theme 5 captured the unexpected uses of Olly displayed by the children. These are listed in terms of the number of instances (xNumber) exhibited by each child and displayed in Figure 5-18. Children displayed a variety of novel interactions and expressed their adaptation to and appropriation of the piece. As in the other studies, these actions were combined and coded under the umbrella term 'unexpected use'.

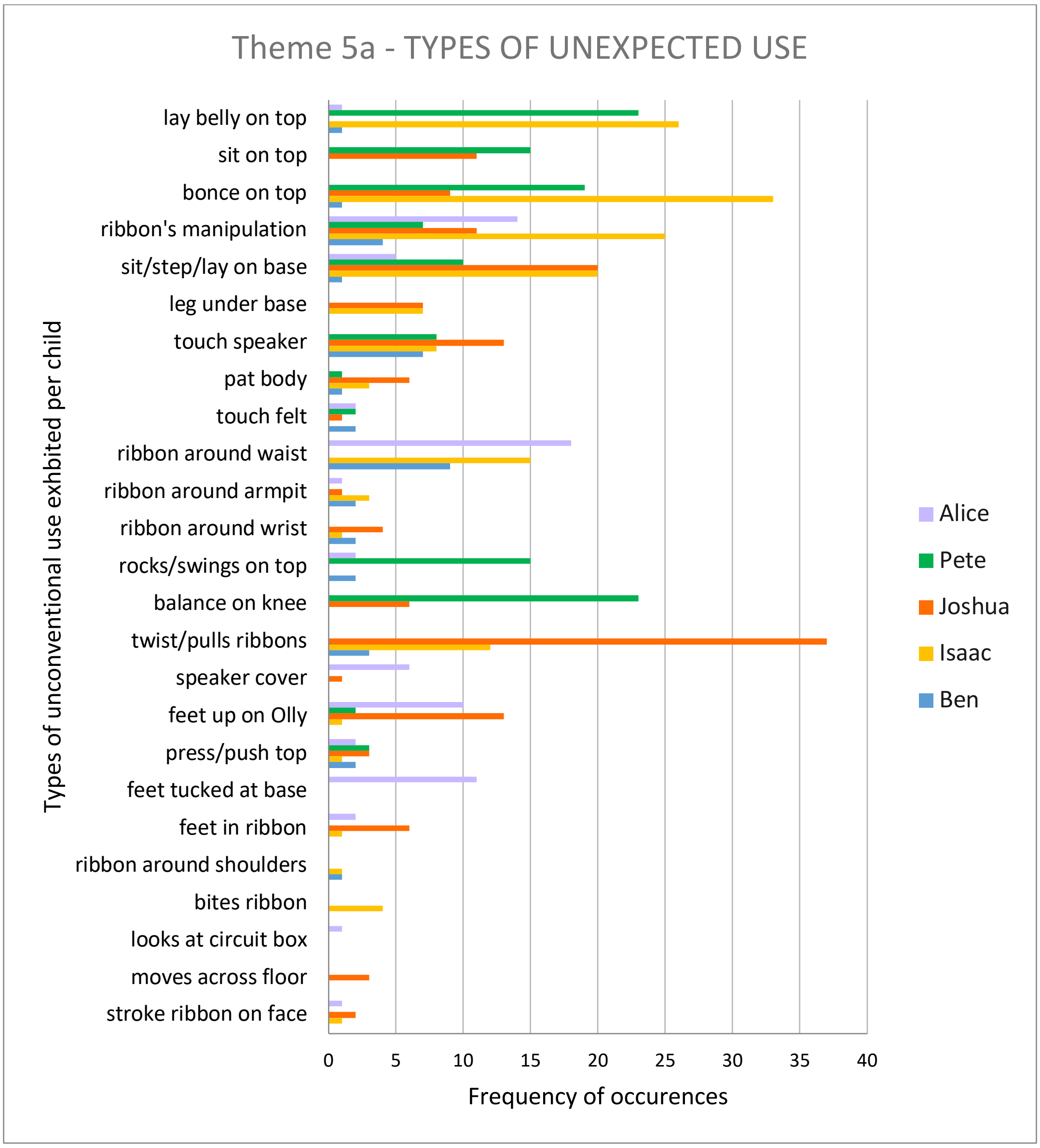

Figure 5-18 Theme 5. Graph showing T5 Olly frequency of unexpected uses per child in study 2

For example, Alice was observed pressing Olly's top with both hands, and used it unexpectedly for an average of 42.7% of her approach times. She also kept the orange ribbon around her neck without pulling it and sat on Olly's base and against the ball while fiddling with a thread. The actions that Alice performed the most were: keep ribbon around the waist (x18), manipulate the ribbons (x14), tuck feet in between the bottom of Olly's body and the base (x11), keep feet up on Olly (x10), touch the speaker cover (x6), sit/walk on the base (x5), wrap feet inside the ribbons, touch the felt, press Olly's body (x2), and lastly with just 1 instance each she looked at circuit box, held a ribbon under armpits, and stroked fabric on her face. Pete, on the other hand spent an average of 59.5% of his approach times using Olly in unexpected ways and he's the child who used it the most for novel purposes. For example, in day, Pete laid on Olly's top and was rocked side by side by the group of peers and adults that had gathered around it. Pete kept laying on Olly with his head down and feet tucked down on the felt base. He exhibited the following behaviours in descending order of instances of occurrence: lay on Olly and balance on Olly's top using knees (x23), bounce on Olly (x19), sit on Olly, and rock/swing, on Olly (x15), sit/walk on the base (x10), touch the speaker (x8), manipulate the ribbons (x7), press/push Olly's body (x3), touch the felt, and keep feet up on Olly (x2), pat Olly's body (x1).

Joshua displayed an unexpected use of Olly that averaged 53.7% of the time and often twisted one of the ribbons around his arm then realised it. He is the only child that moved Olly to a different place in the room by pulling few of the ribbons strongly and sliding the TUI across the floor. Unfortunately, this affected the responses of some of the sensors pulled to move Olly around. Joshua's unexpected uses mostly included: twist and pull the ribbons (x37), sit/walk on the base (x20), touch the speaker, and keep feet up on Olly (x13), sit on Olly, and manipulate the ribbons (x11), bounce on Olly (x9), cover legs under the base (x7), pat Olly's body, and balance on Olly's top using knees, and wrap feet inside the ribbons (x6), press/push Olly's body, and move Olly across the room (x3), stroke fabric on face (x2), touch the speaker cover, and the felt (x1). Isaac instead, used Olly unexpectedly for an average of 40.1% of his approach times, and mostly he demonstrated the following uses: bounce on Olly (x30), lay on Olly (x26), manipulate ribbons (x25), sit/walk on the base (x20), keep ribbon around the waist (x15), twist and pull the ribbons (x12), touch the speaker (x8), cover legs under the base (x7), bite on ribbons (x4), pat Olly's body, and hold ribbon under armpits (x3). He also kept his feet up on Olly while lying on the floor, pressed/pushed Olly's body, wrapped the ribbon around his shoulders, and wrapped his feet inside the ribbons once throughout. The dance teacher said "*Isaac really liked that because he loves the ribbon in dance and I also liked the way he stepped into it. Put it around his waist [..] That was a lovely thing to see him getting some kind of regulation around his abdomen".*

Lastly Ben displayed an unexpected use of Olly that averaged to 51% of his approach time, and he exhibited the following actions: keep ribbon around the waist (x9), touch the speaker (x7), twist and pull the ribbons (x3), touch the felt, and hold the ribbon around the wrist, and rock/swing on Olly, and press/push Olly's body (x2), and to conclude lay on Olly, and bounce on Olly, and sit/walk on the base and pat

Olly's body (x1). Ben's TA observed that *"pulling was good for him [..] because he likes the pull he likes the actual motions of doing things [...]it was quite good because he could go back a bit".*

The dance teacher believed that Olly was more versatile than Mazi and that it offered the children more opportunities to play together as they "*could lay on the technology while the other could still play. While Mazi if you were laid on it, it was a bit difficult to play"*

5.7.6 T6. Share emotions

As described below, all the children expressed a mixed range of emotions. The graph in figure 5-19 shows the overall amount of combined emotions that each child exhibited each day and it includes observations on children's repetitive behaviours, such as twiddling with strings, rocking, hand flapping, stomping, and spinning. These were calculated from when the children took their shoes off for the introduction, to when the TUI was covered again at the end of the session. For negative emotions, the researcher coded when children cried or were visibly annoyed.

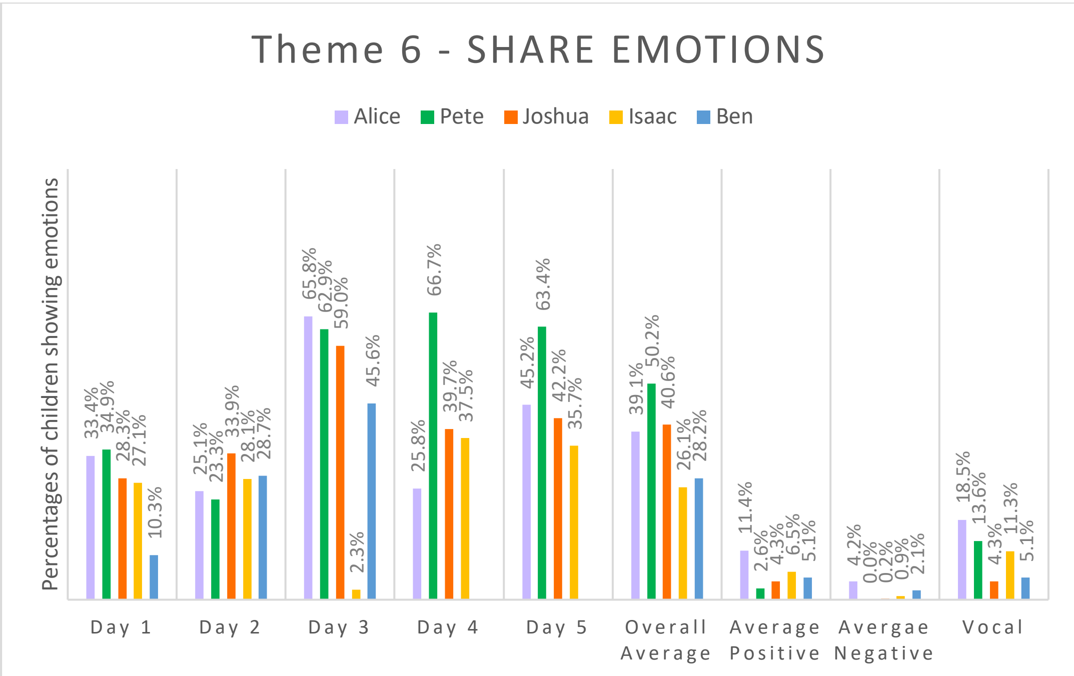

Figure 5-19 Theme 6. Graph showing percentages of daily emotions exhibited by child in study 2

As it can be seen in figure 5-19, most of Alice displayed emotions were vocalizations in the form of echolalia and solitary imaginative play. However, Alice liked to sing as well, usually alongside the music triggered by people playing with Olly and/or just after the music was played. When the sound was off in day 4, she sang less and exhibited the most negative emotions. i.e. moaning sounds - which were usually followed by smiles, as she was perhaps prompted to Olly - but also distressed/loud shouts. In day 2, Alice left and came back to the dance studio before the session finished because "*she had needed a drink of water and toilet [..]*". Her positive emotions were in the form of visible smiles and other behaviours, such as touching adults' body parts, often around and under their arms, playing with a thread found on the floor, and chewing on it (day 5).

After day 1, the dance teacher reported that "*Pete was engaged and able to follow instructions*" and on day 3 she noted that "*he was singing, calm and relaxed.*" Post-study she confirmed that "*he really did explore and self-regulated himself*". Pete also expressed high arousal levels, and over-excitement such as vehemently patting his hands with that of the teacher, clinging on her back, pressing his and/or arms, manipulating people's body parts - especially underarms and so on. Pete started manipulating adults' body parts (arms and hands) from day 3 and particularly on the last day when indeed he also approached Olly for less time. "*Pete became quite overstimulated"* reported the teacher. However, she said that *"the vibrations from the music calmed him down*". At times, in day 3, Pete asked an adult (usually the teacher), to press his head using her hands, but more often he sucked his thumb and was visibly calm. Occasionally, he would keep his eyes closed, perhaps to block out some of the visual stimuli. Pete never displayed a negative emotion. In day 4 his TA noted that "*Pete was very excited today but enjoyed bouncing on Olly*".

Conversely, Joshua manifested negative emotions on day 1, and on day 3, but these were in response to being physically prompted to Olly by an adult. Before the testing phase commenced, Joshua's class teacher - said that important to him was "*being independent*". Therefore, this might have reflected his reluctance to being physically prompted. He exhibited positive emotions by visibly smiling and vocalizing in the form of sounds. His teacher wrote that Joshua *"was very happy, smiling all the time".* Often Joshua sucked his thumb, requested a leg massage, or would hang from or stood around the curtains. He would spin and twist a string, and once, in day 4, he pulled his trousers off. His teacher wrote that "*he was so happy that he took his trousers off. He really enjoyed the session*". At times, Joshua stomped his feet. Comments from the dance teacher read "*Joshua moved in the space confidently (that was amazing as Joshua is an anxious student who needs a great deal* *of support)."* In the post-sessions interview, his class teacher observed that "*he was feeling happy and safe [..] he was feeling comfortable with the space and, with us"* and added that *"I think he was really really regulated, but it creates more excitement for him [..] even the vibration but he was very excited about all the strings in one point".*

Isaac also expressed negative emotions through visible signs of distress (e.g. laments, because the TA prevented Isaac to touch her ear lobes, or because Isaac did not want to sit for the introduction). However, he became much more regulated as the sessions progressed. He joyfully ran around the space and climbed the curtains, or ran through them, he bit his nails and sought to touch or clang onto his TA. When vocal, Isaac was either communicating i.e. needs for toilet (in day 1), asking for help, telling an adult were to sit around Olly, or by vocalising few words such as "no", and "there". On different occasions, Isaac repeated out loud "*O*" or "*Oi*" to refer to Olly and "*pull"* while pulling the ribbons and playing with Olly. After day 3 Isaac's TA wrote that it was *"very inspiring how he regulated himself and he enjoyed the session".* After day five instead, the dance teacher commented "*he really likes the interactive nature of Olly pushing – pulling – laying on – sitting on. [..] He was less anxious than earlier in the day*". In an interview carried out after the sessions ended his TA said that Isaac "*tried to get everyone eventually. First, just the one who-- Ben ran around and ran, and then he even went to Joshua. He really explored the persons as well. Not only Oli. And then up, and then Oli, person, Oli, person, person, person. This person, that person. And then he came to my lap. It was also another nest. The safety something. So, he really did-- sometimes, I felt like he really did neurotypically. Just a neurotypical, very active someone*".

Ben also showed his passion for running around, and sometimes hid behind the drapes or clang on his TA's back. Negative emotions were in the form of moans i.e. in disagreement that they had to leave earlier (day 1), or loud shouts as if he was not happy with Alice being upset on day 2, and with Isaac not sitting down when he was asked to do so, or when he hit another child. Ben hit few children in the three sessions he attended but the teachers always reacted promptly avoiding any issues to continue between them. During the last session, as a way to model the interaction, Ben's TA asked Isaac to run together on behalf of Ben (by using voice and signs) and waited for Ben to copy her. Interestingly, Ben copied her and repeatedly asked Isaac throughout the sessions to run together by using signs and sometimes voice. The requests were almost always reciprocated (see T8 for details). As noticed by the dance teacher *"Ben was able to communicate and Isaac was able to understand [..] this prevented hitting to get attention from a pupil."* Ben's TA confirmed that "*He stayed for the whole session, his communication was really good"* and "*giving them the space was really good".* This result suggested that, if Ben would have attended the last two sessions, perhaps, the two children might have been able to develop their friendship further.

5.7.7 T7. Eye-contacts

In Theme 7 the researcher looked at instances of eye-contact exhibited between the children or between a child and the adults. Few of the observations left by the teachers in relation to T7-Share attention are reported in T8 together with the 'onlooker play' type. Table 5-5 shows the overall combined amount of eye-contacts displayed throughout the sessions and between parts. Eye-contact was coded by the researcher when children seemed to look into each other eyes. However, from the recordings the researcher cannot be certain that children really looked in someone else's eyes or if they looked in an area around the eyes but not directly into them.

T7 Eye contact	**Alice**	**Pete**	**Joshua**	**Isaac**	**Ben**	**Adult**
Alice				1		1
Pete					1	
Joshua				3	3	
Isaac	1		3		5	6
Ben		1	3	5		2

Table 5-5 T7 Eye Contact Study 2

Nonetheless she interpreted these as their attempts to look at someone. Children showed eye-contact mainly when around Olly, suggesting that the TUI had a positive impact on children's social interactions. For example, Alice showed one instance of eye-contact with Isaac on day five, when they were playing music with the ribbon wounded around their waist and Isaac joined in bouncing on top of Olly. The dance teacher post sessions said that *"she has done a lot of eye contact with Isaac".* On day 1 Pete and Ben made eye-contact when the former approached the latter while playing on Olly. Joshua instead, showed instances of eye-contact with Ben on day one (x2), with Isaac day 2 and 3 (x1 each day), and with Ben on day 3. Isaac made eye-contact with Ben on day one, one time (x1), as they first approached Olly, and four times (x4) in day three when they played running. The dance teacher thought that *"because they're [Isaac and Ben] quite small, their eye contact was really good".* Finally, on day five Alice and Joshua also gazed at each other once.

5.7.8 T8. Play types

Theme 8 was added to the final video analysis in order to understand how Olly could be applicable to different types of play. The overall percentages of each type of play were calculated over the times of the sessions that children attended, minus the introduction's times. Illustrative examples of each of these categories of play (see Table 5-4) are given in figure 5-20.

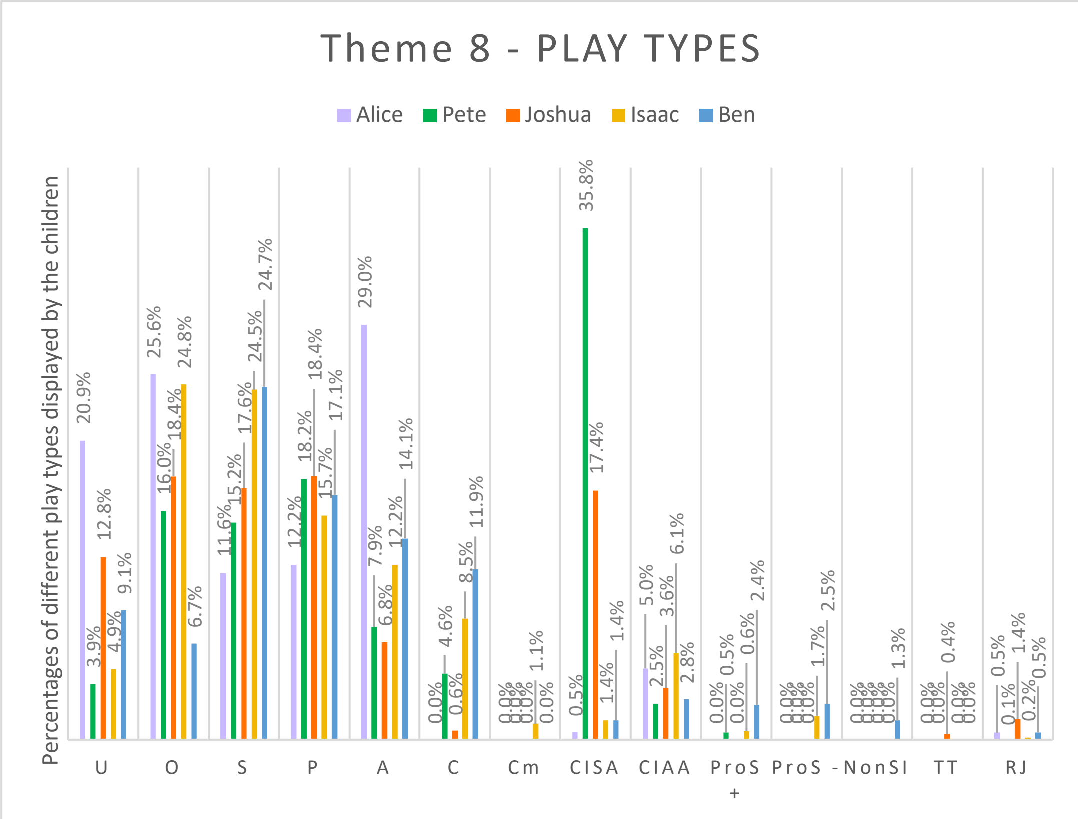

Figure 5-20 Theme 8. Graph showing overall percentages of types of play over the five session

5.7.8.1 Unoccupied (U)

The first type of play observed was Unoccupied play (U), which was indicated by a variety of behaviours. Children exhibited an average of 9.51% of this type of play. For instance, when Unoccupied, Alice waggled her body while she sat on a bench or touched her feet, pulled trousers up, took few steps next to the bench. Pete instead crawled on the floor, walked across the space sucking thumb, or flicked fingers and squeezed their eyes. Similarly, Joshua sat around corners of the room manipulating Olly's cloth cover, or fiddled with a string while sat, or stood around the space, and sucked their thumb. Finally, Isaac fiddled with some symbols, or scratched their head, slid across the floor on his knees or stood around perhaps waiting for Ben to join the chase game, and Ben crawled on the floor and at times also span around and laid his belly down on the floor. When children were prompted to Olly by an adult (PP), it was coded under the Unoccupied play because usually, they were exhibiting Unoccupied play during or just before being prompted.

5.7.8.2 Onlooker (O)

Onlooker play (O) was observed for an average of 18.30% of the time. Usually, children were onlooker within a distance of up to 5 meters. Alice and Isaac exhibited the most Onlooker - overall average time of 25.55% and 24.83% respectively. For example, Alice usually distanced herself from peers when they were getting too close, and often she gazed at them when she was not in Olly's or the peers' close proximity i.e. when sat on benches. Isaac instead, was Onlooker when standing beside or closer to people. However, sometimes Alice also sang along when looking from afar at peers playing with Olly, suggesting that she made a connection with the ongoing activity. Some children, such as Alice and Joshua, preferred spending some time looking, before joining in, indicating that perhaps, they used this time to get comfortable. Alice TA's wrote in session 2 that she "*was exploring the area around the Olly by walking, running and making sounds*", while in the post-sessions interview Joshua's teacher said that *"in the beginning, he was with the ribbon and in one point and he was in the corner with his ribbon and he was like looking like that, you know, like I'm looking to see".*

5.7.8.3 Solitary (S)

Solitary play (S) was exhibited in different forms, and when averaged between the children was the most observed type of play (19.80%). For instance, Alice and Ben would often play alone on their own i.e. without using Olly. Alice hopped about, wiggled her body and made funny voices, while Ben would mostly run around the room and hid behind the curtains. However, in the last session, Alice also played with Olly solitarily, suggesting that with more time, she could have mastered its use. On the other hand, Pete demonstrated more Solitary play with Olly than alone. Similarly, Joshua and Isaac played solo mostly when using Olly, but they also played solo without interacting with Olly e.g. with the light settings of the room (Joshua), running around the space (Joshua and Isaac), pulling the drapes (Joshua), or staying behind them (Joshua and Isaac). Joshua in day 4 went to the cupboard where the stereo is and the researcher interpreted this as if to indicate that he wanted the music on because he attempted to open the cupboard.

5.7.8.4 Parallel (P)

Parallel play (P) mostly happened between peers, but also between children and adults, and always by using Olly in different ways i.e. by being sat on it, leaning against it, or playing with its various textures and parts. Children displayed an average of 16.33% of this type of play. For instance, on day one, Pete was curling backward towards his heels with his face over the speaker and at times pulled the orange ribbon. Isaac got hold of the same ribbon and started playing too by wounding his body in it, and pulling back and forth, while Ben manipulated the felt and ribbons and laid with his belly on Olly's top. Pete kept looking at and laying close to the speaker while sucking his thumb. The dance teacher was beside them and all the other adults were sat at the bench. A different day, i.e. day three, Alice was playing and manipulating the purple ribbon while laying on their TA's laps. The TA was sat around Olly and Joshua laid on the floor next to her and kept the blue and orange ribbons around his ankles (encouraged by the adult), while Isaac was leaning on Olly.

5.7.8.5 Associative (A)

Associative play (A) occurred for an average time of 14% and mainly when using Olly in groups of two or three children. Usually, adults also joined the play or sat around Olly. For example, on day 3, Alice laid between her TA's laps and played the purple ribbon (wounded around their waist), while Pete laid on Olly's base, keeping his legs on it, and pulled the green ribbon. Joshua pulled the orange ribbon, and another TA pulled the blue. There was a sense of togetherness and belongings indicated by the positive emotions displayed by the children and their contributions within the group activity (which in this case was that of making music). However, Isaac exhibited associative attempts also by copying Ben and running after him few times with no response, before developing a friendship and playing cooperatively around Olly.

5.7.8.6 Cooperative (C)

Cooperative play (C) happened for an average time of 5.12% and it was mainly exhibited around Olly by Isaac and Ben during a chasing game that they initiated. For example, Isaac copied or attempted to initiate pro-social initiation of a chasing game with Ben a few times before Ben embraced the game. As he realized what was happening he then started asking Isaac for more running and so they did. Both were waiting for one another whenever they stopped e.g. if one needed a moment to rest and regulate, perhaps by stopping by their TAs, the other also stopped. This indicated that children established their own rules beyond those which are typically spoken, and these were visible by how the children: a) looked at or toward each other, b) decided when to start running by, either signing more to the other, or by looking at each other's bodily cues, and finally c) how they waited for each other. Isaac and Ben shared the same passion for running and they found some strategies to share their interest with one another.

Cooperative play while using Olly was also displayed in different playful contexts. For instance, Isaac played music cooperatively with the adults on day 1, and on day 4, when Olly was broken, he laid with his upper body on it and patted Olly's ball together with Joshua's TA. At first, Isaac said "a" when the TA stopped, as to indicate that he wanted her to play more, then he started asking for "more". As the TA kept patting the ball without Isaac saying "more", the child signalled their discontent by saying "No! No!", so the TA stopped, and Isaac held her hand, before asking again for more. On the other hand, Pete once also demonstrated a cooperative attempt when while laid on Olly's top touching speaker, and rocking on it in solo mode and Ben, Alice, and few adults all joined in by pulling different ribbons (Isaac was Onlooker). This created a rocking motion that Pete seemed to have taken advantage of by untucking his feet from the floor and, perhaps, enjoying the music created by the others. Although his peers' actions were influencing what Pete was doing by himself - i.e. rocking - he joined along and cooperated with the other in letting them direct Olly's wobbly inclination as its ribbons got pulled. In an interview post-testing session, the teacher said that "*the three boys, Isaac and Pete and (Joshua) were down and they're all doing something they're together. They might not be looking at each other but they're actually collaborating together*". After the last session it was reported by Joshua's teacher that he "*made new friends with the adults and collaborated with Isaac and Pete*". Isaac TA wrote after day 3 that she was "*very pleased to see him joining peer's play, approach other kids he didn't know (play chase with Ben, approach Joshua*"

5.7.8.7 Other behaviours (Cm) (CISA) (CIAA) (ProS +) (ProS -) (NonSI) (TT) (RJ)

The other types of observed behaviours are shown in figure 5-20. As a reminder these were:

a. Child-Initiated Seeking of Adult (CISA) when a child sought adult's attention by i.e. grabbing their arms,
b. Child Initiated Affectionate Interaction with Adult (CIAA) when a child showed behaviours such as caressing adult's faces as in the case of Alice, and
c. Pro-Social Interaction with a positive response (ProS +) and
d. Pro-Social Interaction with no response (ProS -).

For example, Ben initiated Pro-Social Interaction with Isaac by running but received no response. It seemed that Isaac got confused by looking at both Ben and his TA signing at the same time and this resulted in no immediate response. Also, Isaac initiated a chase game with Ben by looking at them but he was unable to notice him at first, so Isaac waited beside them. Although Isaac and Ben did not do cooperative play using Olly but running around it, there was harmony between the two of them and it is believed that the setting enabled the friendship to nourish. It was reported by the TAs that the children shared the playground but never interacted before and these results indicate that Olly, but more this environment, provided the children the opportunities to develop a friendship that could have been unnoticed.

Isaac also exhibited competitive play (Cm), both with the adults and with his peers (average of 1.11% of the time). For instance, as soon as some adults approached Olly for the first time on day 1, Isaac took off the ribbon from around his waist and grabbed those held by two TAs. Furthermore, Isaac was also vocal as if he did not want the TAs there. On day four, when Olly was broken, Pete was balancing on Olly's top and Isaac gently pushed him off, bounced on it himself, and looked back at Pete while doing so. This competitiveness was not observed before. However, the events showed that children were able to find their own way out of disagreements.

Lastly, instances of Non-Social Interactions (NonSI), were coded when Ben hit another child, or pulled a TA's hair, visible signs of Taking Turns (TT), were just noticed with Joshua where he was visibly waiting before approaching, and finally

Refusals to join (RJ) were coded when a child was offered a ribbon, but deliberately refused it, or when they complained when they were PP to Olly.

5.8 Discussion

Olly encouraged different types of play. Children in this study displayed slightly higher average percentages of Solitary (S) and Onlooker (O) play than Parallel (P) and Associative (A) play. Among Parten's play types the least displayed behaviour was Cooperative (C) play, perhaps unsurprisingly when considering the level of support that the children received on a daily basis, which is also reflected in the number of adult prompts that some children received to approach and play the sounds (see in T2, T3, T4). Parten (1932) described Solitary (S), Onlooker (O), and Unoccupied (U) play as negative social activities. In this analysis, instead, it is reported that the children used these moments to regulate their energy and sensory levels (and to be themselves), which in turn it is believed to have enabled the children to gain access to the ongoing activity (Rubin et al., 2006). For example, the dance teacher said that Alice "*has to go away and process it because she gets so I think it just becomes so much*" (reported in T2) and her TA said that she "*was exploring the area around the Olly by walking, running and making sounds*" (reported in Onlooker). Joshua's TA on the other hand said that "*he was like looking like that, you know, like I'm looking to see"* (see Onlooker). As in Francis et al. (2018), it was found that all children needed some private time either to regulate, relax or observe before they showed intentions to social bids of interactions. Also, the youngest of the participants i.e. Ben and Isaac displayed more complex play dynamics than their older peers indicating that the age of the children was not correlated to more socially engaged play as in the observations made by Parten (1932) and Piaget (1962). Nonetheless, the TAs and dance teacher were pleased to see how Olly fostered rich social scenarios where children exhibited shared goals, shared attention, joint actions, play, and intentions. For example, as reported by Isaac's TA in Cooperative play "*very pleased to see him joining peer's play, approach other kids he didn't know (play chase with Ben, approach Joshua"*, or by Ben's TA in T6 "*He stayed for the whole session, his communication was really good*". In theme 4 the dance teacher said about Pete that "*[...] You never really get him in that close proximity with others. He's always on the perimeter, but he did that a lot*". Furthermore, instances of eye-contact between children were observed mainly when they played with or around Olly, i.e. Isaac and Ben and Isaac and Alice (T7), suggesting that the TUI was effective in fostering a variety of social activities including eye-contact, important to establish a connection with peers Kleinke (1986).

Interestingly, uncoordinated social attempts have also been noticed e.g. when Ben initiated Pro-Social Interaction with Isaac by running but received no response, reported in the results under 'Other behaviours' in T8, or when Isaac initiated a chase game with Ben by looking at him but received no response. Although Isaac and Ben did not do cooperative play using Olly, they ran around it and went back to it constantly; there was harmony between the two of them and it's believed that the setting enabled the friendship to spark. Ben's TA reported that "*giving them the space was really good"* (see theme 6). Moreover, the youngest of the group brought a real bounce to the sessions and it is thought by the researcher that having a mixed-aged group of children might be beneficial when studying social play and regulation in autistic children. Surprisingly, Isaac's TA felt that "*[..] he really did neurotypically. Just a neurotypical, very active someone"* (theme 6).

Music seems to have influenced moods particularly with Alice, as noted by the dance teacher and as reported in T3 *"Once she realized there was no music [...] she became unhappy*", and with Pete, as reported by the dance teacher under theme 6 *"the vibrations from the music calmed him down*" and "*he was singing, calm and relaxed*". Alice also particularly enjoyed singing and replicating similar melodies to those played with Olly. Interestingly, all the children reacted noticeably differently on day 4 as they used Olly more roughly than usual. Joshua went to the cupboard where the music is usually played by the stereo during Dance as if to indicate that they wanted the music on (T8-Solitary). Isaac was making music by drumming on Olly's body with a TA (T3), pushed Pete off Olly's top, which is something they never did before then (see cooperative play types under T8. Pete displayed over-excited behaviours (T6). Not all children seemed to have enjoyed the sonic feature i.e. Ben explored all the sounds but actively played very little.

However, the choice of music seemed appropriate as it was reported by the dance teacher that Olly sounded *"so peaceful"* (see theme 3). The beneficial potential of music for supporting non-verbal communicative skills i.e. low-level joint attention skills, and initiation of behaviours i.e. eye contact (Geretsegger et al., 2014) have been confirmed by the findings. Music might have also helped with children's emotional regulation (Zacario and Whitebread, 2015). However, few TAs reported that they were not sure of the sonic impact e.g. Joshua TA said *"I think he was stack [sic] in the point of, oh I can pull this, it wasn't like cause and consequence because his development. [..] it was a sensory experience".* The dance teacher however said that "*the music playing stimulated Joshua – he was listening and smiling".* This is interesting as in study one it was reported that Joshua enjoyed "*playing the different notes*" with Mazi (reported in chapter 4.7.3).

5.8.1 What was learned from the design

Olly was introduced to the children by using a song inspired by approaches such as Attention Autism, used to grab children's attention. However, this approach doesn't always entice all children. For example, some of the them struggled to pay attention to Attention Autism's practices (AA) during usual school hours. Under T1, in an interview preceding the testing sessions, it was reported by Pete's class teacher that *"He does have concentration issues"* and *"you need to grab his attention".* However, it was found that the children demonstrated joint attention abilities and a general interest in this part of the sessions, indicating that framing the introduction around AA practices worked well to grab the children's attention. The dance teacher confirmed this in theme 1. Also, Isaac's TA said that *"After a slightly difficult day (changes in routine, little accident, less outside play) he was able to wait more on the bench for "Hello"* (T1).

Theme 5 was particularly useful to highlight the multi-functionality of the TUI, its *openness* and *ambiguity* (Eco, 1997; Gaver et al., 2003), which the researcher believes that allowed the children to be creative with their use of the technology (Scheepmaker et al., 2018) and enabled freedom of expression and agency beyond current PD practices (Frauenberger et al., 2017; Malinverni et al., 2014). As confirmed by one TA (in T2), and consistent with the previous findings of study 1, these results confirm that the round shape design, built to be shareable, conveyed positive meanings and affected social behaviours (Larson et al., 2009; Hornecker et al., 2007). The combined use of textiles, such as felt, elastic lycra, and music provided rich multisensory feedback and a soothing experience appreciated by all the children and TAs. For example, Isaac TA referred to Olly as "*a nest*" (theme 2).

Children were regulated but not bored, i.e. Joshua's TA said that he was "*really regulated*" and added that Olly *"creates more excitement for him [..] even the vibration but he was very excited about all the strings in one point"* (see T6). Joshua's teacher said that Olly was *"[..] a sensory experience*" (reported in theme 3), while the dance teacher, in a post-testing session interview, reported that Pete "*really did explore and self-regulated himself*" (in theme 6). Similarly, Isaac's TA reported in theme 6 that it was *"very inspiring how he regulated himself and he enjoyed the session"*. Most of the children exploited the versatility of the TUI and used it either to gently stroke it and manipulate it (Alice), feel the vibrations of the speaker (Pete, Joshua), or to self-apply some body pressure (Pete, Joshua, Isaac, and Ben). Olly was also used as a weight-bearing activity i.e. by Pete and Joshua, and the researcher believes that its versatility might have provided different strategies for self-regulation. As the dance teacher said, the stretch sensors integrated inside Olly's ribbons, offered the children more sharing opportunities "*while Mazi if you were laid on it, it was a bit difficult to play"* (T5). It also offered a wider variations of interaction styles. Some children went inside the ribbons, other pulled it from standing outside, and other manipulated it with their fingers or feet.

However, Olly's design needs to be reinforced. For examples, the connections are flimsy and tended to break easily i.e. as seen in session 4 when Olly was broken. Stronger connections should enable the technology to be more reliable. Replacing the soft-play dome with the inflated therapy ball didn't work well, especially because Olly requires stability. The more powerful speaker used for Olly, than that used for Mazi, worked better in this study as the notes could be clearly heard even if there was noise coming from outside.

5.8.2 What was learned from the methodology used

The implementation of a multidisciplinary approach that included an evaluation of social play allowed the researcher to adopt a more holistic and comprehensive understanding of the children social engagement and to evaluate more holistically the impact that Olly had on the children's experiences.

However, the researcher's time management skills were challenged, especially because she planned to be ready a month earlier the actual date that the testing sessions began (as mentioned in chapter 5.4), but because she was the designer, maker and programmer of the TUI, she had to post-pone the starting date of the testing phase. This didn’t cause any specific problem for this study, but if this delay had happened i.e. in study 3, perhaps the study could have not gone ahead at all.

Adding the analysis of theme 8 revealed that children, especially Isaac and Ben, displayed collaborative play dynamics around Olly i.e. they run after each other around it, and took breaks by going back to it. However, as the dance teacher also noted, some children played collaboratively also in unexpected ways i.e. such as she reported in theme 8 under collaborative play for Isaac, Pete and Joshua “*They might not be looking at each other but they're actually collaborating together*”. This further analysis also enabled the researcher to observe the children in those moments where they might seem disinterested in what’s proposed to them, i.e. Onlooker and Unoccupied play types. As researchers we tend to disregard these moments or to regard them as children not liking what they are doing, but here they revealed to be important factors that contribute to the positive experience of the children.

The framework for observation provides a rich collection and analysis of data, however as it stands, the general comments left by the TAs and dance teacher do not reflect what happens in each theme, and as per study 1, the researcher applied her own interpretation to contextualise their comments within the themes. However, luckily this time all the TAs left some comments in their observations sheets alongside the ratings of the 5-points system, although not all of them did it after each session, and this enabled a rich collection of qualitative data than that received in the previous study. In future studies it would be good to obtain some feedback for each theme observed, so that they can easily be mapped to the results. Furthermore, the concept of sharing a toy during a free playful activity is not extensively explored in the field of HCI (Spiel and Gerling, 2021) nor within education (Wood, 2007), and as commented by Ben’s TA giving the children this opportunity was important.

The framework used for assessment is useful because it provides a holistic view of what happened in the testing sessions and allows to see how much children engaged in the sessions i.e. playing music with Olly or playing in unexpected ways, who they played with, what emotions and behaviours they expressed. The criteria or themes observed in the framework can help understanding how different types of TUI might encourage different play behaviours, emotional states and uses. This approach, which was piloted with study 1, and it’s still in evolution, could contribute to strengthening a consensus within the HCI community on how to evaluate playful technologies for autistic children more holistically (Brulé et al., 2019).

This approach demonstrates that researchers can develop open playful technologies in ways that are friendlier to neurodivergent types of play and interests (Spiel and Gerling, 2020), by offering multiple and different interaction styles that resemble stimuli that children seek in order to entice them and by collecting multiple information from multiple sources. Children should be allowed the freedom (within the limits of safety) to play as they want. For example, Isaac's negative emotions were expressed when he was prevented to stand during the introduction's times. Lastly, as reported by the dance teacher, the semi-structure nature of the sessions worked well "*you have to have a clear structure for our children to be able to have that moment to explore because they know that when it's starting and they do know when it's finishing and in the middle it can be that freedom*" (see section 5.7).

The study however, highlighted also some broader limitations. Firstly, some adults appeared to be a barrier to the children's participation. For example, Ben was prevented by his TA (the less experienced staff member) to stand from the bench and moving/play freely, perhaps to approach Olly and peers. At one time Alice's TA also prevented Joshua to play on Olly as they pleased, and even the dance teacher said that "*at the beginning she overpowered Alice"* (section 5.7). Therefore, she was asked not to participate to session 5. This seems to be in line with what Smith et al. (2013) proposed about how the whole ecology in which the system is deployed, including the space, the set-up and the presence of adults, might negatively affect an experience. The TAs were also often found to play with Olly by themselves too much. This resulted in there being too many adults around it, which did not work towards facilitating interaction between children. The TAs got very distracted and spent too much time interacting with Olly.

Therefore, the people, alongside the environment, play an important role in shaping children's experiences and researchers should be mindful of that. Consequently, it's suggested to always gain some experience working with SEN children in their preferred contexts, prior to starting any research in the wild. Furthermore, researchers should feel confident in demanding support from highly qualified staff members. The institution with which the researcher worked, offers highly specialized provisions for autistic individuals, and all staff is regularly trained in child protection safeguarding and in evidence-based approaches in Special Education Needs. Other schools might not offer the same level of staff training and access to expertise as the Garden school does - and that also the researcher received when working there. This could have potentially affected the outcome of this study as the researcher worked in an almost ideal environment and had extensive experience working with neurodivergent children.

In was noticed that the mobile phone used by the researcher to record the start of the sessions (due to the curtains covering the children getting ready), created a disconnect between the researcher and the children.

Where to store Olly was also a problem, both during the testing sessions and after. The TUI could not be left at the school hence the researcher had to bring it back and forth from QMUL every Thursday afternoon. Furthermore, it was not left in school after the testing phase for the children to continue to play with because a) there was no storage space for Olly at the school, b) it was a prototype, and the researcher realized that it needed some improvements in terms of its reliability with the sonic outputs, and its robustness, and c) the teacher was not confident in using the microcontroller.

Lastly, the technology was tested with a small group of physically able children who liked music. These children showed preferences for textile materials and bouncing balls of soft toys. The same design might not suit all, as not everybody like music or textiles, and/or benefit from deep-pressure touch. However, this approach to shareable soft design and holistic evaluation could be used by other researchers wanting to explore the impact of different TUIs on social play and sensory regulation. This could be achieved by tailoring the designs to the children's interests, using the framework to guide their observations, and by creating an experience that enable freedom and value children's differences.

5.9 Conclusions

This study investigated the types of play and regulatory opportunities afforded by a sonic textile multi-user tangible technology designed around the preferences of a group of minimally verbal autistic children within a semi-structured ludic educational setting. It was argued that when designing technologies that aim to scaffold playful and social experiences for minimally verbal autistic children there is a need to expand the design space to be more inclusive and accessible. This could be achieved for example by taking a more holistic approach toward the design of playful TUIs, the environment and the analysis of the findings. Important to this study was to focus on different aspects of play, particularly spontaneous and social play, but also on opportunities for self-regulation because children's participation in leisure activities is influenced by their sensory processing abilities. The study demonstrated that the use of stretch sensors facilitated children's social interaction with and around Olly; while enabling children to be 'Onlooker' was beneficial to their regulation and participation. Olly's *open* design enhanced its versatile attributes, while the study's semi-structure enabled freedom of expression and agency. It was found that some TAs might have affected the experience of some children negatively, and this highlights the importance of designing for the whole ecology not just the technology itself. This second study could contribute to narrow the gap in the existing literature on self-directed play, tangible technology and autism.

6 Design Study 3: Olly Mazi

Building on the results of the previous two studies, this chapter presents the final study developed as part of this PhD research. The study is called όλοι μαζί, pronounced Olly Mazi, from the Greek 'All Together'. By combining the names of the previously developed TUIs, Olly Mazi, aimed to reinforce the idea of togetherness, which resonated with one of the research's aims of eliciting playful social interactions between children. The goal of this study was that of addressing previously unanswered questions with regard to aspects of sonic interaction and design interaction. The aim was to compare the children's responses in relation to the two tangibles to understand key factors for effective TUIs for social play in autism such as if one TUI enabled more social play than the other. From study 1 and 2 it was still unclear to what extend the music impacted children's experiences, as the TUIs were tested just when the power was on. Therefore, this study tested Olly and Mazi in two states: with the music on, and with the music off.

It differs from the previous two studies in few ways including the fact that Mazi and Olly were tested with one group of children coming from the same classroom. The selection of the participants this time was done by the dance teacher, as the previous Headteacher didn't work there anymore. This group of children was also younger than those in the previous groups (5 years vs 5 to 10) and it was larger than the previous two (7 vs 5 children). Furthermore, the technologies tested were not designed around the needs of this group of children but conversely, the features of design guided the selection of the children. The dance teacher thought to work with this group also for logistic reasons. The analysis was conducted in the same way as it was conducted in study 2, using the same criteria for observation, however the dance teacher and TAs were asked to fill their observation sheets by theme this time, and to leave few comments in each of the 7 themes they observed. Interestingly, in study 2 the dance teacher compared Olly to Mazi and said that children could create more music with Olly and that it also offered to the children more possibility to use it in together and for different purposes. Therefore, the researcher was curious to see if one of the two technologies clearly worked best for scaffolding social play dynamics.

The contributions offered by this study are threefold. 1) It contributes to validating inclusive guidelines, developed throughout this PhD research, created to enable minimally verbal autistic children to enjoy open-ended, spontaneous, and socially engaged play mediated by sonic e-textiles tangible technologies. This is achieved through presenting a final study, which took place at the Garden School, in London, UK, over 3 sessions, spread over the course of three weeks. 2) It offers a reflexive comparison between a new group of children's responses to two previously built TUIs, Olly and Mazi, and discusses how the TUIs affected the children's play and self-regulation. 3) It contributes to the development of a more holistic approach to be used by other researchers and educators interested in exploring the potentials of technologies in supporting spontaneous social play and self-regulation in non-speaking autistic children. This is achieved by presenting a multidisciplinary and flexible approach to data collection, design, and evaluation that is sensible to the children's needs and preferences. This study demonstrates that researchers do not necessarily have the need of creating tailored designs for different groups of children.

6.1 Motivations

The motivations behind this final study were to address some open questions related to a) children's preferences with regard to the two Mazi and Olly, b) the different interactions styles afforded by each TUI, and whether Olly facilitated longer and more social interactions and c) to determine whether the sound generally impacted children's interactions. The sub-questions that this study aimed to address were:

a) How does a different group of autistic children react to two already made technologies when given the choice? Is there any difference on how they interact with Mazi or Olly?
b) Can the designs be used by different groups of children than those they were inspired by?
c) What differences there are (if any) in children's behaviours when the power of the TUIs is turned off or on?

By exploring the above questions this study aimed to investigate further few of the four main research questions (mRQs) presented at the beginning of this thesis in chapter 1.1. In particular, this study explored the differences in children's behaviours when the power of the TUIs was turned off because this helped answering the main research question 3 (mRQ3); it looks at how a different group of children respond to two TUIs designs inspired by different children, which helped answering (mRQ1); and lastly it further explores the challenges and opportunities created by these two TUIs when working with high support autistic children. This contributed to answering mRQ4.

6.2 Procedure

The study was structured as per the previous studies, by an initial formative phase, the iterative prototyping phase, the testing phase, the analysis and the final discussion. The iterative prototyping phase described here however, reports on the repairs that the researcher made on Mazi and Olly before the testing phase started as the TUIs were already designed. In order to address the sub-questions mentioned in section 6.1, Olly and Mazi were tested at the same time, in the same space, and with the same group of children. The TUIs were tested together at the same time because it was not possible to test just one TUI at a time due to practical constraints that evolved around the space, and teacher's availability. For example, as per the previous studies, although this fell within the children scholastic routine, it was not an integral part of the curriculum. Instead, the dance teacher was kindly using 30 minutes of her PPA time (Planning, Preparation, and Assessment) on Thursday afternoon to run the testing session. The rest of the afternoon she carried out her PPA duties, whereas during the week she worked with other classes, and/or the dance studio was occupied by other activities. Finding another space proved challenging, and that space was the only and best option available at the Garden, but it was vacant just on Thursday afternoon from 2:15 pm to 3 pm. Therefore, the choice of testing the TUIs together at the same time, in the same space, and with the same group of children evolved around practical and logistical constraints.

To explore whether the sound impacted children's interactions, the intention, was to alternate the order of the presentation of the two TUIs. For instance, the first session started with Mazi and Olly's power turned off for the first half of the session, then the power was turned on for the second half of the session - *order a* - (table 6-1). The second session started with the TUIs power turned on for the first half of the session, then off - *order b*. This alternation was done to see whether the results were replicated in both conditions (for instance the children could have had more energy during the first half of the sessions). Although this solution was adopted due to the above practical constraints, it still allowed a comparison of children's behaviours with the TUIs in both states and helped to address some of the main research questions.

Session structure. Order a	**Session structure. Order b**
2:15 pm Start. Shoes and socks off	2:15 pm Start. Shoes and socks off
2:18 pm Attention Autism song. Mazi and Olly are covered under a cloth. As the song finishes they are unveiled	2:18 pm Attention Autism song. Mazi and Olly are covered under a cloth. As the song finishes they are unveiled
2:20 pm Mazi and Olly are in the room, uncovered and music OFF for the first 10 mins	2:20 pm Mazi and Olly are in the room, uncovered and music ON for the first 10 mins
2:30 pm "It's time for music ON!" Mazi and Olly are both switched ON for the next 10/15 mins	2:30 pm "It's time for music OFF!" Mazi and Olly are both switched OFF for the next 10/15 mins
2:40/2:45 pm Teacher counts down again from 5 and says "Mazi and Olly have finished!" "time for celebration!" At this point the teacher continues with "Shoes and socks ON!" 2:45/2:50 pm End. Children leave the room	

Table 6-1 Session's structure

6.3 Formative phase

The formative phase of this study started in October 2019 and ended at the end of February 2020.

6.3.1 Participants recruitment

The selection criteria for recruiting participants were different to the previous studies because the TUI designs were already been inspired by two different groups of children. The children were selected by the dance teacher of the Garden, who was asked to recruit children that would have enjoyed Mazi and Olly's features. Before the study commenced, the Headteacher of the Garden school stepped down, and the researcher was put in contact with the new interim Headteacher, who promptly collaborated to the work. For this study, however the dance teacher selected the children and she preferred to work with a group of children from one class. To avoid working with children with comorbidities and medical conditions, she decided to work with the Reception's class, called Bumblebee. When the study commenced all pupils had just turned 5 years (between 1-4 months prior to the study) and started going to the Garden school in September 2019. The dance teacher thought that proposing a playful social activity to the younger and newer children of the school would have been beneficial to their scholastic experience. Ben's TA in an interview pre-testing phase confirmed that children didn't have many opportunities to play together. *"We've got the swing but they're not really playing with each other. They're kind of just on the swing. I don't really think some of them realise that anyone else is on the swing with them".* Bumblebee class was formed by 7 pupils, 4 girls, and 3 boys. For anonymity reasons, as in the previous studies, this study refers to the children using pseudonym such as Anna, Elodie, Selina, and Tula, to refer to the girls, and Steve, Theo, and Ray to refer to the boys (see Table 6-2). This was interesting as in the previous studies there was a bigger rate of males to females. However, gender differences were not evaluated in this PhD. This group of 7 children was younger than the others that participated in the previous two studies and had two more members. The researcher did not know any of the participating children, but she knew the class teacher because she was a teaching assistant (TA) during the period that she worked at the Garden. However, they worked in different classrooms.

6.3.2 Participants insights and data collection

Similar to the previous two studies, the recruited children were observed prior to the testing phase during two dance classes, one P.E. lesson, and one music lesson (which they had just recently started). The researcher organised two meetings with the dance teacher, one to recruit participants, and one to define the structure of the activity. In one of these two meetings, the dance teacher was opposed to the idea of testing the TUIs without sounds, as in the previous studies, because she thought that the sessions would have been too boring for the children. Instead, she suggested that because the pupils were too young they should have listened to some music during the transition from the class to the dance studio (to help them differentiate between their dance lessons and this study), and the sessions should be shorter i.e. without the hello part and the celebrations at the end (as in the previous studies). The researcher however opposed to the idea of letting children listening to music during the transition from class to the dance studio as it was not something that children normally did, and she did not want to introduce anything too different during transitions. Prior to testing the technology, a further two separate meetings were held with the Bumblebee's class teacher and all the TAs. These were organised to decide and explain how the activity would have unfolded, to get to know the children and to discuss what was expected by the TAs in terms of interventions and observations. From the information collected about the children, an in-depth profile of each child, including their likes, dislikes, and triggers was created and it is summarised in Table 6-2. Children's observations started on the 11th of February 2020. Anna and Steve were supported on a 2:1 basis i.e. worked together with one TA, as well as and Selina and Theo who were supported by one other TA, while

Elodie, Tula, and Ray were supported on a 1:1 basis i.e. by the other three TAs individually (see Table 6-2).

Child	Likes	Dislikes	Support strategies	Age	Gender	SCERTS	1:1
An	Clear, consistent routine, holding a small toy, Snacks, Playing, Running, Being outdoor, Adults' attention, Tickles, New things	Being rushed, Time and space to process info, Changes, Waiting	Clear language and clear instructions, Makaton, Model actions and key vocabulary for me to imitate, use positive and encouraging language and praise so that I feel confident and willing to have a go, give time and space to understand and practice new skills	5	F	SP	
El	Having a clear routine, Songs and music, Bubble, Sensory play, Feathers, Foam, Relaxing, Dance	Being rushed, Time and space to process info, requesting, Changes, Turn-taking, Waiting	Makaton, Clear language and instructions, Model actions for her to imitate, Model key language, use positive and encouraging language and praise so that she feels confident and willing to have a go, give her time and space to understand and practice new skills	5	F	SP	x
Se	Knowing my routine, Bubbles, Music, Dance, Singing, Being outdoor, Musical toys, Dance and drama, Repeating things, actions twice	Being rushed, Time and space to process info, Changes, Waiting, Turn-taking	Clear language and clear instructions, Use Makaton, Model actions to imitate, Model key language, use positive and encouraging language and praise so that I feel confident and willing to have a go, give time and space to understand and practice new Skills, let me repeat things twice, as that helps me moving on from activities.	5	F	SP	
Tu	Warm water bottle, Snacks, Clear routine, Songs, music, Dance, sitting on vibrating cushion, play time/climbing, Nap when tired	Not being rushed, Time and space to process info, being able to request what I want/need, Waiting, Turn-taking	Clear language and clear instructions, Model actions for her to imitate, Model key language/PECS, use positive and encouraging language and praise so that she feels confident and willing to have a go, give her time and space to understand and practice new skills	5	F	SP	x
St	Clear consistent routine, holding small stretchy toy, Snacks, Playing, running, Being outdoor, Adults' attention, Tickles, New things	Waiting, Turn-taking, Changes, Time and space to process	Clear language and clear instructions, Use Makaton, Model actions for me to imitate, Model key language/PECS, use positive and encouraging language and praise so that I feel confident and willing to have a go, give a stretchy toy when I feel unsure or I have to wait. Reassure me	5	M	SP	
Th	Clear routine, Singing, Music, Outdoors activities, Climbing, Legos, Dance	Not being rushed, Time and space to process info, Changes, Turn-taking, Waiting	Clear language and clear instructions use coreboards and visuals, Model actions to imitate and key language, use positive and encouraging language and praise so that I feel confident and willing to have a go, give me time and space to understand and practice	5	M	SP	
Ray	Adult's attention, Straws and strings, clear routine, Singing, Music, Outdoors activities, Climbing, Interaction with others	Not having adult's attention, Time to process info, Changes, Turn-taking	Use positive and encouraging language and praise me a lot for all positive behaviour and interaction, give me choices by using visuals, use clear and key language, give clear instructions, Model actions for me to imitate, give me time and space to understand and practice new skills	5	M	SP	x

Table 6-2 Summary of the children's collected profiles Study 3

In day 1, the TA working with Anna and Steve was absent, and their class teacher attended the session instead. Aside from Theo, all children wore a nappy, and all the pupils were at the Social Partner stage in the SCERTS model. Due to their young age, children did not follow the Performance levels rating but instead, the researcher was given a One Page Passport for each child - a one-page child's profile - and one document with their primary targets defined by their class teacher. These targets were: a) Communications and Interaction, b) Cognition and Learning, c) Social, Emotional and Mental Health and lastly d) Sensory and/or Physical and were mostly related to the SCERTS framework (apart from d - which is non SCERTS related).

For example, the Social, Emotional, and Mental Health targets required children to improve various abilities. Some of the targets aimed at developing skills necessary to i.e. assemble a lid onto a container during snack (Anna); take an extra turn with an adult during intensive interaction (child-initiated interactions that persist for two consecutive times) (Elodie); look at stage 1 and 2 of Attention Autism (Selina, Tula, Theo); request mutual regulation strategy using their own visual support once per day (Ray); take two turns during a motivating activity (Steve).

The sensory and/or Physical targets instead, aimed at toileting skills (Anna, Steve, Tula); eating (Elodie, Theo); brushing teeth (Selina), and washing hands (Ray).

The types of data collected for later analysis consisted of the same data type collected in study 2, plus the post-sessions questionnaires that were sent to the teachers instead of doing face-to-face interviews. This was due to the spread of COVID-19. The questionnaires were inspired by the questions that the researcher asked face-to-face during the post-studies interviews that she carried out previously in study 2. As reported by the teachers, apart from Steve - children did not usually know how to take-turns. During the meeting, one of the TAs said that Steve "*was the one that maybe we thought could learn*". Several TAs observed that when children were in the Dance Studio "*they go and play with each other around the curtains*", and one TA suggested that the curtains, part of the dance studio set-up should "*maybe put it in one corner"* during the study. In one of the meetings the TAs and the dance teacher were specifically asked to leave comments for each of the 7 themes they observed.

During the first dance lesson observed by the researcher, she noted that Tula, Selina, and Anna often laid over and/or touched some pillows and fabrics scattered around the floor. Tula sometimes runs around the room with Steve, Theo, and Ray. Furthermore, Ray and Elodie were more people-oriented, while Ray and Theo also liked climbing on the ballet bar in front of the big mirror. Interestingly, in the second dance lesson, the dance teacher on her own initiative scattered some bouncy balls around the room. Selina and Ray were observed bouncing and laying over them, Selina also touching the textiles on the floor in front of the mirror as well as Anna. Generally, children enjoyed looking at their reflected images in the ballet's mirror, but mostly they liked running around the space and spent lots of time behind the curtains that surrounded the two sides of the studio. This was not a surprise as, during the interviews carried out in the formative phase, it was reported by the TAs that children spent most of their time around the curtains. Theo and Ray sometimes copied each other. Children needed adult's physical prompts to participate in the dance lesson's activities, but they were not forced to join in.

The P.E. lesson was divided into four sections: dance, ball games, parachute, and choosing. During choosing, when children could choose what they wanted among a varied selection of equipment/toys, most children choose to play with some bouncing balls by laying on, rolling over, and bouncing on them. Steve requested for tickles. In a further observation carried out during the music lesson, the class was split into two groups, the first of which included Anna, Elodie, Tula, and Steve, and the second included Selina, Theo, and Ray. The latter group was said to be less involved in the music lesson, and the TAs and class teacher said that they did not engage in the lesson as much as the former group. During music, children were invited to come to the whiteboard and to interact with it by making some marks on its surface. At the press of a screen button, the marks were scanned and played back in the form of music. The observations revealed that Theo and Ray were easily distracted throughout the lesson. Selina also arrived at the lesson from the playground dysregulated (crying), but she easily recovered, and her mood changed during the music lesson.

All the children from the first group, and most of those in the second, seemed to enjoy the musical aspect of the lesson as they smiled throughout, and paid attention to the sounds and the visuals created by them and their peers.

6.4 Iterative prototyping phase

Mazi and Olly, have undergone some repairs prior to, and during the three testing sessions of this final study. As discussed in chapter 1, both Mazi and Olly were exhibited at Ars Electronica in 2018 and 2019, after the studies ended, and both were exhibited at a QMUL during a visit from a group of disabled musicians in early 2019. Therefore, Olly's circuit and connections were re-made from scratch (see Figure 6-1) because as already seen in study 2, the connections of the 4 sensors placed inside each of the elastic ribbons were not stable.

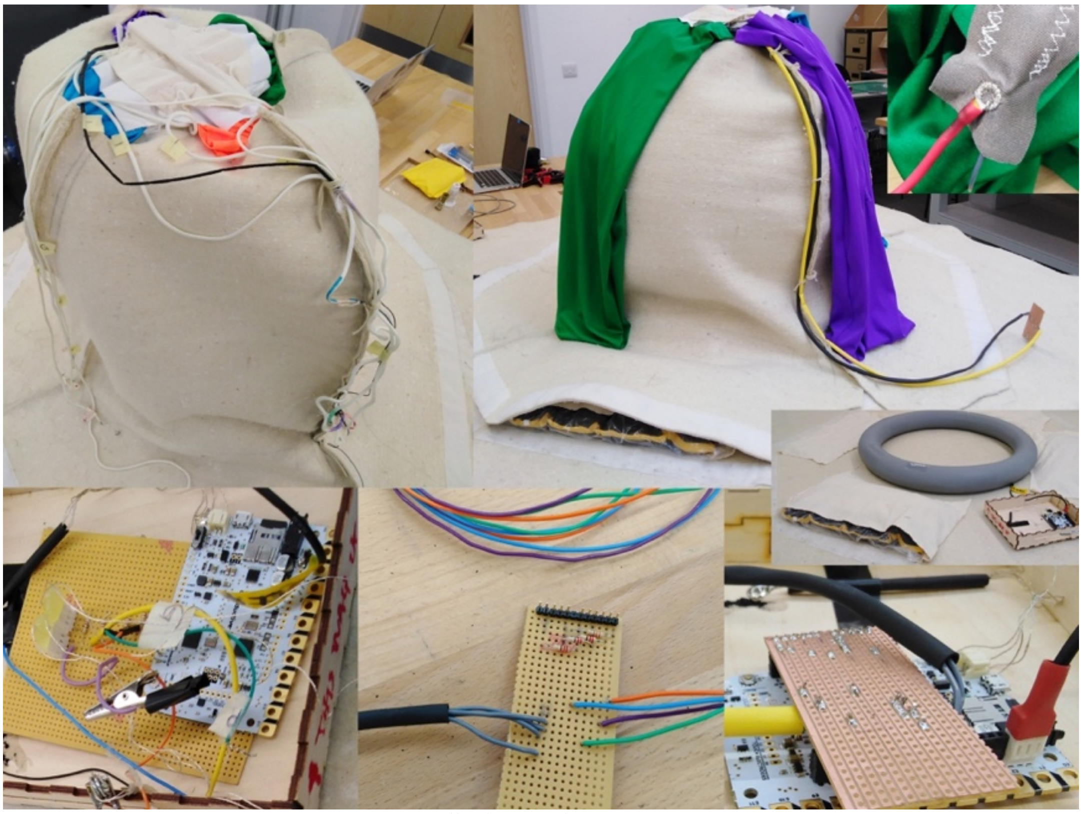

Figure 6-1 Olly design adjustment pre-testing

The long conductive threads that connected them to the circuit were damaged due to the prolonged use that Olly sustained the previous year (especially at Ars Electronica) and the connections to the board were messy (see figure 6-1 left bottom side). Therefore, the conductive threads were replaced with softcore wires. These were soldered to male-to-female header pins connected onto a protoboard as seen in figure 6-1 (middle bottom picture). The protoboard was then connected to the Bare Touch Board as shown in figure 6-1, bottom right picture. The soft-core wires were connected to the soft stretch sensors by being soldered to an eyelet loop wire terminal, which was sewn onto each sensor (figure 6-1 top right), five pockets made with recycled cotton fabric were sewed to the base to accommodate the weights which prevented the ball from moving around when the ribbons were pulled (see Figure 6-1, small picture in the middle of the right side).

Mazi’s circuit instead was reinforced by adding some threads to the existing connections and by isolating the soldered threads (connected to the Bare Touch board) with hot glue (see Figure 6-2).

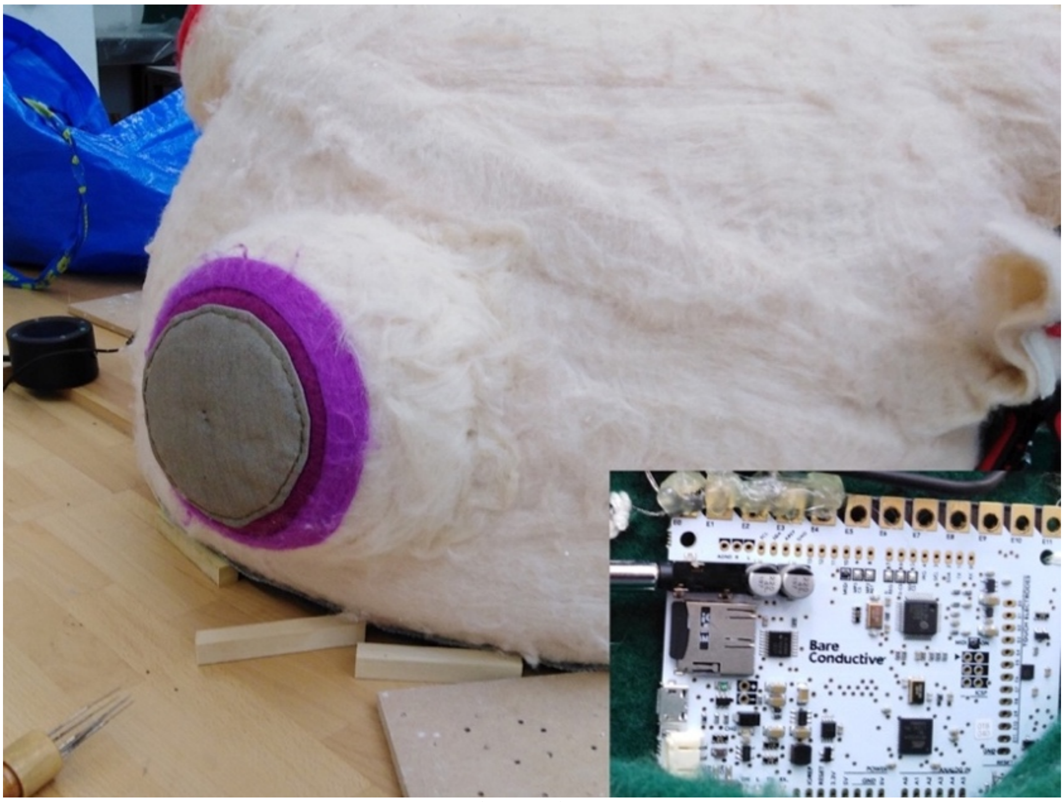

Figure 6-2 Mazi design adjustment pre-testing

A new base was also made with Olly’s left-over cuts-out using the 3 mm thick industrial felt sheet, and it was attached under Mazi’s base to make it more robust.

As per the previous studies, before the study commenced, each classroom was given a folder with a copy of the tracking sheet, extra notes sheet, pen, extra symbols, and Objects of References (OoR).

The OoR consisted of a combination of the first prototype developed for Mazi by using half felted tennis ball, which the researcher also used as OoR in Study 1 and 2, and a piece of elastic lycra that resembled Olly’s ribbons (See Figure 6-3). During the testing sessions, the designs were iteratively improved.

Figure 6-3 Object of Reference for Olly Mazi

For example, for the second session, snaps buttons were added around the perimeter of Olly's base where the circuit box and the speaker are, and the speaker's front was covered by sewing some hessian fabric around the perimeter of the felted pouch (see Figure 6-4). This was to prevent some of the children to temper with the felted cover, or with the speaker. One of the interactive bubbles was also re-stitched to reinforce the connection to the circuit, and some hessian fabric was added to the felted pouch that hosted the speaker (Figure 6-4).

Figure 6-4 Olly design adjustment during testing

Throughout the sessions the researchers added more wool fibres to Mazi's body, which was felted using a multi-needles tool, to make the felt more compact, and consequently more difficult to pull apart (see Figure 6-5).

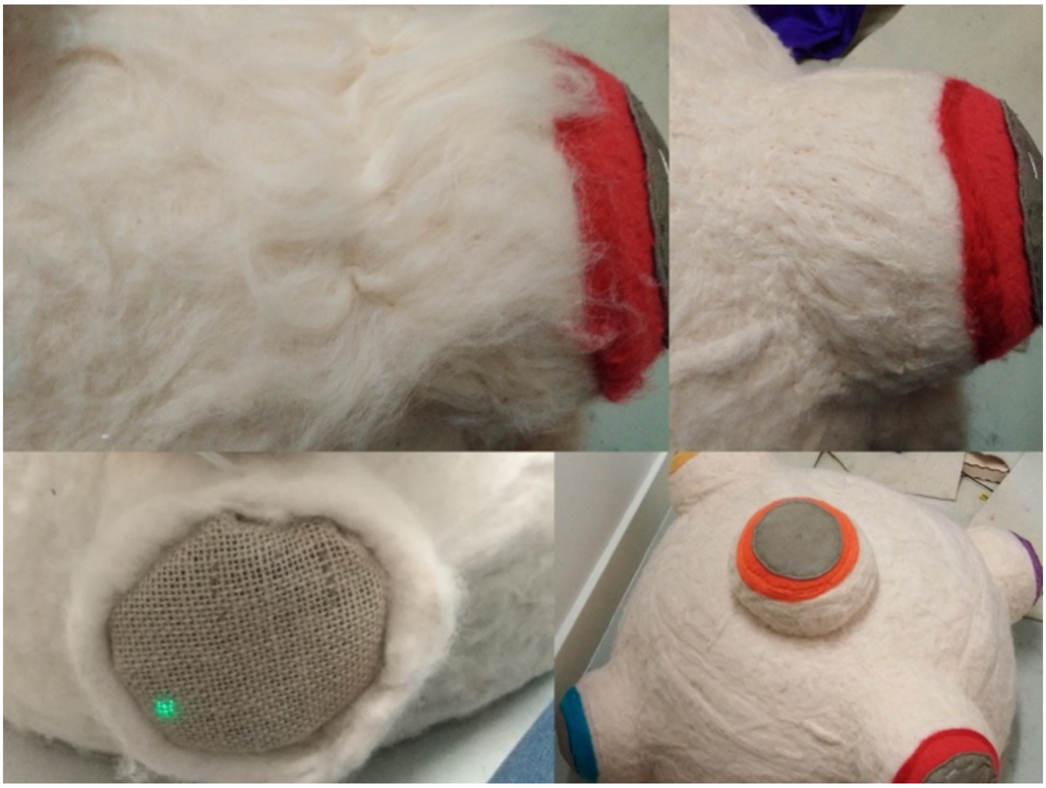

Figure 6-5 Mazi design adjustment during testing

These changes were made because these children were very explorative and curious about the TUIs and their curiosity went beyond what the researcher imagined. Some children pulled Olly's speaker as if they wanted to hold it in their hands or manipulated the pouch that contained it and tried to put their hands under it. Children also played with the threads that stitched the conductive e-textile of Mazi's top, pulled some of its wool fibres, fiddled with the snaps, and generally put their fingers inside any of the cavities they found.

6.5 Testing phase

The testing phase started on the 27th of February 2020, after the Half-term break, on Thursday at 2:15 pm, and it was scheduled for the duration of 30 minutes (per session). As explained in chapter 3 (Figure 3-6), for this study two Xiamoni-Yi mini-cameras were used. Furthermore, the children were constantly recorded by the dance teacher, who regularly shared the pictures she took of the children with their parents during and after each lesson using an app called the ClassDojo. Therefore, contrary to the previous two studies, parents received feedback from the dance teacher as the sessions were taking place. Some of the pictures taken by her were later shared with the researcher. Figure 6-6 shows few examples of pictures taken by the dance teacher and shared with the children's families and the researcher). Children were used to getting photographed.

Figure 6-6 Few of the pictures taken by the dance teacher shared with the researcher

Carrying out the video recordings of the sessions just by using the two mini-cameras provided some challenges, as the recordings presented some obstructed and limited views of few children, especially in one session.

The sessions started with the children arriving in the dance studio and taking their shoes and socks off, as usual. Then they sat, possibly on the benches, for the duration of the introductory song (average of 54 seconds). However, having just started in September 2019, the children were young and new to this type of routine, i.e. sitting to wait. Therefore, it was decided to keep the sessions fluid to see how they would react. The TUIs were placed on the opposite side of the bench and were covered by a cloth as per the previous studies (Figure 6-7).

Figure 6-7 Olly Mazi dance studio set-up

Unlike Study 2, where the dance teacher pulled the drapes in front of the bench to reveal the TUIs in two moments, she thought that this group of children would have benefitted more from having the view of the covered TUIs unobstructed.

The testing sessions were planned for 5 consecutive weeks (as per the previous studies), but due to the COVID-19 pandemic, and the lockdown down measures that the government put in place at the beginning of March 2020, it was interrupted after only 3 sessions. Unfortunately, as seen in Table 6-3, Steve attended just the first session.

OLLY MAZI	**DAY 1**	**DAY 2**	**DAY 3**
Duration of sessions in seconds (includes Introduction's times)	******* 1249	****** 1433	****** 1647
Duration of Introductions times in seconds per session	33	80	49
Children representative colour: Anna*; Elodie*; Selina*; Tula*; Steve*; Theo *; Ray*			

Table 6-3 Sessions' length and visual representation of daily children attendance

The activity started with a quick 'hello' to all children and the adults. Then the teacher moved behind the TUIs to sing the 'under the cloth' song, and this marked the beginning of the sessions. At the end of the song, the teacher uncovered the technologies while the adults made surprised sounds. Then the dance teacher showed the children how they could interact with Olly and Mazi; this would happen independently from the order in which the TUIs were tested (order *a* or *b*). Then they waited to see what happened.

In contrast to the previous studies, where the TAs were given more freedom to intervene as they pleased, this time they were specifically asked not to intervene unless a child needed them, and they were told to avoid playing with the TUIs themselves, especially when no child was interacting with them. The aim was to create better opportunities for the children to understand the cause-effect interaction, and it allowed to look at children's spontaneous intentions beyond adult interventions. The start and end of the sessions were shortened, as per the dance teacher's initial suggestions (no congratulations).

Throughout the study, the curtains were eventually tacked between the mirror and its wooden bar, because the teachers decided that they were too distracting (see Figure 6-8 right). This strategy was adopted following the dance teacher's decision of experimenting with new ways of disabling the use of the curtains in the space without having to remove them and to see how the children reacted.

Figure 6-8 Curtain pulled vs Curtains tucked in mirror's bar

6.6 Data Analysis

The evaluation was carried out using the framework for observation that was extended in Study 2 (see Table 5-3, and 5-4). To recap, the results reported here analysed the children's responses in relation to 8 main themes analysed by the researcher on the video recordings, combined with the teacher's feedback. The themes are briefly re-introduced below as:

T1. Introduction to the TUIs

T2. Approach TUIs

T3. Touch to activate sound

T4. Play music together

T5. Use unexpectedly

T6. Share emotion

T7. Eye-contacts

T8. Play types

As in Study 2, however, the dance teacher and the TAs were each given one observation sheet to evaluate the children on the first 7 themes (figure 6-9). The dance teacher tracked all seven children, whilst each TA observed the child(ren) they worked with. As in study 2, in T7 the dance teacher and TAs were asked to evaluate whether children shared their attention, instead of looking at eye-contacts. The dance teacher and TAs were asked to leave comments under each of the 7 themes.

STUDY III “OLLY MAZI” - Bumblebee class	Observations	#
1 Attention Autism: looks interested in the presentation of Olly and Mazi	DAY 1	
2 Approaches Olly and/or Mazi with confidence. Independently or with prompts.	DAY 1	
3 Pulls the elastic ribbons and/or touches the bubbles to activate sounds	DAY 1	
4 Plays notes together with peers or partner	DAY 1	
5 Uses Olly and/or Mazi creatively. Show use of Olly for else than playing notes (i.e. deep-pressure, climbing, squeezing, patting etc)	DAY 1	
6 Share emotions: express appropriate emotions, able to self-regulate	DAY 1	
7 Share attention: When not close to Olly Mazi, child shows attention towards others interacting with tech and follows what’s going on	DAY 1	

Figure 6-9 Teaching Assistants (TAs) one page (one day) tracking sheet for Study 3

To reduce the amount of paper that the dance teacher had to fill, her observation sheets contained three days per page instead of one (see example Figure 6-10).

STUDY III “OLLY MAZI” - Bumblebee class	Observations	#		#	
1 Attention Autism: looks interested in the presentation of Olly and Mazi	DAY 1		DAY 2		DAY 3
2 Approaches Olly and/or Mazi with confidence. Independently or with prompts.					
3 Pulls the elastic ribbons and/or touches the bubbles to activate sounds					
4 Plays notes together with peers or partner					
5 Uses Olly and/or Mazi creatively. Show use of Olly for else than playing notes (i.e. deep-pressure, climbing, squeezing, patting etc)					
6 Share emotions: express appropriate emotions, able to self-regulate					
7 Share attention: When not close to Olly Mazi, child shows attention towards others interacting with tech and follows what’s going on					

Figure 6-10 Dance teacher one page (three days) tracking sheet of one child

The post-study questionnaires, which the researcher sent to the dance teacher and the TAs via email, were divided into three sections and contained a total of 28 questions. The questions were related to the children’s experiences with the technologies and with their peers, their regulation, the TUIs designs, the sonic interactions, and more general questions such as issues with the technologies, their level of prompts, etc. The questionnaires and few samples with answers can be found in Appendix E. The combined feedback of the dance teacher and the TAs, and the general one given by the class teacher, alongside the post-study questionnaires, contributed to create an insightful and rich description of the findings. Few examples of dance teacher and TAs feedback can be found in Appendix D.

6.7 Findings

An analysis of the findings is presented using the same mix of quantitative and qualitative approaches used in the previous studies. Three sessions were conducted with an average duration of 25 minutes and 51 seconds.

Theme 1 (T1) to Theme 7 (T7) give illustrative examples and quantitative analysis of how children responded and reacted around Olly and Mazi, while Theme 8 (T8) is more descriptive of the play types displayed by the children and the interactions that occurred between them.

Interestingly, the class teacher in the questionnaire reported that "*such session should be introduced as a regular activity in early year curriculum to encourage students developing their active learning and playing and exploring skills in a safe environment*". She also added that "*the experience was very positive, well-pitched and age appropriate. Bumblebee students have an innate curiosity and your prototypes fully caught their attention. Olly and Mazi enables students to use different senses to explore according to their abilities. Students who sought pressure found it by pulling strings with legs or back, those more active were able to jump on prototype and press buttons, those more sensory received feedback from the material used by touching or stroking their body against it. All in all, it seemed that both prototypes suited their different needs in many ways."* Additionally, the dance teacher wrote that *"The study been cancelled due to Covid 19 was very sad as I think if we had finished the children who are harder to reach would have mastered interacting with Olly and Mazi*". This was confirmed by the TA supporting Selina and Theo who said that "*children like Olly Mazi sessions and if they can have more sessions we could see more improvements"*. From the interviews carried out in the formative stage, Ben's TA confirmed that children did not play with peers and most of them never engaged in social playful activities as the playground did not offer many social opportunities

After around 4 months that eh study was abruptly ended, on the 19th of July 2020, the researcher was contacted by one of the TAs of the Garden via a Whatsapp message because she wanted her to know that "*Ray is asking for Olly Mazzi [sic] everyday. And he makes me write it on a piece of paper so that he can carry it with* *him*". This text and the content of a zoom call that the researcher had with the dance teacher 10 months after the study finished are also reported in the findings and the final discussion.

6.7.1 T1. Introduction to Olly Mazi

The introductions lasted an average of 54 seconds. Figure 6-11 shows the percentage of time that each child spent looking at the covered TUIs. The results are calculated over the introductions that each child attended.

From the graph, it can be seen that day 1 is the session that children exhibited more interest toward the introduction, followed by day 3 and day 2. This may be due to the novelty aspect. However, as observed by the dance teacher, on the second day, the weather meant that the children were unable to do any outside activity, and that might have impacted children's interest levels, as many arrived into the space dysregulated *"the second session the children had spent the day in school due to the weather and were not keen on sitting on the bench for the Attention Autism".*

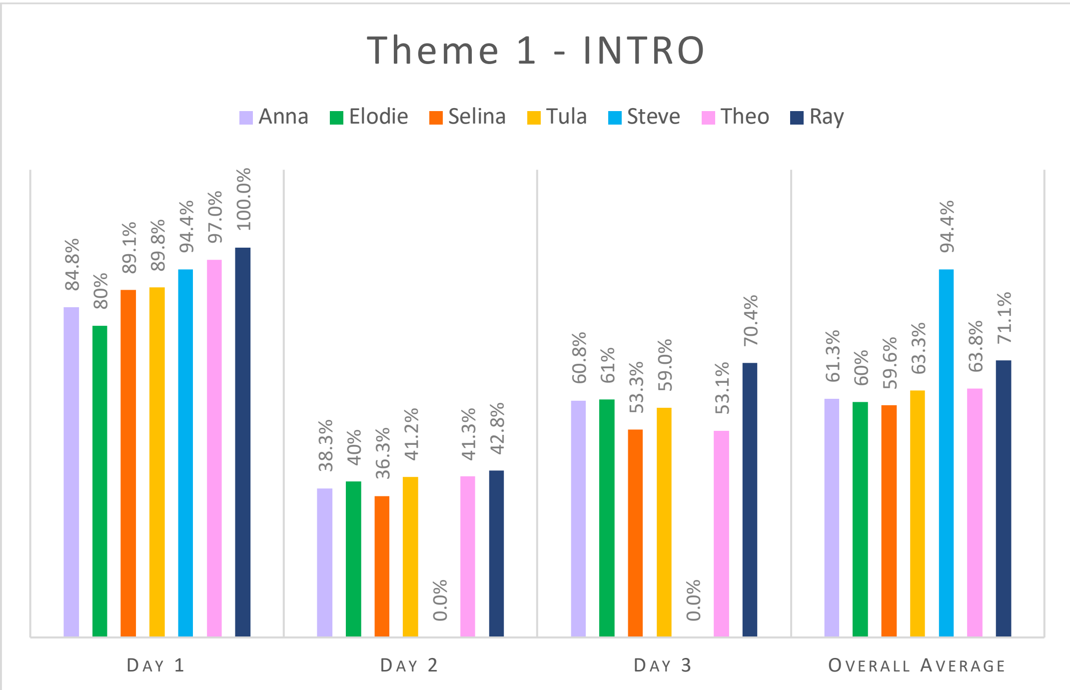

Figure 6-11 Theme 1. Graph showing percentages of daily interest toward the Intro per each child

Elodie and Tula started crying out loud as they were directed to the bench before the song started, and Anna and Selina had to be physically prompted to sit down, as it seemed that they were really keen to move around and explore, instead of sitting. Nonetheless, Anna's TA wrote on the observations of that day that "*she was already excited when she entered the room and saw both technologies covered under the blanket. She smiled and did good waiting (a little bit excited. Needed a bit of PP to* *stay sit*". By contrast, Selina's TA wrote "*wasn't very happy to sit on the bench, because she likes to run around. When she sits looked occasionally at AA*". Similarly, in the post-study questionnaire, the TA working with Elodie wrote that she "*hated the wait for olly and mazi, she couldn't stop crying when we held her back, she was trying her fully best to get out and run towards olly and mazi [sic], overall, she enjoyed and loved it, specially [sic] with the sound on*". On the other hand, Theo and Ray never required any prompting to sit down for the introduction and the dance teacher noted that in day 2 "*the other pupils where crying and Theo was able to stay calmer*". Theo's TA reported that '*He was really excited to play with the toy*" and after day 3 she wrote that he "*was really excited but he didn't need my full support*". Some children's moods perhaps were affected also by the fact that the TUIs were covered during this phase. For example, in day 2, Elodie's TA reported that the pupil was "*very upset when Olly and Mazi was [sic] covered, but as soon as the cover was taken off, she was in a exited [sic] and happy mood. She observed both at the beginning then started playing*".

Nonetheless, one TA commented in her questionnaire that "*it was [a] very good idea to hide it and make them wait, creating expectation and anticipation, increasing their interest and curiosity*". Furthermore, in day 3, most of the children arrived in the studio more regulated than in the previous session. For example, Selina's TA observed that "Selina was *able to wait more today. She was calm*". By contrast, it was reported that Tula was "*dysregulated, wanted to leave the bench, took off shoes quickly, very motivated*". Considering the children's young age, they responded better than expected to this part of the sessions.

6.7.2 T2. Approach Olly Mazi

As in the previous studies, it was considered an approach when the children were less than around 120 cm far from Olly (Hall 1966). The approaches were calculated over the overall sessions' times, minus the introductions, and are presented in percentages of time spent by the children approaching the TUIs, as shown in figure 6-12, 6-13, and 6-14. The results show how much children approached the TUIs overall, and if they did so independently (I) or with prompts (P) (figure 6-12); which TUI was approached the most (figure 6-13), and how much time the children approached when the music was off (figure 6-14). As it is illustrated in figure 6-12, some of the children exhibited more approaches than others, and interestingly, most of the children approached independently and spontaneously. Figure 6-12, represent a combination of approaches to Mazi, to Olly, and to both, as sometimes children were found to be standing in between both.

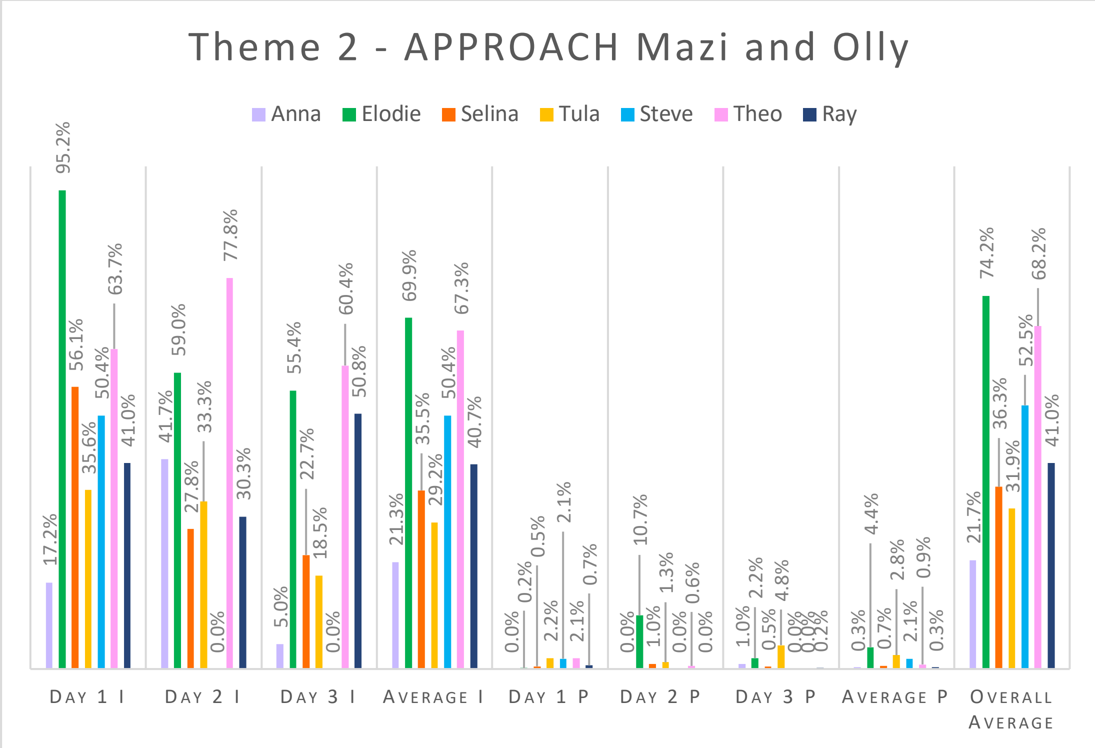

Figure 6-12 Theme 2 - Independent and prompted approaches and overall approaches' average per child

These results were appreciated by the teachers and by the researcher. For example, the class teacher really appreciated "*The opportunity that students were given to explore an interactive musical toy using their body, in a relaxed and unprompted environment so they could use their initiative to enjoy and relax*".

Minimizing the level of prompts seems to have positively affected children's agency and self-expression, as confirmed by the dance teacher in the questionnaire "*prompts were minimal as we had discussed in planning we wanted to achieve more spontaneity*" and this "*made the experience more child-led*" as "*they were enabled to use their initiative to explore, learn and play with a new toy in a safe environment*".

Figure 6-13 shows a comparison of the individual daily approaches to Mazi and to Olly. Most of the children spent more time approaching Olly than Mazi. Nonetheless, Theo clearly demonstrated more interest toward the latter, by approaching it for much longer time than any other child.

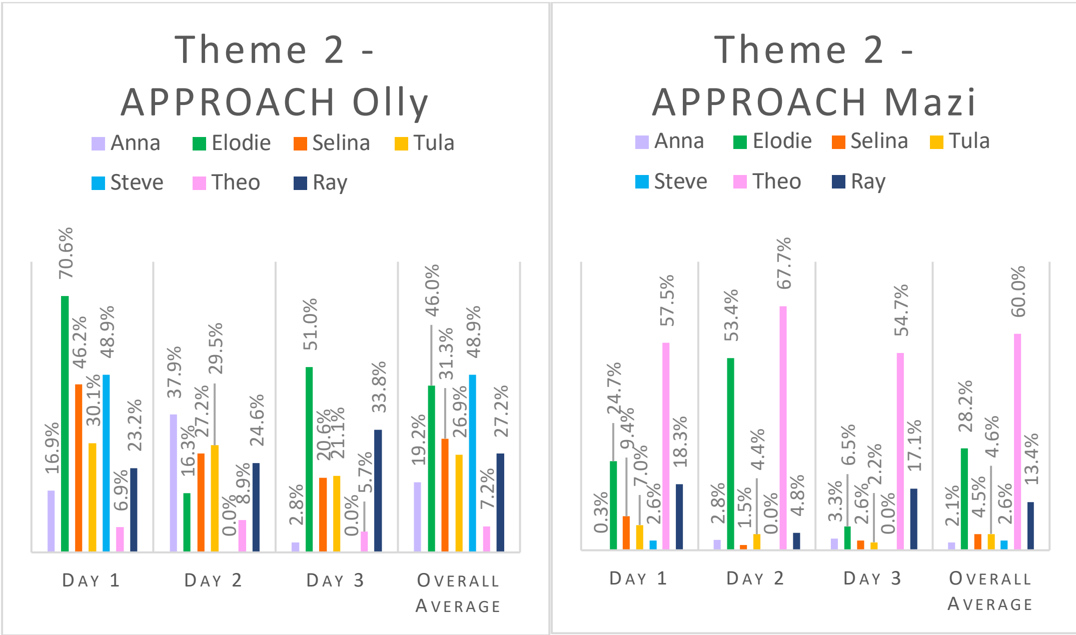

Figure 6-13 Olly vs. Mazi's approaches

Figure 6-14 instead, shows how much time children approached the TUIs when the music was off (average of 13%). When compared to the overall average of approaches (46.5%), this result indicates that children approached mostly when the sound was on (average of 33.4%).

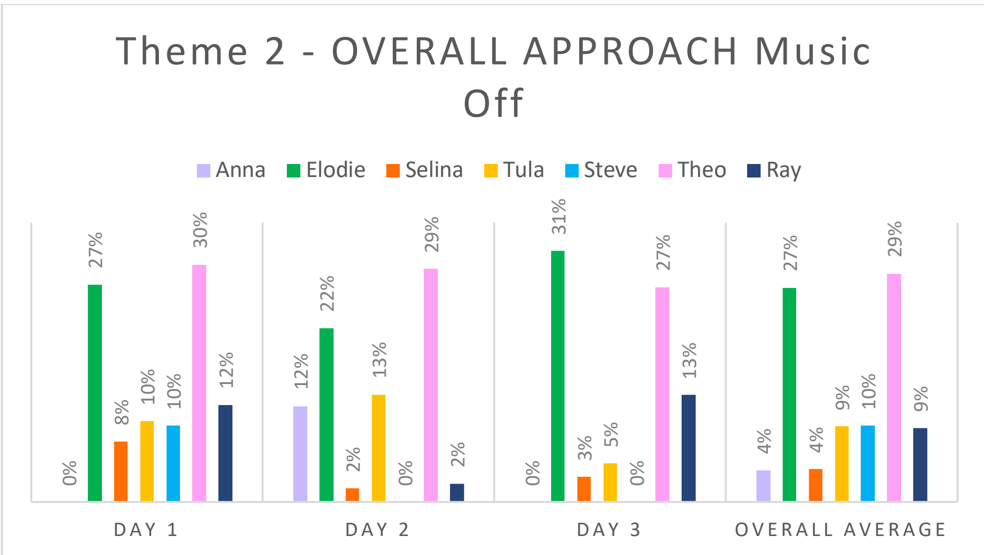

Figure 6-14 Theme 2 – Overall approaches when music is off

The class teacher, who attended just the first session, in her questionnaire gave some insights as to what it is that she thought attracted the children. "*The material and textures you used to build the external parts play a role in their engagement. You took into consideration the sensory aspect of it and choosing a soft, neutral colour and comfortable material was the fitting choice to satisfy that need. Adding relaxing tunes* *to it adds to the experience, especially for those who respond well and are motivated by music, such as Selina and Tula".*

6.7.2.1 T2. Children approaches

Anna approached the TUIs for an overall average time of 21.7%. Considering that from the observations she did in the formative phase, Anna appeared to be a very autonomous individual - rarely engaged in the offered activities - these results were encouraging. As shown in Figure 6-12, Anna approached the most in day 2, and generally displayed spontaneous and independent interaction with Olly, indicating her preference for it over Mazi (Figure 6-13). In day 1, Anna was very excited and in a post-sessions interview the class teacher reported that she constantly screamed to "*regulate herself*". The comments from the TA's observation sheet of day 1 read "*Approached many times, she would run from the bench towards Olly and Mazi, wait, observe then scream in excitement and ran back to the bench. She then ran and touched the Olly and Mazi with excitement screams*". After day 2 she wrote that Anna "*ran to it independently. she didn't need any prompt, she looks interested.*" As illustrated in Figure 6-14, Anna never approached the TUIs when the power was turned off, suggesting that the sound sparked her curiosity. In day 3 she looked very tired and the TA confirmed that "*she was looking at it at a distance. lying on the bench. she was clam and tired (eye closing)*".

Elodie, on the other hand, approached the TUIs for an average time of 74.2%. She did so independently by interacting mostly with Olly (Figure 6-13) and she approached the most in day 1 (Figure 6-12). Elodie went to the TUIs when the power was turned off for a small percentage of her overall approaches (average of 27%) (Figure 6-14), meaning that she mainly approached the TUIs when the power was turned on. The TA working with Elodie wrote after day 1 that she moved "*very independently [sic] to explore both Mazi and Olly. Did not need any prompt to imitate*". The second day the TA noted that "*as soon as the cover was taken off from Olly and Mazi she let go of my hand and ran towards it. Nor even once she came back to me or to anyone else. She was fully independent and confident".* Elodie would often run towards the TUIs as soon as they were uncovered. However, in the third session, Elodie was escorted outside after around 15 minutes from the start, because she was feeling unwell. In comparison, Selina approached much less (average time of 36.3%) (Figure 6-12), of which an overall of 4% of approaches were when the sound was off

(Figure 6-14). Similar to Anna and Elodie, Selina approached more Olly than Mazi (Figure 6-113), and mostly approached independently. She also went to the TUIs more when the power was turned on. In day 3, Selina left the room after around 17 minutes into the sessions to go to the toilet and was outside for a total of 6:55 minutes. The TA reported that "*when music started she started to approach *at some point she did poo and lost attention*". As confirmed by the TA, Selina also "*try [sic] to push back other students to have it for herself."* Several other students exhibited a competitive spirit when approaching the TUIs and this is better discussed in theme 8-Play types.

Tula approached for an average time of 31.9% and mostly did so independently. approached the most Olly. Her TA commented after the sessions that "*she definitely preffered [sic] Olly*". On day 1, the dance teacher noted that Tula "*moved towards Olly and Mazi climbed on immediately*". As reported by her TA after day 2 she often played with the curtains first "*[..] she straight away went towards Olly and Mazi, but then she just passed and went behind the curtain for the first 5 minutes. Then she went to Olly and stayed there for 2-3 minutes*", and after day three "*First she went behind the curtain but then laid on Olly with a big smile*". After the study, the TA commented that "*[..] She found her confidence to approach Olly"* and "*she didn't need particular encouragement to explore".*

Steve attended just the first session and approached the TUIs for 52.5% of the time (Figure 6-12), 10% of which when the TUIs' power was switched off (Figure 6-14). He approached mostly independently, and interacted more with Olly (Figure 6-13). The TA working with him observed that Steve "*approached Olly and Mazi confidently and independently very happy to run around then observed friends playing and ran towards*" and the dance teacher confirmed that he was "*motivated [..] independent*". Theo on the other hand, approached for an average of 68.2% of the time and did so when the sound was off just for 29% of his overall approaches (Figure 6-14). Therefore, like the other pupils, Theo approached the most when the TUIs were powered. By contrast to his peers, however, he approached more Mazi than Olly but like the others he always approached independently. After day 3 the TA wrote that "*he was really confident. He approached it straight away by touching and moving Olly+Mazi*". As confirmed by the dance teacher Theo was "*motivated—run independently*" and "*run towards Mazi and Olly with happiness*".

Lastly Ray approached for an average of 41%, and 9% of his approaches were made when the TUIs' power was off (Figure 6-14), indicating that all children mostly approached Mazi and Olly when the sound was on. However, after the study the TA observed that "*Ray liked both [...]*". Ray approached Olly for about twice the amount of time that he approached Mazi and always approached independently. His TA wrote after day 1 that "*he was confident however it took him time as he was more interested in the curtains and running to grab my attention*". By the time that session 3 ended, the TA noted that "*as usual he ran up to the objects with excitement. He explored Olly and Mazi by going on top of it.*" In the questionnaire, she wrote that Ray "*generally went to the one who had less people*".

6.7.3 T3. Touch to activate sounds

Within the children's overall approaches, the times that each child spent triggering the sounds, by either playing with Olly or with Mazi, have been analysed and converted in percentage. These percentages are displayed in Figure 6-15, which illustrates a comparison of the overall individual sound interactions exhibited by each child with Olly and Mazi over the three sessions.

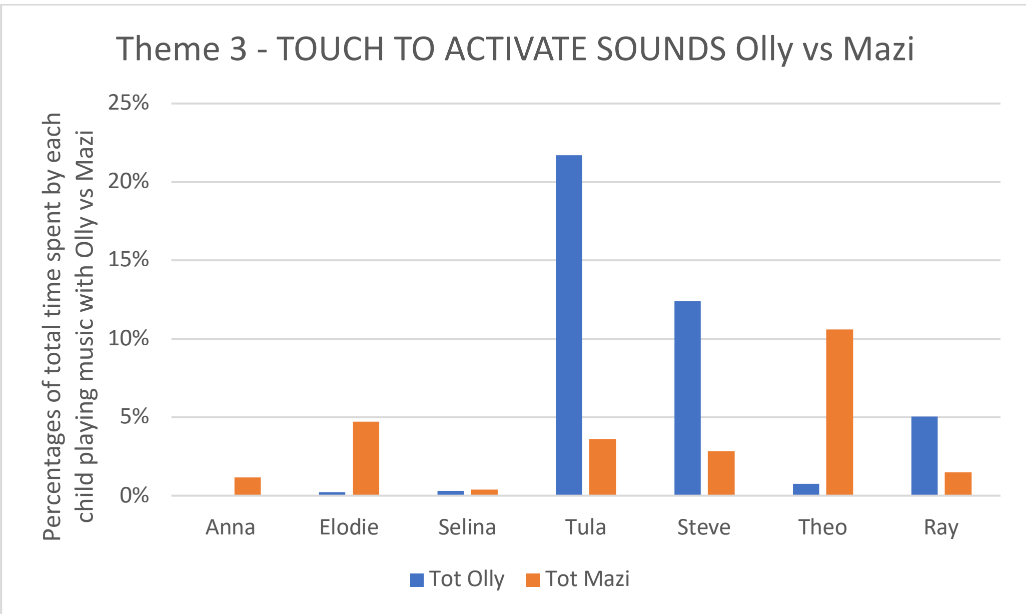

Figure 6-15 Theme 3 Touch to play music Olly vs Mazi

Generally, Figure 6-15 illustrates that children played music by using Olly and Mazi for almost an equal amount of time (51% vs 49%). Anna played music on the third day (20 minutes into the session) just using Mazi for an average time of 3.5% and it's not clear to what extent she understood the cause-effect interaction. After the study, Anna's TA (who also supported Steve), reported that "*[..] the lack of lessons* *did not allow them to have a complete understanding of the way it works.*" However, she added, "*that Anna found it pleasant. She smiled when the sound started and she was seeking visual contact with it*" and she considered the sounds to have been a motivational stimuli for Anna "*She was more and more motivated to go to the lesson and happier to see that it was time to do Olly and Mazzi [sic]. She smiled, she laughed and she had more vocalizations".*

Elodie instead played music with the TUIs for an average time of 5.4%, she played mostly independently (average 4.8%) and used more Mazi than Olly. She was physically prompted (PP) when playing music with Olly, while she did not receive any prompts to play music with Mazi. As reported by the TA after the study "*Elodie really loved it as soon as the sound came on, she was happy and surprised at the first but as she explored she loved it she would pull for the sound to come on and jump".* It appeared that Elodie *"layed on side and pushed mazi [sic], it was like she was trying new way to make a sound.*" Furthermore, the TA noted that the sound added to her enjoyment as "*she understood that by pulling and jumping on top the sound will come on, and because of the sound Elodie really enjoyed it. [...] For sure if there wasn't a sound to olly and mazi [sic] it would have become a little boring but surely she enjoyed and loved it"*

Conversely, Selina played music only on day 1 and she is the child that have spent less time playing music (average of 0.4%). Selina triggered sounds by using both TUIs in equal measure and played independently. However, when activating sounds she often laid on top of the TUIs to rock (Olly) or to balance on it (Mazi). Therefore, it is not clear whether playing music was a deliberate action. After day 2 the TA wrote that "*Selina didn't pull ribbons, push buttons. she enjoys to lie [sic] down on it and listen*". Nonetheless, after day 1 the dance teacher noticed that she touched "*the bubbles",* and the TA wrote that she "*didn't pull ribbons but tried to touch the bubble few times."*. However, the TA was not sure whether the child was interested in the sounds "*It's hard to say [..] in my opinion, her fun was to swing on Olly when lie down on it and then she explore [sic] with the textures. I think she like more physical sensations then cause-effect results".*

Tula instead is the child that played music the most (average of 25.7%) and did so predominantly while using Olly (21.7% vs 3.6%). As it can be read from the TA's comments after day 1, Tula was very confident from the start "*She touch [sic] the* *ribbons, put her legs through, played with it*". Similarly, after day 2 the dance teacher observed that she "*wrapped the ribbon around her feet and neck*". In the first and last days she received some prompts. The TA commented after day 3 that "*with TA prompt she put body through the ribbon*". Although the TA thought that the sound impacted Tula's experience, she reported that the child did not realise the cause-effect interaction "*I did not see her realizing the cause-effect [..] She likes music, sounds, rhythm (all the kids in the class). The sound might have affected her experience, despite of that she might not realized the cause- effect".* Contrarily, post-testing phase the class teacher, who attended the first session, reported that Tula "*paid attention to her movements and repeated it a few times to get the same effect",* indicating that the child was aware of the cause-effect. Steve, attended just the first session and triggered sounds for an average of 15.2%. Every time that he received some prompts was to play music using Olly, while to play with Mazi he did not receive any support. Steve played music more by using Olly (12.4%) than Mazi (2.8%). The dance teacher's commented after day 1 that he was "*Curious. Touched*" and it was observed by the TA that Steve had an understating of the cause-effect interaction as he "*pull [sic] the elastic many times when the music started. he [sic] kind of had an idea of what's going on with elastic ribbons, again touched the bubbles many times for the sounds*".

Within his approaches, Theo played music for an average time of 12.1%, mostly played independently and triggered music using Mazi much more than using Olly (10.6% vs 0.7%). This could be because, perhaps, he might have not understood how to trigger the sounds using Olly. However, this clear difference suggests that Theo preferred Mazi over Olly. After day 1, his TA wrote "*Theo try to pull ribbon but he was more excited and interested of pressing Mazi buttons*", and after day 2 she said "*Theo was exploring ribbons by touch, smell instead of pulling them. He press [sic] the bubbles knowing they will give sounds.*" In the questionnaire, the TA commented that the "*sounds stimulate Theo curiosity. He press [sic] more often buttons to listen to the Mazi sound*".

Ray on the other hand, triggered the sounds for an average time of 6.4% and did so mostly independently and by using more Olly than Mazi (5% vs 1.5%). However, sometimes, Ray appeared to be copying his peers rather than playing spontaneously. As stated by his TA in the questionnaire "*Ray pulled the toy to make* *nose [sic], but he generally needed someone to start it off for him. As he was really motivated with climbing and things that was around him"*. In day 1, Ray activated the sounds just by interacting with Mazi, while in day 2 he just pulled Olly's ribbon once, as if to copy one adult (his action followed that of an adult), and in day 3 he played music by using both Olly and Mazi, perhaps, as his confidence grew throughout the sessions. The dance teacher commented after the last session that Ray "*Confidently touch [sic] the bubbles— patted*". In the questionnaire, the TA observed that he "*wasn't pressing on it constantly. He would usually need some sort of support for him to pull and press. But overall I think he did like [sic] the idea of the sound because our kids usually likes [sic] music*". The class teacher confirmed that "*most students have*" understood the cause-effect and that "*the sound caught their attention and therefore had an impact on their overall experience.*"

6.7.4 T4. Music making together

As in study 2, among the times that children played music, theme 4 shows the time that each child spent playing music together with peers, with adults with both, and/or solo. Figure 6-16 however, illustrates a comparison of the overall individual percentage of times that children played music together by either using Olly or by using Mazi. This is calculated over the times that children spent activating music.

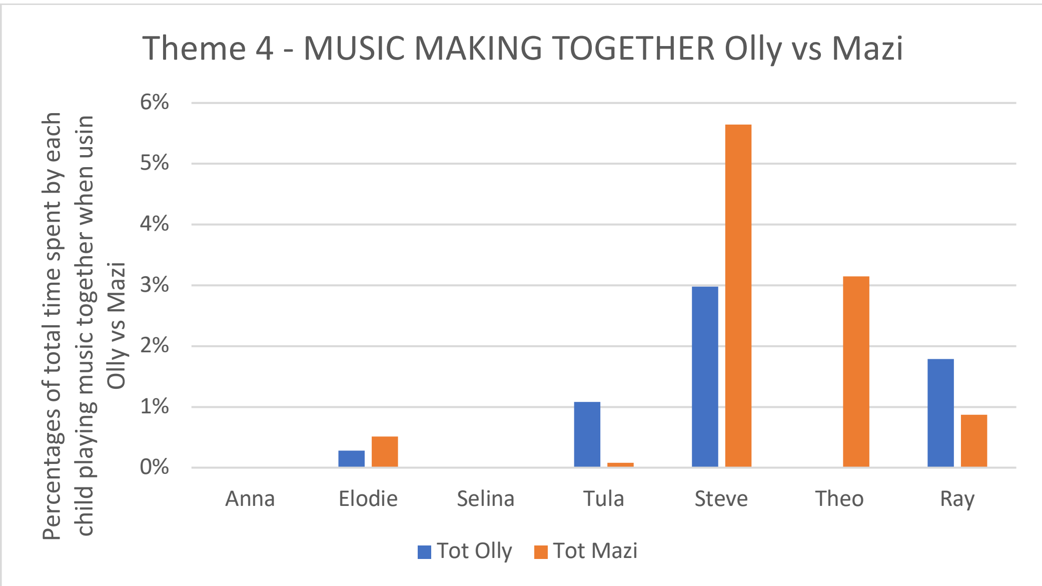

Figure 6-16 Theme 4 Play music together

The graphs in Figure 6-16 show that, overall, children played together more with Mazi than Olly, indicating that Mazi solicited more socially engaged music-making than Olly.

Interestingly, Anna played music just in day 3, mostly while being alone (average of 2.5%), or with adults (1%), and never played music with peers. However, the TA reported that "*the music and the sounds that other created made her feel excited and curious. She was attracted by the sounds and she showed interest, not only in the technologies but also in the peers who were creating it.*" The TA thought that "*the sound effect was behind the huge excitement of Anna",* and while Anna played music for little time this was considered a positive result because "Anna *normally ignores or does not feel attracted to peers. I think she understood that the technology was creating such an interested sound thanks to the action of the others [..] She is normally more quiet [sic] and does not show so much interest in peers, while during the lesson, she was looking at them and smiling"*

Elodie played music with peers on day 1 and day 2, but not on day 3 (average of 0.6%). However, on day three, Elodie left after 14 minutes into the session as the TA said, she was ill and dysregulated, and this might have impacted her play during that day. Predominantly, Elodie played music in solo mode every day (average of 4.6%) and played almost in equal measure with Mazi (0.5%), and Olly (0.3%). However, after day 2, the TA wrote that "*She started playing alone but as soon as Theo came they both were like taking turns and playing with each other, in excitement they were both screaming and jumping together".* In the post-study questionnaire, the she reported that "*she was copying others and playing at the same time, so for example if Tula pulled olly [sic] Elodie would run to her and do the same so it's not like she wouldn't go near if someone other child [sic] is already there but she would go and interact with them and copy."* On camera, the researcher never saw Elodie copying other peers.

Unfortunately, Selina played music just on day 2 and by herself (average of 0.4%). In the questionnaire the TA confirmed that Selina "*like to be independent, doesn't show much interest to other students, but she interact [sic] when she think other student chase her".* Nonetheless, she also added that the pupil "*smiled at Theo at some point and jumped over it with him side by side"* and this was a positive result as *"In general she plays on her own [..] depend on her mud, when upset she didn't like to play alongside others, when happy and explore objects didn't mind other children next to her*". Tula instead played with adults on day 1 (average of 0.3%), and seldomly (day 1 and day 3) she played with peers (average of 2%). Tula mainly played in solo mode throughout the three sessions (average of 24.5%), and when playing together with peers she mostly used Olly (1.1% vs. 0.1%). After day 2, the dance teacher's feedback read "*not keen on other peers*" while in day 3 she confirmed that Tula "*interacted briefly with peer*". However, in day 3, when playing with a peer (Ray), Tula received physical prompts (PP). In questionnaire the dance teacher wrote that "*Tula needs more time to adapt to new experiences*", indicating that she needed more time to feel confident and perhaps, to play music alongside other people.

Steve, on the other hand, played mostly solo (average of 6.6%), with peers (4.1%), and with both adults and peers (4.5%). As shown in Figure 6-16, he played music together by using more Mazi (average of 5.6%) than Olly (average of 3%). After the sessions his TA reported that he "*finds sharing very hard. He shared Olly and Mazzi because I think he understood that, the more kids are using it, the better (more sounds appear). The architecture of Olly and Mazzi is big enough to share.*" Steve is one of the children that played with peers the most (after Theo), and the TA noted that he "*was only participating one day but he was playing along others.*"

Throughout the study, Theo played mainly solo (average of 8.5%), but in day 1 and day 2, he also played music with peers (average of 2.2%), and together with adults and peers (average of 1.3%). In day 3 he played with just adults (average of 0.1%). Theo just played music together more when using Mazi (3.1%). In day 1, the TA observed that "*Theo was jumping and laughing, he xplore [sic] Olly and Mazi alongside with other peers*" while the day 2, he became quite possessive of Mazi. This was noticed also by the dance teacher who wrote that he "*Was not keen in sharing Mazi with anyone*". Nonetheless, in day 3 the dance teacher observed that he "*interacted with peers*". Lastly, Ray played music increasingly throughout the sessions and played together more by using Olly (1.8%) than Mazi (0.9%). Ray played with peers in days 1 and 3 (average of 1.4%), with adults in days 2 and 3 (average of 0.4%), and with both adults and peers (0.6%) in day 3. Furthermore, he played solo for an average of 4.1%. His TA noted that Ray often copied others "*if someone showed him that if you pull or touch the sound comes out, he would usually copy and do the same".* This might have affected his spontaneity in the ways he used the TUIs.

6.7.5 T5. Creative uses of Olly Mazi

Figure 6-17 shows the combined overall percentage of time that children spent using Olly and Mazi in unexpected ways. To recap, the researcher defined any unexpected use when children displayed other uses of the TUIs than that of playing music with them.

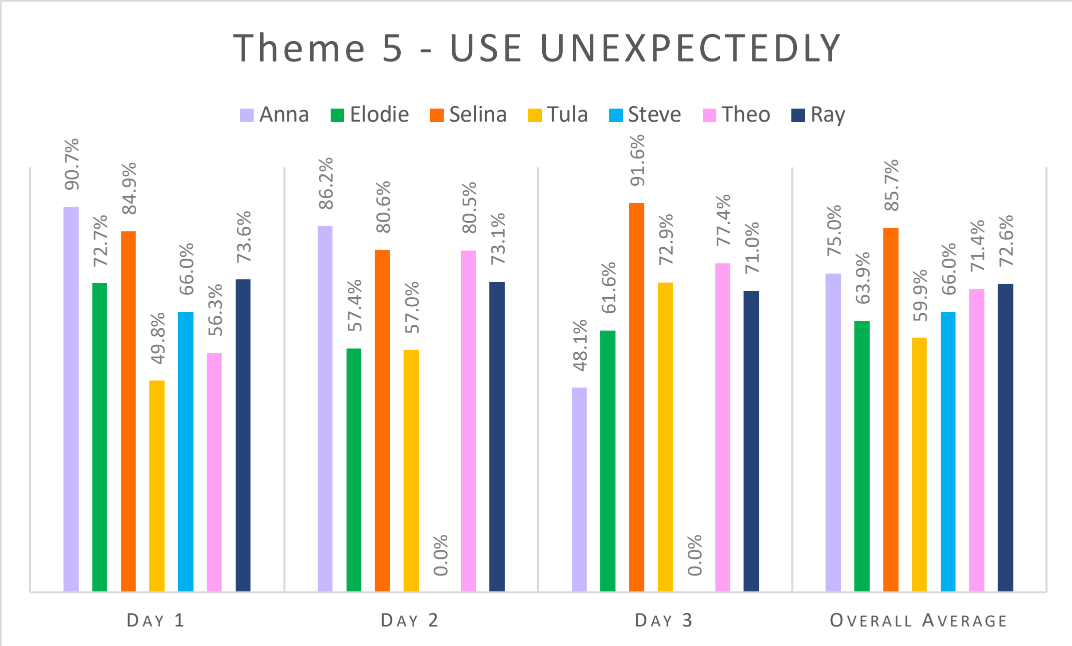

Figure 6-17 Theme 5, Uses unexpectedly combined and overall percentages

Generally, most of the children's approaches have been spent using the TUIs unexpectedly, suggesting that the *open* designs inspired the children's self-expression with, and appropriation of, the technologies.

Within the children's unexpected uses, figure 6-18 illustrates a more detailed account of the percentage of time that children spent using Olly unexpectedly compared to Mazi. As it can be seen in figure 6-18, aside from Theo who used more Mazi, generally, children displayed more unexpected uses with Olly. This might be because Olly had a base where children could comfortably sit around, or perhaps because it gave more opportunities for different types of interactions such as through the elastics, the felt, the rocking motion of the ball, the carpet and so on. After the study, the dance teacher reported that "*the material that covers Olly is very tactile and sensory. The shape is inviting for pupils to sit on, lay on, stand on. Embracing and cuddling Olly is easy (shape). The size is appealing and to young children as they can see over the top – a view of all of the shape. The ribbons are bright and colourful and soft to the touch*". However, she added that "*Mazi was more popular due to design the pupil can receive a response quicker with their Body [sic] ex. Sit on, lay on, stand*". She also said that with Mazi it "*was easier to create sounds*".

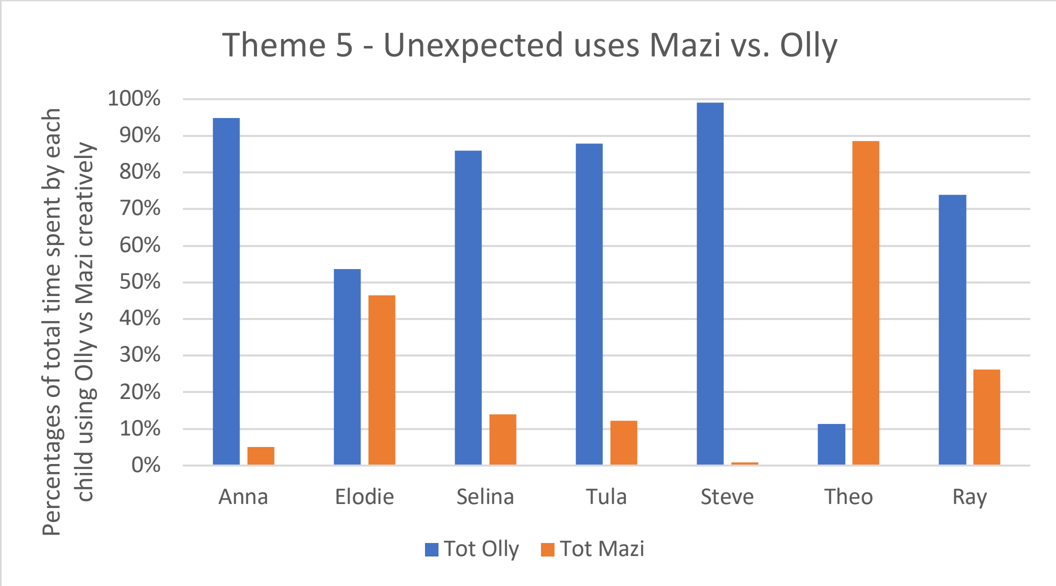

Figure 6-18 Theme 5, percentage of time spent by each child displaying unexpected uses with Olly vs Mazi,

The types of unexpected uses, performed the most are listed in Table 6-4, and Table 6-5, and are reported in the text below in descending order and per number of instances exhibited by each child (xNumber).

T5 Mazi Total Frequency of use	**Anna**	**Elodie**	**Selina**	**Tula**	**Steve**	**Theo**	**Ray**	**Averages**
Lay belly on top	3	17	7	3	0	35	5	10
Sit on top	2	0	2	6	0	52	2	9
Bounce on top	0	0	3	0	0	10	0	2
Leans against	1	19	5	2	1	97	7	19
Pulls/manipulate wool	0	8	0	0	0	1	0	1
Press bubble	0	0	2	2	0	0	0	1
Speaker	0	4	0	0	0	14	2	3
Pat body	0	5	0	0	0	11	1	2
Touch body	2	5	1	3	0	22	5	5
Climbs	1	9	1	2	0	21	15	7
Foot on	1	6	0	0	0	5	4	2
Hug	0	4	0	0	0	67	5	11
Touch bubble	1	6	1	3	0	34	4	7
Press hands	1	11	9	2	0	33	11	10
Jumps on	0	1	0	0	0	55	7	9
Balances on	0	0	2	0	0	7	13	3
Cover with jumper	0	0	0	0	0	28	0	4
Head on bubble	0	0	0	2	0	8	1	1
Thread	2	5	0	1	0	8	0	2
Looks at circuit box	0	1	0	0	0	0	0	0
Moves across floor	0	2	0	0	0	75	5	12
Chin pressed on bubble	0	0	0	0	0	4	1	1
Rocks on ball	0	0	1	0	0	0	0	0
Looks under jumper	0	0	0	0	0	3	0	0

Table 6-4 Theme 5 Mazi frequency of unexpected uses per child

For example, as seen in Table 6-4, the unexpected uses exhibited the most when interacting with Mazi, included but were not limited to: leaning against it (x19), moving Mazi across the floor (x12), clinging to and embracing it with harms as if to hug it (x11), some of the children laid their belly on its top (x10) and some pressed their hands on it (x10).

As shown in Table 6-5 instead, the overall uses that children exhibited the most when interacting with Olly included: stepping/walking on Olly's base, which they did for an average of 40 times (x40), laying their belly on top of Olly (x12), and pressing their hands on it (x12), and sitting/laying on its base (x10).

T5 Olly Total Frequency of uses	**Anna**	**Elodie**	**Selina**	**Tula**	**Steve**	**Theo**	**Ray**	**Averages**
Lay belly on top	12	2	34	21	0	2	12	12
Sit on top	1	0	2	8	0	0	0	2
Bounce on top	2	3	3	2	0	0	21	4
Ribbon's manipulation	10	7	1	5	8	4	4	6
Sit/lay on base	22	5	0	8	16	4	14	10
Leg under base	0	4	0	1	0	0	0	1
Touch speaker	8	24	0	1	7	2	4	7
Pat body	11	0	2	3	3	1	0	3
Touch body	3	0	5	5	0	1	26	6
Ribbon around waist	2	1	0	7	0	1	1	2
Climbs	8	0	1	14	0	1	27	7
Press hands	4	19	31	10	0	2	20	12
Rocks/swings on top	2	6	9	11	0	0	13	6
Balance on	0	0	3	8	0	0	17	4
Jumps on	0	5	0	0	0	1	13	3
Pull ribbon	0	3	0	1	0	1	4	1
Feet up on olly	1	0	0	0	0	0	0	0
Leans against	12	4	1	5	4	3	7	5
Face on base	0	2	0	0	0	0	0	0
Snaps	18	2	0	1	0	0	1	3
Steps/walks/stand on base	69	46	25	26	17	31	64	40
Bites ribbon	1	0	0	0	0	0	0	0
Box	3	0	0	0	1	0	1	1
Stroke ribbon on face	0	0	0	0	0	1	1	0
Velcro	0	0	0	0	1	0	0	0
Stands up	0	0	0	0	0	0	13	2
Hug	0	0	2	0	0	0	1	0
Foot in ribbon	0	1	0	0	0	0	0	0
Face on top	0	0	0	0	0	0	2	0
Wobble ball	0	0	0	4	0	0	7	2
Knee on	0	0	0	1	0	0	0	0

Table 6-5 Theme 5 Olly frequency of unexpected uses per child

A frequency-based analysis helped to achieve a better understanding of the different types of play that the TUIs encouraged the most, which in turn helped understanding how they could best support different types of play. For example, it was reported that Anna liked to receive deep pressure when interacting with Olly (the TUI she approached the most). After day 1, the dance teacher noted that Anna "*lay on the ground under the base— deep pressure*", after day 2 she wrote that she "*lay next to Olly and leaned against Olli*" and after day 3 she noted that Anna "*lay on the side*". Similarly, the TA observed that Anna "*loves playing with the small silver buttons and make deep pressure, climbing, even hiding her feet under the fabric*".

Calculating the overall percentage of time instead allowed to compare this type of uses to the musicking ones.

Anna displayed an overall average of unexpected uses equivalent to 75% of her approaches (Figure 6-18). The uses that she performed the most are reflected in Table 6-4 and Table 6-5. When interacting with Olly (Table 6-5), she mostly walked/stepped on base (x69), sat/laid on base (x22) and was interested in the snap buttons (x18), laid with her belly on top of Olly (x12), leaned against it (x12). Anna seldomly interacted with Mazi (Table 6-4), but when she did, Anna laid belly on its top (x3), sat on it (x2), touched its body (x2), etc. Elodie instead used the TUIs unexpectedly for an average time of 63.9%. The dance teacher thought that she liked "*leaning over [Mazi] for deep pressure*" and the TA reported that "*Olly and Mazi were both jumped, climbed and pressed on by Elodie. She loved pressing and when it made sound she would jump and squeeze*". This observation suggests that, perhaps, some of Elodie unexpected uses were in response to the sounds activated. During the second pre-testing class interview, some TAs said that she is a "*very sensory*" child. When using Olly, Elodie used it mostly to walk/step on its base (x46), touch the speaker (x24), press hands on its body (x19), manipulate the ribbons (x7), rock/swing on it stop (x6), etc. When using Mazi instead (Table 6-4) she mainly leaned against it (x19), laid her belly on its top (x17), pressed her hands onto it (x11), climbed (x9), pulled/manipulated the wool (x8), touched it with her feet (x6) etc.

Selina demonstrated an unexpected use of the TUIs equivalent to 85.7% of her approach times. In a pre-session class interview it was reported by the TAs that she *"likes deep-pressure"*, and this was observed also during the sessions. The dance teacher commented after day 2 that Selina *"lay on seeking deep pressure"*. The TA noticed that the pupil *"climb, touch, lie down on Mazi"*. However, she might have confused Olly with Mazi, as Selina interacted more with the former. In day 3, it took her longer to initiate bids of interaction with Olly *"[..] does everything. Today just took her more time. She was not that focused (but in the end she did it)"*. It appeared that Selina *"did poo and she lost her attention"*. After the study, the TA's opinion was that the child's *"fun was to swing on Olly when lie down on it and then she explore with the textures"*. Selina used Olly mostly to lay on its top (x34), to press her hands against it as she was about to lay on it (x31), to step/walk/stand on its base (x25), and to rock/swing on it (x9). Similarly, but less frequently, she used Mazi mainly to press her hands on its top (x9) and to lay with her belly on the top bubble (x7), or to lean against it (x5) etc.

Tula used the TUIs for an average of 59.9%. After the first session, the TA noted that "*She was leaning on Olly like a big hug. she put her body and legs through the ribbon, laid down on the floor legs still in the ribbon."*. After day 2, she commented that Tula "*banged her head on Mazi's buttons. also laid down on Olly with tummy on it*". Before the study commenced, it was reported by the TAs that Tula "*likes soft blankets and maybe others soft things*". In day 3, the dance teacher confirmed that she sought "*deep pressure- laying on top*". In fact, the actions that Tula performed most when using Olly (Table 6-5) included stepping/walking/standing on Olly's base (x26), laying her belly on its top (x21), climbing on it (x14), rocking and swing on it (x11) and pressing her hands against the ball (x10). When using Mazi, instead (Table 6-4), she mostly sat on its top (x6) and in equal measure laid on it, touched the bubbles, and touched its body (x3). In the questionnaire the TA observed that "*[..] she laid on top of Olly with a smile and put her body through the ribbons".*

Steve instead used the TUIs unexpectedly for an average time equal to 66%. During the study, it was noted that "*Steve jumped, pulled and laid on both Ollie and Mazi, he was wiggling and laughing then run back to the bench, observed and ran again".* In the second pre-session class interview it emerged that he "*likes deep-pressure*". After the study the TA reported that Steve "*enjoyed the shapes and the textures".* He was seen using Mazi unexpectedly just once to lean against it (Table 6-4), while he used Olly to step/walk/stand on its base (x17), sat and laid on the base (x16), manipulated the ribbons (x8), touched the speaker (x7), and leaned against it (x4).

Theo exhibited unexpected uses of the TUIs equivalent to 71.4% of his approaches. After day 1, the TA wrote that "*he press [sic], climb on it, mostly he lie down on it to listen to the sound (that encouraged him to press the buttons)*", whereas the dance teacher observed that "*Theo did (i.e. deep pressure, climbing, squeezing, patting, etc).* In day 2 the TA noted that he "*likes to lie on Olly and Mazi, press, push around, touch*" and after day 3 she said that "*Theo like to go on top of Mai+Olly, moving it from one corner to another*". The dance teacher confirmed that the child sought "*deep pressure*" and did "*climbing— squeezing— patting*". After the study the TA noted that Theo "*was impressed with touch the buttons and they light up and give sound*". Interestingly the dance teacher reported that he "*had created an attachment from the visuals Mum* *[sic] had shared with him at home – he was in love*". This attachment was clear during the study by the ways the child interacted with Mazi. For example, he used Mazi to lean against it (x97), move it across the floor (x75), he hugged it (x67), and jumped on it (x55), or sat on its top (x52) etc. Olly's unexpected uses were mainly through stepping/walking/standing on its base (x31), sitting/laying on the base and manipulating the ribbons (x4), or leaning against it (x3).

Ray instead used the TUIs unexpectedly for an average time of 72.6%. During the testing phase, when using Olly he mostly exhibited: steppin/walking/standing on its base (x64), climbing on it (x27) and touching Olly's body (x26), bouncing on its top (x21), and pressing hands on it (x20), balancing on it stop (x17), but also sitting on its base (x14). When using Mazi, Ray mostly did: climb on its top (x15), and balanced on it (x13), pressed his hands on it (x11), leaned against it (x7), or laid on it, touched it, moved in across the floor and hugged it (x5). In the questionnaire, his TA reported that the on/off button of the speaker was a distraction for some children *"It was discovered by the kids and it was a distraction for them as they were really motivated to see what was under the Olly"* and added that that "*there were too much distractions around, the curtains were out kids had the freedom to climb up the curtain. Or even playing behind it [..]*". The dance teacher instead noted that Mazi's felt "*was removed from the structure (we do not want children eating the material*)". These aspects highlighted some design challenges further discussed in limitations. Theo and Selina's TA however said that children liked the "*design of Olly and Mazi, especially the white texture covering the technology*" suggesting that children liked the material.

Generally, in the post-study questionnaire, one of the TAs (Selina and Theo) observed that "*Some of the textures where more motivating for them then the cause-effect of the MAzi [sic] Olly technology.* Another TA (Elodie) reported that "*For sure the shape of olly and mazi was fun because it was round so they all were laying back and jumping on top [..] Material was good because it was soft and fluffy for them to kick push pull jump*". It was further expanded by Tula's TA that "*the round shape was inviting. The size was their size, they could reach it, it could hold them (especially Olly). The material was soft, they probably liked it because they (Tula, Ray, Selina, Theo, Steve) laid on it. Most of them tried the ribbons, they liked the elasticity of this, especially Ray and Tula, she might also liked the colour of the ribbons".*

6.7.6 T6. Share emotions

As described below, throughout the duration of the three sessions, all the children expressed a mixed range of emotions. Figure 6-19 shows the overall combined amount of emotions that each child exhibited each day over the duration of each session. These emotions were coded as positive (+), negative (-), vocalizations (V), and other (/) such as coughing, chewing, stomping, and spinning, and were calculated from when the children took their shoes off, before the introduction, to when the TUIs were covered again, at the end of the sessions. The overall amount of displayed emotions are illustrated in figure 6-19. Generally, after the testing sessions finished, the dance teacher commented that "*children were very motivated with Mazi and Olly and the sensory input they received was meaningful and fulfilling"*. She also added that "*In dance it is different interactions as we move quite quickly between activities – more direction. Mazi and Olly moves at a slower/ relaxed pace which enables more time for the children to find a peaceful place"*. Aside from Elodie, who expressed the most negative emotions, particularly in day 3 in the form of crying and shouting, because, as reported by her TA she "*wasn't feeling well*", the children exhibited mostly positive emotions and vocalised frequently. Negative emotions were shown particularly at the beginning of the sessions, during the introductions, and/or at times, even before the introduction started.

After the testing period ended one TA observed that "*Children find difficult to sit while olly mazi [sic] were covered, It was kind of Attention Autism part*" and the dance teacher confirmed that "*The pupils were very upset in the first session as we had requested they sit on the bench for Attention Autism– once they were released to explore they became regulated. The distress did not continue in the next sessions pupils waited and self-regulated with the support of the staff"*. Children were new to the school and to the approaches adopted, but it was thought that having a clear beginning and ending to the sessions (i.e. introductions with attention autism inspired song), would have been better than leaving them completely free. The TA working with Tula in the post-testing interview said that because "*the session was free-flowing but still had a start, and end clearly differentiated, it was structured in a way. They were independent but staff was available for their needs. They all needed less prompt and it could have been positive experience for all of them"*. Waiting for the song to finish was a new thing for all of them, but they overcome that challenge as the sessions progressed. For example, after day 1, the TA working with Anna noted "*very excited and happy, the whole time she observed then screamed in happiness*", and on day 2 the dance teacher observed that Anna was "*Calmer when approaching Olly – Smiling*". On day 3, Anna "*was clam and tired (eye closing)*".

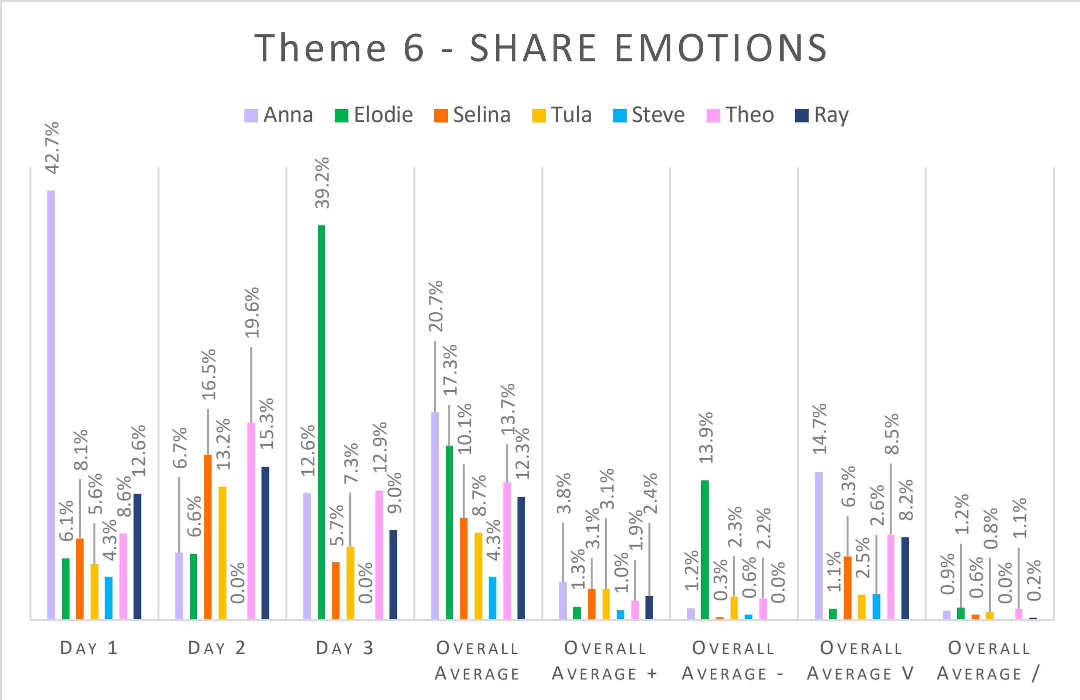

Figure 6-19 Theme 6 Share Emotions

As mentioned in T1, in day 2 the dance teacher reported in Anna, Elodie, Selina, Tula, and Ray's observation sheets that "*the weather meant that there was no outside play and there was lots of crying*". Nonetheless, her comments of that day about i.e. Anna were that she was "*Calmer when approaching Olly – Smiling*", and of Elodie she said that she was *"very happy when near Olly"*. The dance teacher highlighted that during the session the children were *"not as much crying and distress. (I felt they were aware of what was going to happen next). The children were very chilled and relaxed after each session and we had no issues with (Behaviour/transition)"*. This indicates that throughout session 2 'Olly Mazi' allowed the children to calm down and regulate themselves although they arrived at the sessions dysregulated.

Generally, the TA wrote in the questionnaire that Anna experience was "*Positive and surprising. Anna was happy and excited, running around the room, when she is usually playing in silence in a corner*". The TA thought the her and Steve were regulated because "*The room has space enough for them to join [sic] or be apart whenever they want. The technologies don't require constant interaction, they are not very demanding and respect the rhythm of the children*". Anna's vocalizations were mainly spelling interjections and exclamations, such as high pitch sounds and shouts of excitement, while negative emotions included hitting other pupils when around Olly, and some adults when she was standing around one of the benches. Other emotions included chewing on something and fiddling with her finger but these were expected because in a pre-testing phase interview, it was noted by the TAs that Anna required something to fiddle with to keep herself regulated.

In a similar way, the comments reported by Elodie's TA after day 1 were positive "*Elodie smiled and laughed throughout the session showing her enjoyment and interest about the new activity*". After day 2 day the dance teacher confirmed that she was "*very happy when near Olly*", but she "*wasn't feeling well so ended Olly Mazi*". In the questionnaire the TA noted that "*Elodie experience was very positive she enjoyed every little bit of olly and mazi, she couldn't wait for the covers to go off so she could run and explore. She took turns with olly and mazi she would go to olly and then mazi*". Elodie's other emotions were in the form of coughs, especially on day 3, while most of her vocalizations were in the form of high pitch sounds, and exclamations when manipulating some wool fibres, and/or running towards Mazi, but also when hopping around the room. In a pre-testing phase interview, the researcher was told that Elodie required something to fiddle in her hands to keep regulated.

On the other hand, Selina's TA noted that she "*has to run up and down*". After day 1, it was observed by the dance teacher that she was "*happy".* Seemingly, after day 2 the TA reported that Selina "*seems very happy in the environment. Played with Mazi [it was Olly] but as well ran around the room*". After day 3 the dance teacher commented that she "*self-regulated using Mazi and the mirror*". This might perhaps indicate that the TUIs was efficient in providing opportunities for self-regulation. After the testing sessions Selina's TA (who also worked with Theo) said that "*It was very nice experience to see how children explore new object with so many different sounds, shape and texture. I could see Olly and Mazi make on them big impression. Students like to touch it (even pull the textures out), touching, lie down on it and swing.*" Selina showed negative emotions in the form of i.e. moans, as she sought one TA's hand to apparently touch her head. In day 2, she went to one TA and shouted as if something was hurting her head, but the TA did not understand the problem. The child did the same with a few other TAs. She displayed positive emotions in the form of smiles and vocalizations, which were mainly spelling interjections and exclamations, especially when laying and rocking on Olly. Her positive emotions were exhibited when around Olly, but also when playing freely and independently around the room. O*ther* behaviours that she exhibited included spinning and squeezing her eyes.

Tula's feedback was also overall positive. In day 1, the TA observed that "*her facial expression was relaxed smiley"*, while in day two she reported that Tula "*came to me with a smile, tried to invite me to play. when she wanted a bottle she went to find it at the bench*". In day 3, she confirmed that Tula was "*Smiley most of the times, calm or excited. The former sitting on the bench quietly and watching; the latter running up and down*". Before the study commenced it was reported that she commonly requested her bottle to regulate, while in the questionnaire, her TA wrote "*I used less prompt as she was regulated throughout the sessions. [..]Usually she claims her bottle throughout the day and finds difficult to stay seated at times. These times she needs prompt [sic] but it wasn't necessary in Olly-Mazi*". This is particularly encouraging, as it seems that Tula needed less support than she usually did in other scholastic contexts to engage with the TUIs and also she was able to regulate without holding the bottle.

The TA commented, after the study, that "*Overall it was a positive experience for Tula. She looked relaxed, happy, exploratory, curious".* Her vocalizations were a combination of spelling interjections and exclamations i.e. ah, oh, eh, bah, ta, and the negative emotions included moans and crying sounds (during the introductions and also prior to the start of the session), particularly in day 2. Other behaviours exhibited by Tula were mainly due to coughing, and her positive emotions included laughs and smiles (which happened especially when interacting with Olly), suggesting that the TUIs positively impacted her experience.

As observed by his TA also Steve was "*very happy as it was new very jumpy and excited*". However, this might also indicate that the novel effect of the TUI could have impacted his positive responses. Nonetheless, in the questionnaire the TA reported that he "*enjoyed the shapes and the textures*", and the dance teacher noted that he was "*self-regulated very happy".* In a class interview, it was said that Steve liked to have a squishy toy to play with, which helped him regulate, but during the session, he did not require one. Steve's negative emotions were expressed in the form of grimaces, e.g. when he wanted to move freely, but the TA was holding his hand. One time, he looked as if he got scared by a mix of events happening around him (Anna sudden shouts, Ray jumping off Olly's top next to him). Vocalizations were mainly exclamations, and his positive emotions were in the form of smiles.

Theo was "*happy – bouncing - confident-regulated*" (dance teacher, after day 1). In day 3 the dance teacher and TA both reported that "*he was shouting in happiness. He was really excited*" and "*very happy*". After the study, the TA noted that "*even when he gets [sic] upset Olly or Mazi helped him to distract and divert to back to play again with it*". As observed by the teacher *"he seems to be very happy when play with Olly and Mazi",* indicating that Olly and Mazi, might have positively impacted Theo's experience. Other emotions were mainly jumping, but on day 3, the child was also observed chewing on something as he came into the room before the sessions started. Prior to the testing phase it was reported that Theo "*is using the chewy but recently*", but the TAs were "*not too sure if he does really need that".*

Even Ray reacted well. As reported by his TA he "*was happy and excited. Repeated Hello [child's name] Olly Mazi".* In day 2 and day 3 the teachers said that he "*spontaneously shared vocally Mazi and Olly*". He never expressed negative emotions and when he vocalised he mainly repeated "*hello [child's name]*" and "*Olly Mazi*". In the questionnaire his TA reported that "*he was happy [] enjoyed the session and it was a completely different experience for him".* Other behaviours included kicking a metal grate on the wall or coughing (especially day 3). When vocal, apart from saying "*Olly Mazi*", and "*hello*" followed by "his *name*", Ray sounded as if he was singing, or repeated a sequence of numbers and/or words. As already mentioned, on the 19th of July, after around 4 months that the study was terminated, due to the spread of COVID-19, the researcher was contacted by one of the TA via WhatsApp messages which read: "*just to let you know that Ray is asking for Olly Mazzi everyday [sic]. And he makes me write it on a piece of paper so that he can carry it with him*". Indicating that the child was missing Olly Mazi.

Generally, the dance teacher in her questionnaire wrote that "*Children self-regulated by moving to the perimeter of the area when Olly and Mazi was crowded – working things out. In [sic] development of Early Years children with Autism the above observations are quite encouraging as the children have only been in the school since late September 2019."*

6.7.7 T7. Eye contact

Throughout the sessions, this group of children seldomly made eye-contact with their peers and/or with adults. Table 6-6 illustrates the number of times that eye-contact was observed between peers, or between children-adults, and it also shows the person that the child made eye contact with e.g. an adult or another child.

T7 Eye contact	C1	C2	C3	C4	C5	C6	C7	Adult
C1								1
C2						3	2	
C3								
C4						1		2
C5						1		1
C6		3		1	1			
C7		2						3

Table 6-6 T7 Eye Contact Study 3

For example, Anna displayed eye-contact with adults when playing around the bench, while Elodie made eye contact with Theo and Ray when they were interacting together with and/or around Mazi and/or Olly. Contrarily, Selina never made eye contact with anyone, while Tula did so with Theo, when he followed her at the curtains, and with few adults, when she was interacting with Olly. Steve also made eye contact with Theo when interacting with Mazi. Lastly, Ray made eye contact with Elodie and few adults when around Olly and Mazi. As in the previous study, instances of eye-contact were observed between peers, mostly, when interacting with the TUIs, suggesting and reinforcing the idea that the technologies facilitated this kind of social interaction. However, the researcher cannot be sure that children really looked in each other's eyes.

6.7.8 T8. Play types

Finally, to understand what types of social play the TUIs encouraged the most, this section presents the overall percentages of times that children exhibited different social play types (figure 6-20). These were calculated over the overall attendance of each child, minus the introduction's times.

As introduced already in chapter 3 and 5, these were labelled as Unoccupied (**U**), Onlooker (**O**), Solitary (**S**), Parallel (**P**), Associative (**A**), Cooperative (**C**) play and Other play types. The *Other* behaviour observed were the same as in study 2. These are shown in figure 6-24. Contrarily to what was found in Study 2, the children in this group never displayed any Pro-Social Interaction with a positive response (**ProS +**), which was coded when initiations of bids of interaction were immediately and positively reciprocated by peers.

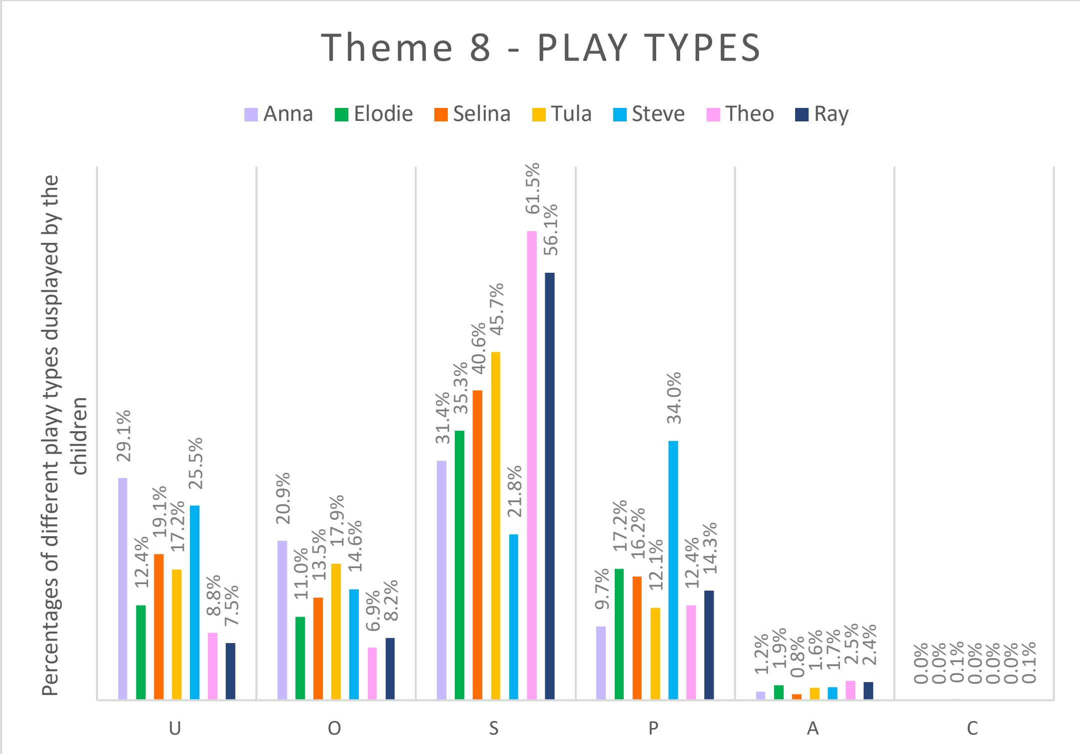

Figure 6-20 Theme 8 Social Play types

The types of play displayed the most by the children in descending order were: Solitary **S** (average time of 41.8%), Unoccupied **U** (average time of 17.1%), Parallel **P** (average time of 16.6%), Onlooker **O** (average time of 13.3%), Child-Initiated Seeking of Adults **CISA** (average time of 4.5%), Competitive **Cm** (average time of 2.4%), Associative **A** (average time of 1.7%), Child-Initiated Affectionate Interaction with Adults **CIAA** (average time of 1.2%), Turn-Taking **TT** (average time of 0.6%), Pro-Social No Response **ProS** / and Negative Response to bid of interaction **-R** (average time of 0.2%) and finally Refuse to Join **RJ** and Cooperative Play **C** (average time of 0.1%).

The TA that supported Theo and Selina reported that "*Children were more able to reacted [sic] spontaneously to Olly and Mazi, and they have more chance to interact with another students [sic] then looking for an adult hand*".

6.7.8.1 Unoccupied (U)

The unoccupied play was the second most displayed type of play (average time of 17.1%), and although its negative connotations (Parten, 1932), it enabled the children to have some time off from the occurring events, where they could regain their focus and regulate. Few TAs also noted that perhaps U play empowered some children as "*they were free to join as much as they wanted [..] I think they felt more* *free [sic] and in control because they did not feel any pressure*" (Steve and Anna's TA). Similarly, Tula's TA said that "*the session was free-flowing. [..] They were not forced to go to Olly-Mazi, they could do it in their own time. It might have been important to Anna who needed the most time of them to approach Olly*". Unoccupied Play was displayed in a variety of ways.

For example, Anna spent 29.1% of the time walking across the benches, holding a little wooden toy, fiddling with something in her hands, sitting on the bench, or standing by the bench, and at times she picked somethings from the floor and ate/chewed it, or scraped some paint off the wall. Anna was the child that exhibited most U play followed by Steve (25.5%), who did so by mainly crawling on all 4s across the floor to move between the two benches and the TUIs, by sitting next to the TUIs and looking around (but with no specific focus of attention), and/or walking around the room. Selina was the third child who most displayed this type of play and she exhibited 19.1% of it. Selina mainly walked around the room, often looking down, stood next to the curtains and/or the TUIs, seldomly span around, or swan her arms, hopped with legs crossed, and wiggled her body as if in need of the toilet (day 3).

6.7.8.2 Onlooker (O) and Share attention

Onlooker instead was the fourth most displayed type of play (average time of 13.3%) and it was exhibited when a child looked at other peers but did not participate in the play. It could be performed by being physically beside peers or from a distance, but always in a co-located environment. For example, Anna who's the child that looked at peers the most (20.9%), often did so from sitting on the bench. The TA reported that she "*observes from different places of the room and smiles*" (Day 2), and "*was looking at the other at the end of the lesson (when music started)*" (Day 3). Tula instead was Onlooker for an average of 17.9%. During the study, the TA noted that "*She went away sometimes from Olly and monitor from a distance* […] *looking at Olly Mazi plus the others from a distance*". On the other hand, Steve and Selina, who respectively displayed an average of 14.6% and 13.5% of onlooker play, often did so as they were approaching the TUIs, or when an adult played music with them.

6.7.8.3 Solitary (S)

Solitary play is the most displayed type of play (average of 41.8%). Within this time, Figure 6-21 illustrates whether the children exhibited solitary play by playing alone around the room (i.e. interacting with the environment such as the curtains), or by interacting with the TUIs alone. Apart from Elodie and Theo, the children played more solitarily by playing alone around the room than with the TUIs.

For example, Theo who displayed solitary play for 61.5% of his attendance, often jumped and/or hopped around or on the benches quite vigorously, he happily smiled, looked at his reflection in the mirror, ran towards the curtains, and played with his jumper around the door area (by covering the glass window at the door), or stayed behind the curtains. Ray instead, who displayed solitary play for an average of 56.1% of the times he attended, ran around the space or towards the TUIs, stayed behind the curtains, climbed onto the drapes, and jumped on benches.

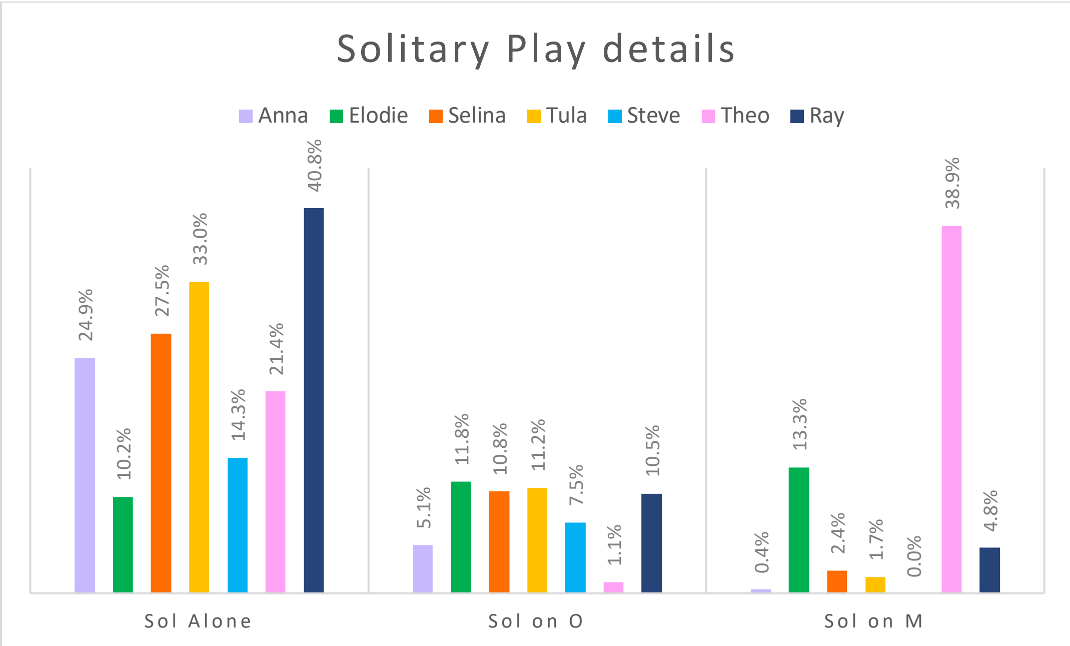

Figure 6-21 Theme 8 Social Play Types

Similarly, Tula (45.7% of Solitary play) hid behind the curtains, played with her mirror's reflection, ran around the space and around the TUIs, and wrapped her body into the curtain's drapes. Interestingly, aside from Steve who played solitarily mostly when the TUIs power was turned off, the other children displayed S play using the TUIs more when the music was on. This suggests that the music accompanied most of the solitary playtimes during the sessions, and it indicates that it had a honey pot effect, which enticed the children to play with the technologies.

6.7.8.4 Parallel (P)

Parallel play was observed just between peers, but in few occasions, adults were also playing music with them. P play is the third most displayed type of play (average time of 16.6%). Figure 6-22 shows the overall parallel play displayed by each child and offers a comparison of this type of play displayed by the children between Mazi and Olly. Again, all children displayed more parallel play mostly when the music was on, suggesting that it influenced children's socially engaged interactions. Apart from Theo, children displayed more parallel play when using Olly (average of 13.7%) than when using Mazi (average of 2.9%). This could perhaps suggest that Olly better afforded this type of play.

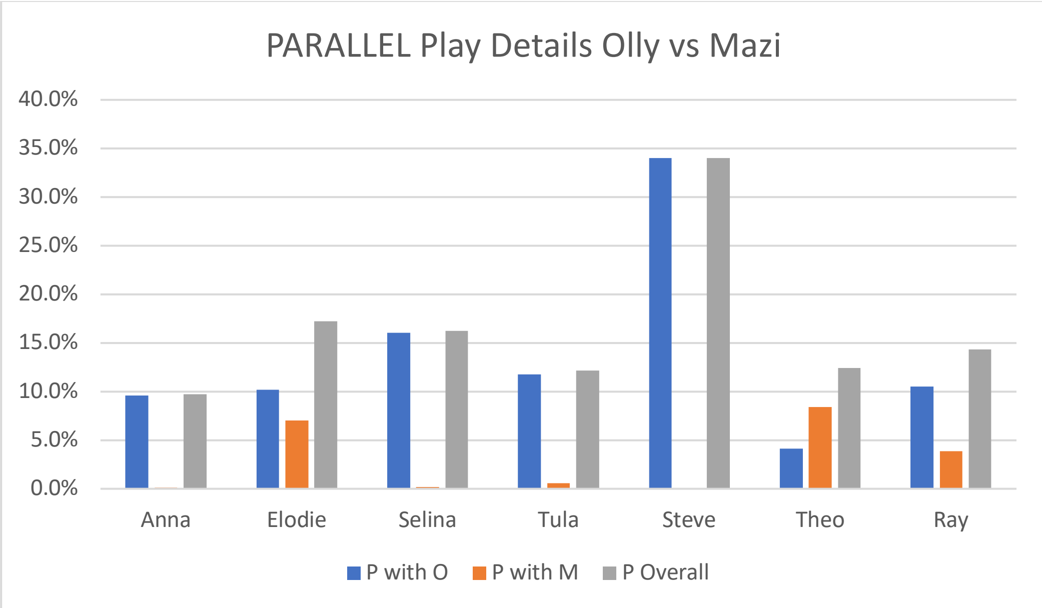

Figure 6-22 Parallel Play details showing if children exhibited Parallel play with Olly or with Mazi and the overall Parallel play displayed by each child

For example, Steve who exhibited 34% of parallel play by using Olly when playing with Anna, sat on its base and touched a ribbon, then patted the speaker as if wanting music, while Anna laid on it when the dance teacher started playing music. Another time Steve was playing with Olly instead he stood on the weights at the base of Olly touching the top and a ribbon, while Tula stood on her knees on the felt bit of the base and leaned on the ball and pressed her hands on it, and Theo crawled by on all 4s on the base but he was actually playing with Mazi.

Elodie, who displayed an overall parallel play of 17.2% while playing with Anna, Selina, Tula and Ray, played slightly more using Olly. When using Mazi instead, Elodie did parallel play with Theo. For example, once Elodie was interested in the speaker, while Theo leaned on it and patted the top bubble; another time she touched Mazi's top bubble, and Theo leaned against it and covered Mazi using his jumper. By contrast, Selina often displayed P play by sharing Olly with Tula and Elodie, or Anna and/or Steve (16%). In day 2, she shared Olly with three peers Tula, Anna, and Steve. At one point she displayed parallel play with Steve and Theo, as Theo stepped at the border of Olly's base, Steve pulled a ribbon alongside the dance teacher to make music, and she stood on the weights at the base of Olly while looking at Steve and the dance teacher.

6.7.8.5 Associative (A)

The associative play happened when a child displayed identical or similar activities (watching, copying) to those of other peers and it was the seventh most displayed type of play (average of 1.7%). All children showed some kinds of associative play. Figure 6-23 displays the overall percentage of time that each child spent exhibiting associative play by either using Mazi or Olly.

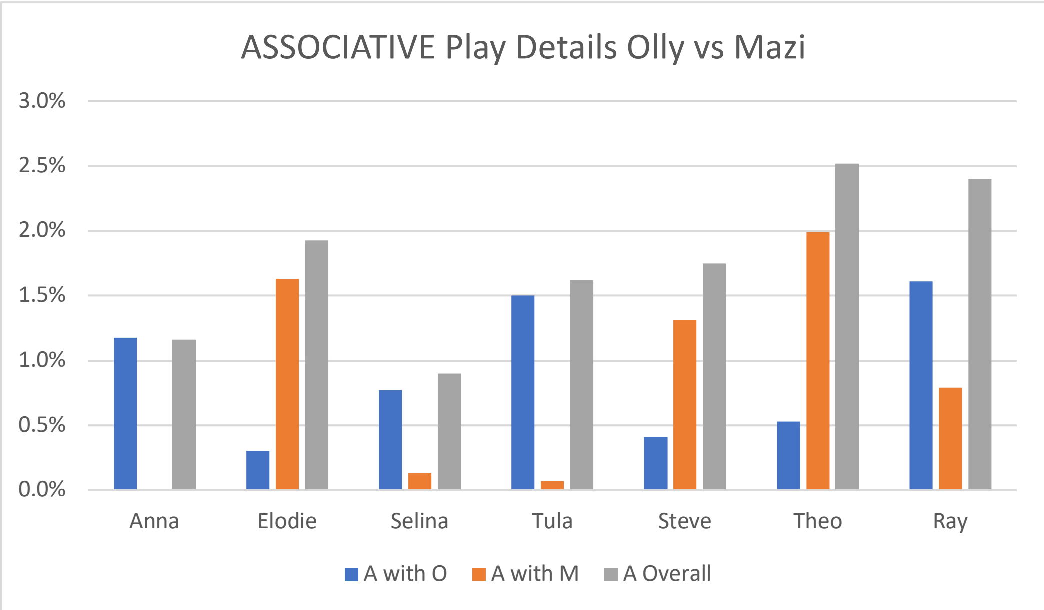

Figure 6-23 Associative play with Olly or with Mazi and the overall Associative play displayed by each child

Children displayed associative play just when interacting with the TUIs. Both Mazi and Olly facilitated associative play in almost equal measure (Olly 0.9% vs Mazi 0.8%). Interestingly, all the children demonstrated associative play more when the TUIs had their power turned on (music was on) than when it was off. In the questionnaire the dance teacher wrote that "*all children had subtle interactions – touching Mazi or Olly at the same time i.e. (Elodie and Ray) (Tula and Theo)*" and Elodie's TA added that "*[..] it was a free time for them to explore and played around with each other, they copied each other too while jumping and pulling olly and mazi*".

When combining together the associative play exhibited by each child while using Mazi, or Olly, Theo is the child that exhibited the most associative play (average of 2.5%). For example, in day 3, he often demonstrated this play with Ray, e.g. by leaning on Mazi and patting the red bubble once, while Ray sat on a side bubble of Mazi on the opposite side with his knee and looked at the mirror and triggered a note. Ray exhibited an overall average time of 2.4% of associative play, and apart from Theo, he did so also while interacting with Anna, e.g. when they pressed Olly's top together, or with Selina e.g. when in day 2 they both aimed to lay/climb on Olly's top and she pressed with both hands at the same time that Ray jumped on it with knees.

Another child who exhibited a fair amount of associative play is Elodie (overall average time of 1.9%). For example, in day 1 most of her displayed associative play was with Theo when using Mazi. Elodie lifted one arm up and patted the top bubble, and Theo followed after her jumping on with one knee and patting the top bubble too. She also walked on the base at the same time as Ray did so and exhibited associative play also with Anna, as she stepped on Olly's base above the weights, and Elodie stepped on the speaker and the circuit's box. Lastly, Steve who attended just the first session, exhibited an average of associative play of 1.7% and was observed displaying it with Tula, when both pulled a ribbon to play music with Olly, and with both Tula and Ray when they all played music on Mazi. Tula however was prompted by the dance teacher.

6.7.8.6 Cooperative (C)

Cooperative play, which is when a child actively engaged in the same activity as their peers and influenced or modified the activity of others, was exhibited just by Ray. However, in the questionnaire the dance teacher wrote that Olly and Mazi were "*A place to gather – an object of reference: [sic] Looking at each other, laying together, and sitting together, turn-taking [..] Social interaction has definitely being facilitated as Mazi and Olly are motivating objects and the children gather and share space together which helps them communicate with each other (positive or negative)"*.

For example, Ray played collaboratively for an average of 0.1% while using Mazi with Steve and Tula, and with Steve and Theo, in day 1. Contrarily to e.g. Steve, who seemed to be on an exploratory mission of his own, every time that Ray displayed cooperative play, it looked as if he wanted to add to the sound that was already played by some of his peers. That is at least, what the researcher felt. He displayed cooperative play by looking at the other children and then acting. When he cooperatively played with Tula, the latter was getting prompted to approach Mazi, while when playing with Steve and Theo, Ray looked at the peers playing around him and patted the bubbles three times - once using his foot and twice using his hands.

6.7.8.7 Others (Cm) (CISA) (CIAA) (ProS +) (ProS -) (NonSI) (TT) (RJ)

The other types of play displayed the most are shown in Figure 6-24. Among all the types of play, the fifth most displayed type of play was Child-Initiated Seeking of Adults or **CISA** (average time of 4.5%). Children sought adult's attention to ask for help with something, or to seek comfort/attention.

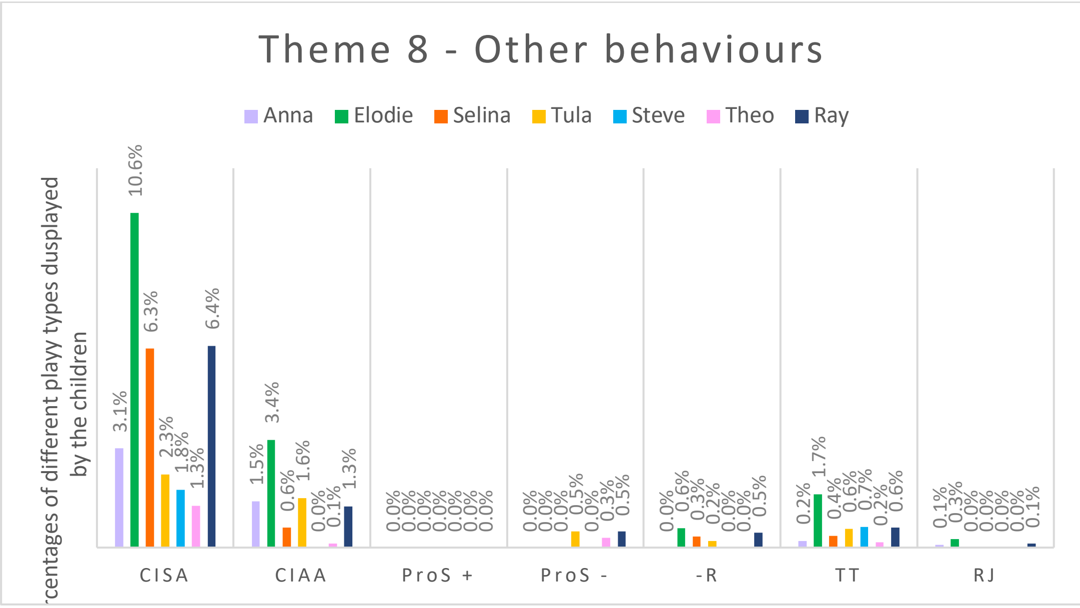

Figure 6-24 Theme 8 - Other Play types

For instance, Ray in days 2 and 3, approached different TAs and told them various things i.e. "*see you next time*", "*Annina*". He also moved very close to one TA, and looked at her very closely, perhaps touched her (the researcher couldn't see form the videos) and behaved as if he wanted some attention and/or to be noticed by the adults. This was displayed by walking/standing/sitting in front of or next to her. Selina instead held one of the TA's hands when sitting on the bench (day 1) and reached for different TAs as if wanting help with something around her head or sat on a TA's laps (day 2). In the questionnaire, the class teacher reported that "*Some students [sic] (Ray, Steve, Anna, Theo) checked in with the adults every now and again by looking at them, possibly for reassureance [sic] or for novelty of the situation (I.e. free to explore however they wanted)*".

Contrarily to the previous studies, Competitive play or **Cm** is an activity that all children displayed throughout the sessions (Figure 6-25). This was demonstrated for an average of 2.4% and was the sixth most exhibited type of play (slightly more than Associative). Children often competed by wanting to lay on top of Olly, and/or to play with Mazi, and as it can be seen in Figure 6-25 they competed more over Mazi than Olly (average of 1.6% vs 0.6%).

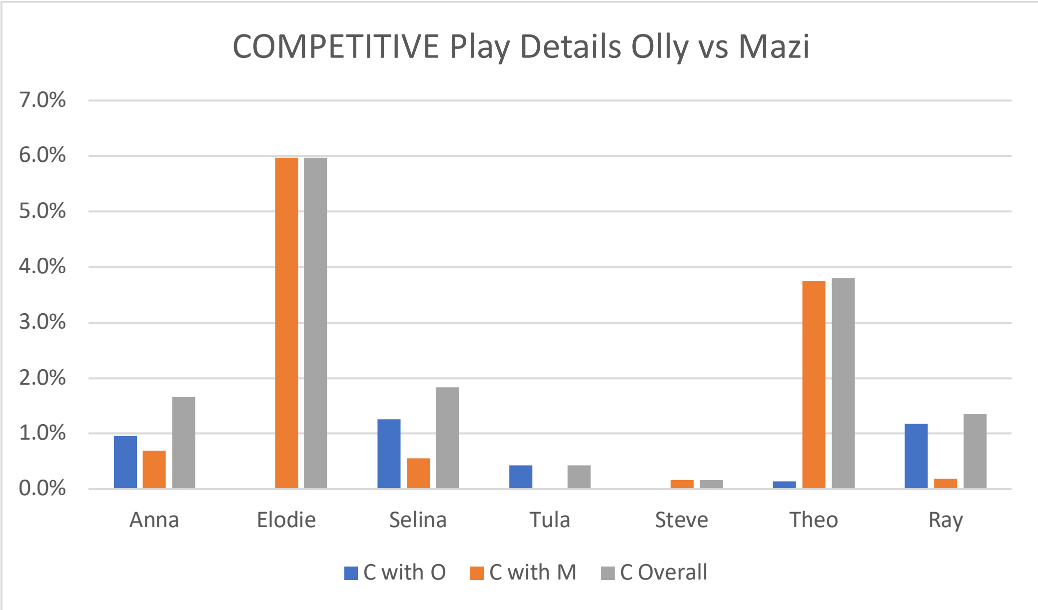

Figure 6-25 Competitive play showing if children exhibited Competitive play with Olly or with Mazi and the overall Competitive play displayed by each child

For example, Theo always competed to gain full control over Mazi. He shouted high pitch sounds, jumped in place, swung his arms, and patted his hands on Mazi and or on his legs. In the questionnaire, the TAs reported that "*He liked Mazi a lot, he didn't like to share with it*". Anna, on the other hand, was the only child that displayed competitive play in the form of hitting her peers. While the other children used different tactics, such as pushing and/or holding the TUI to gain more control over it to 'force' their way through the gaps, Anna used her hands to 'gently' hit her peers. No child was seriously hurt or cried as a consequence.

Other types of play included Child-Initiated Affectionate Interaction with Adults or **CIAA** (average time of 1.2%). This was coded when a child showed behaviours such as sitting on a TA's laps instead of sitting on the bench, or leaning against an adult (Anna and Selina did that), or by holding their hands and/or stroking an adult's face (Tula, Elodie). Turn-Taking (**TT**) (average time of 0.6%) instead, was coded when a child clearly waited for their turn, or for the best moment to approach. Surprisingly, although it was reported in a pre-testing interview that just Steve started to work on taking turns and waiting because "*he was the one that maybe we thought could learn*" all children exhibited these behaviours. They also displayed Pro-Social Interactions with No response (**ProS -**) (average time of 0.2%), and Negative Response to bid of interaction (**-R**) (average time of 0.2%). For instance, Elodie avoided interacting with Ray who followed her around Olly. Also, Ray avoided interacting with Tula when Tula started following him by putting her hands on his shoulders, and he indicated that he did not want her hands there by moving away. The least displayed 'Other' play type was that of Refusing to Join (**RJ)** which alongside Cooperative play happened just for an average time of 0.1%. For example, RJ was coded when a child was offered a ribbon but deliberately refused it. This happened with few children, such as Anna in day 2, Elodie in day 1, and Ray in day 2. However, the TA said that Elodie "*pulled ribbon once but then got upset because she wasn't feeling well*", therefore the fact that she was unwell might have impacted her willingness to play.

6.8 Discussion

The reflections below attempt to shed some light on the three sub-questions that this study aimed to explore. These research questions were threefold; a) How does a different group of autistic children react to two already made technologies when given the choice? Is there any difference on how they interact with Mazi or Olly?; b) Can the designs be used by different groups of children than those they were inspired by? c) And what differences there are (if any) in children's behaviours when the power of the TUIs is turned off or on?

These questions contributed to answering open issues that were highlighted in the four main research questions (mRQs). The sections below offer a reflexive discussion of the results by presenting the different responses exhibited by the children to two already made playful e-textile sonic TUIs designs, and those exhibited between Mazi and Olly (sub-questions a), which helped answering mRQ1 and mRQ3; an overview on how the TUIs impacted children's social play behaviours and how this different group of children emotionally reacted to the TUIs and the environment (sub-question b), which helped addressing mRQ1, mRQ4, and mRQ2; and the children's behaviours when the power of the TUIs was turned off, which in turn helped understanding mRQ3. Lastly, it provides an overview of what was learned about the designs and the methodology used, answers further mRQ4.

6.8.1 Children's responses: Olly vs. Mazi

Aside from Elodie and Theo, most children approached Olly more than Mazi (figure 6-13), and they played music with both Olly and Mazi in almost equal measure (figure 6-15). Olly was also used more unexpectedly than Mazi (figure 6-18).

However, when playing music together they used more Mazi than Olly (figure 6-16). Remarkably, the dance teacher reported that children preferred Mazi because "*it was easier to create sound*" (T5). However, children liked Olly because it was "*very tactile and sensory*" (T5). In study 2 she thought that Olly afforded better social interactions as children were able to lay on it while other could still use it in different ways i.e. to pull the ribbons (as reported in).

Interestingly, the pupils used the TUIs unexpectedly in similar manners, the only big difference being that Mazi could be moved across the floor, offering extra opportunities for a weight-bearing activity, which is a sensory strategy often used by Occupational Therapists (OTs) to calm and engage some children (Zisserman, 1991). However, children might have moved Mazi and not Olly because it was easier for them because of its slightly smaller shape. Another difference was that Olly could be rocked on and the ribbons offered a wide range of manipulative opportunities (see T5).

Generally, children exhibited turn-taking skills that were not expected due to the information gathered in the pre-testing interview (T8-TT). For example, one TA reported that "*Elodie [..] was taking turns with both of them*" (as reported in theme 4). This perhaps indicates that the children had the necessary skills for social development to happen (Toth et al., 2006) but they might have needed more opportunities to express them. Interestingly, Ray's TA noted that "*he generally went to the one who had less people*" (see theme 2), suggesting that maybe, the less crowded TUI was favoured by some children, and therefore children's responses to the TUIs might have been affected by the children's presence. However, the class teacher, who attended the first session, commented that few features might have attracted children's attention such as the materials, the texture and the music (as seen in T2).

6.8.2 Children's responses: Social Play

The majority of social interactions happened around Olly and Mazi, suggesting that the TUIs were a social stimulus for the children (Hornecker et al., 2007; Kendon, 1990). As reported by the dance teacher and one TA in T8-Associative play type, some children touched Olly and Mazi "*at the same time*". From the results of this study, children demonstrated longest times of Parallel play by using Olly, whereas Associative play was exhibited in equal measure with both TUIs (see T8). However, children played more music together by using Mazi (figure 6-16). Interestingly, also Competitive play happened mainly with Mazi (see T8). Perhaps, children competed more over Mazi than Olly, as it is slightly smaller in size than Olly and it's easier to move around, or maybe because it lacks a carpet where children could gather around together by sitting or standing on it, and this discouraged its attributes of shareability (Hornecker et al., 2007). However, the majority of competitive play, when using Mazi, mainly emerged due to one child, Theo, who became very protective of Mazi from session two and as his TA noted in theme 8 he didn't like to share it.

Conflicts, which arose during Competitive play, and in short bursts, required some 'measure of compromise' (Piaget, 1962). Because, during the study, these conflicts happened within a safe context, children could demonstrate and practice skills such as reconciliation, risk-taking, ownership, self-determination, accommodation, and conflict resolution. According to Hochhauser et al. (2015), interacting in successful conflict resolution is challenging for autistic children due to their lack of self-confidence, communication, cooperation, and compromise skills. Nonetheless, throughout the three sessions, through playing with the TUIs and among themselves, the children demonstrated various abilities necessary for successful social interactions, such as compromise (conflicts lasted only a few seconds and never escalated), imitation (the children used the TUIs in very similar ways), social and spatial awareness (exhibited by the onlooker behaviours and eye contacts, turn-taking initiatives and the children's playful activities), psychomotor skills (displayed by the children's play behaviours – pulling ribbons, pressing bubbles, balancing/jumping), self-regulation, self-confidence, and cause-effect.

In contrast to the negative connotations assigned by Parten (1932) to the Unoccupied (U) and Onlooker (O) play, during the study it was observed that O play enabled some children to develop social awareness and to have access to the ongoing activity (Rubin, 2006). This is confirmed by i.e. Tula's TA who said that she *"monitor from a distance […] looking at Olly Mazi plus the others from a distance"* or by Anna's "*she observes from different places of the room and smiles*" (see T8-Onlooker). Although this study did not look at the correlation between the transitions of types of play displayed by the children, it was observed that being Unoccupied enabled the children to have time to adjust their arousal level and to self-regulate (Case-Smith et al., 2015), and to manage their sensory inputs (Suarez, 2012). As seen in the results of theme 8 throughout the sessions children were more in control because they didn't feel any pressure "*they could do it in their own time. It might have been important to Anna who needed the most time of them to approach Olly"*. Hence, U play might have been empowering for few children, (such as Steve and Anna). The positive impact on children's social play was highlighted also in the questionnaire by the dance teacher (see T8-Cooperative). The class teacher instead highlighted how studies such as this could contribute "*to encourage students developing their active learning and playing and exploring skills in a safe environment"* (section 6.7) and therefore it's an important contribution toward reducing the gap between educational approaches to free play (Wood, 2007) and academic research on autism, play and technology (Brulé et al., 2019). Children's free exploration was enabled by reducing the adult's prompts. As reported by Theo and Selina's TA the "*children were more able to reacted [sic] spontaneously to Olly and Mazi, and they have more chance to interact with another students then looking for an adult hand*" (T8). Even Tula's TA said that she "*used less prompt as she was regulated throughout the sessions"* (T6) suggesting that allowing children to be independent and free not just empowered them but also enabled them to self-regulate.

6.8.3 Children's Self-Regulation

Because anxiety levels are usually higher in social contexts (Rodgers et al., 2016), it was important to offer the children the opportunities to regulate their arousal states, and it's believed that alongside the freedom left to the children, and the natural soft and malleable materials, the music helped in this regard, and positively influenced children's emotional regulation. Overall, children's emotions were very positive, and many children vocalised often, which was something that was not observed during the formative phase observations. For instance, as reported in T3 by Anna's TA due to the auditory output "*She smiled, she laughed and she had more vocalizations"* suggesting that perhaps the sounds provided emotional regulation opportunities and facilitated children's self-expression beyond common school activities. The class teacher explained that "*the experience was very positive, well-pitched and age appropriate"* and added that *"All in all, it seemed that both prototypes suited their different needs in many ways"*(see section 6.7). The TA supporting Tula, believed that the children were regulated because "*they were independent*" (T6). The slower and relaxed pace at which the session was set was also reported to be good as it enabled children to "*to find a peaceful place"* (see theme 6 dance teacher's comments).

The TA supporting Anna and Steve suggested that children's regulation might have been influenced also by the size of the room (T6). The dance teacher said that "*Children self-regulated by moving to the perimeter of the area when Olly and Mazi were crowded".* It's Important to remember that in day 2, when children started the sessions quite dysregulated due to the weather, which meant they could not go out to play during the day, they ended the session regulated and happy. Anna was *Calmer when approaching Olly – Smiling*" and Elodie was *"very happy when near Olly".* Again, the dance teacher noted that "*The children were very chilled and relaxed after each session and we had no issues with (Behaviour/transition)*" (T6).

Therefore, the researcher believes that children's regulation was scaffolded by a combination of factors that are difficult to isolate but that all suggest that the semi-structured and open-ended sessions, together with the affordances of the materials used and the music, worked well for this group of children and allowed them to be independent and supported intrinsic motivation and self-determination (Spiel and Gerling, 2020).

6.8.4 Sonic Interaction: Music vs Silence

All children approached the TUIs predominantly when the sound was on (T2). This, alongside the comments of the TAs and teachers, suggests that the music had a *honey-pot* effect and it indicates that the sound positively impacted people's experiences (Hornecker et al., 2007). Overall children played music with Olly and Mazi for about the same amount of time. However, children played music together more by using Mazi. As already mentioned, the dance teacher believed that this happened because with Mazi it's "*easier to create sound*" (T5). Several months after the study ended, in an unrelated zoom call between the researcher and the dance teacher, the latter told her that Early Years children did not have the skills necessary to play an instrument, and even if some of the children were not interested in making music, the important thing was that they were: "*with us, in the moment, present, motivated and spontaneous*". She added that Year 5 or 6 might have been more able to play music together.

Perhaps, the technologies offered a sound interaction that was too complex for this age group, and it could be that not all children understood how to play music with Olly. However, for example, the class teacher believed that "*the sound caught their attention and therefore had an impact on their overall experience*" (T3). Nonetheless, it was reported that most children understood the cause-effect interaction i.e. "*Ray pulled the toy to make nose"* (T3), Steve "*pull [sic] the elastic many times when the music started"* (T3) Theo "*press [sic] the bubbles knowing they will give sounds*" (T3), and Tula "*paid attention to her movements and repeated it a few times to get the same effect"* (T3). As suggested by one of the TAs (T3), the short duration of the study might have impacted children's full understanding of the mechanics of the sound interaction. Elodie's TA commented that, without music, the children would have found the activity boring (T3), suggesting, perhaps, that music contributed also to the children's emotional regulation (Zacario and Whitebread, 2015). Therefore, it's believed by the researcher that for those children who like music, this medium could be a positive stimulus for grabbing children's attention, encouraging participation and potentially scaffolding emotional regulation.

6.8.5 What was learned from the designs

Considering some of the positive results discussed above, the designs were found to be enticing to the children and facilitated opportunities for social play and self-regulation. The sonic interaction offered by Olly was much more reliable than in study 2 as the TUI never broke and the sensors responded always as expected. Therefore, when designing large scale e-textile sonic TUI it's suggested that softcore wires are better suited to stand prolonged and rough usage than conductive threads, and designers should find a way to combine hard and soft components without compromising affordances. This highlights one of the challenges of working entirely with soft e-textile materials to create soft playful TUIs. Considering what was reported in T5 by the dance teacher, Olly might have facilitated a more varied sensory experience than Mazi "*the material that covers Olly is very tactile and sensory. The shape is inviting for pupils to sit on, lay on, stand on. Embracing and cuddling Olly is easy (shape). The size is appealing to young children as they can see over the top – a view of all of the shape. The ribbons are bright and colourful and soft to the touch*". However, she added that "*Mazi was more popular due to design the pupil can receive a response quicker with their Body [sic] ex. Sit on, lay on, stand"* (T5).

Perhaps Olly, being bigger in size, required a more overt interaction to i.e. lay or sit on it as the children were small, therefore they laid more on Mazi because it afforded this action better than Olly, hence providing them with an immediate somatic feedback. As the dance teacher reported that Mazi was "*easier to play*" perhaps a simpler sonic interaction might be best to elicit social musicking behaviours between younger autistic children (aged 5 or younger). However, as it can be read from the above comments, it seems that the size of Olly was just about the right for these group of children as it enabled them to have a clear overview of the whole TUI and the other peers.

The designs however presented some challenges such as those related to the speaker. For example, on day 1 the speakers of both TUIs were easily accessible, and few children tried to take them off their protective felted pouches (Elodie). In the first session, Theo also turned Mazi speaker on by mistake, and consequently, Olly's speaker was also turned on by the researcher, even though the music should have been off for few more minutes. Anna fiddled with the snaps buttons that enclosed Olly's circuit box and Olly's speaker. The TA working with Ray also observed an issue with the on/off button of the speaker *"It was discovered by the kids and it was a distraction for them as they were really motivated to see what was under the Olly"* (see T5). As noted by the dance teacher, the hand felted wool that Mazi was made of, was easily pulled off by few children (Ray and Elodie), (see theme 5) and the stitches of conductive threads on the top bubble were also broken by one child (Elodie).

6.8.6 What was learned from the methodology used

The more free-handed approach used during the testing sessions of this study, that is, having asked the TAs to don't intervene, have enabled an understanding of the level of spontaneous and independent activities and indicated the children intrinsic motivations in playing with the TUIs. The free-flowing nature of the session enabled the children to be in control. However, this group of children all came from the same classroom, while in the other two studies just few children came from the same class. Therefore, the fact that they knew each other might have meant that they felt more comfortable playing with each other and this could have affected their interactions. However, even if children are in the same classroom often this doesn't mean that they play together. For example, in study 2 Isaac and Ben, who were the youngers of the group, didn't know each other even though they played in the same playground, but they still displayed more spontaneous and social interactions than Alice and Leroy who came from the same classroom.

The researcher therefore believes that some younger autistic children might be more inclined to participate spontaneously in a socially engaged play activity than older groups (aged between 7-10) perhaps because they are more disinhibited than their older peers. Asking the TAs and the dance teacher to leave comments in each of the 7 themes they observed in this study was a great addition to understanding how to best use the evaluation framework. The researcher, when reporting the results this time found it much easier/faster to write them as she didn't have to go through all of the comments left by the TAs and dance teacher to see what phrase referred to what theme, and then if they contradicted or confirmed the observations she made. Working with one classroom was also easier for the researcher because it enabled her to talk just with one class teacher, and all the TAs were always present all at once. For example, explaining them as a class how to give the feedback and then having the attention of the teacher too helped encouraging them to complete the observations sheets well and after each session. This resulted in having a more accurate feedback and a richer analysis.

The approach and the methodology used generally worked well for this group of children, however the analysis is still too long, and it takes too much time. The framework for analysis should be reduced or the analysis should be conducted just qualitatively and manly using the teachers' feedback as this might help to bring the children more alive. Working with one class could also be a disadvantage as the researcher found that she gathered less information on each child due to the fact that the children were discussed more as a class rather than individually by each separate TA. Also, her observations during that phase were harder because she had to take notes about each child. Furthermore, the researcher had a limited time to interview the TAs and observe the children before the testing phase began, because the ethics, which had to be resubmitted for this study, took longer than expected to be approved and the researcher did not want to move the date set for the first testing session. Analysing the video recordings of the whole sessions with bigger numbers of children could pose other challenges. The curtains, which were part of the dance studio, seem to have been problematically distracting for some children. For example, Ray's TA in theme 5 "*there were too much distractions around, the curtains were out kids had the freedom to climb up the curtain. Or even playing behind it [..]*". The short length of the study was also a big limitation as it seems that, if children had more time, they could have mastered the use of Olly and their understating of the cause-effect interaction, and perhaps, engaged even more socially.

6.9 Conclusions

This study demonstrated how children responded to two TUIs the design of which were inspired for two different groups of children. The selected children liked music, soft and malleable textures, and deep-pressure, which were stimuli offered by both TUIs, and this enabled them to enjoy the two designs. Generally, most children played more with Olly than with Mazi. Furthermore, apart from two children, Olly was also the TUI that children used the most unexpectedly. When using the TUIs in unexpected ways children adopted similar interaction styles and approaches, meaning that the TUIs offered similar affordances. Interestingly, however, children used Mazi more when playing music together than Olly. This could be due to the fact that although Olly and Mazi were based on the same design principles, they offered different interaction styles, and perhaps, Mazi offered an easier or more straight forward interaction that provided the children with an immediate feedback. Furthermore, it was found that the TUIs enabled children's regulation by offering sensory stimulations that children normally sought and liked. Furthermore, it was reported that the music made the experience more fun and this was reflected in the children's responses and in the teacher's observations and questionnaires. It should be noted that practical and technical limitations, including the spread of COVID-19, the small-scale study, and issues with the designs, might have limited the outcomes of the findings, which cannot be representative of the general population. Nonetheless, it's believed that this study makes an important contribution through the thorough analysis and discussion provided that can feed into theoretical and analytical development of future research for social play, technology and autism.

7 Final discussion

This final chapter offers a comparison between the 3 studies presented in chapters 4, 5, and 6 and aims to address the four main research questions (mRQs) posed at the beginning of this research, which were:

mRQ1. How do groups of minimal to non-verbal autistic children respond to playful sonic e-textile TUIs?

mRQ2. Can we design and evaluate playful sonic e-textile TUIs to provide sensory regulation and to encourage social interaction in nonverbal autistic children?

mRQ3. Which design features of the playful sonic e-textile TUIs presented in this PhD are supportive of social play and sensory regulation?

mRQ4. What are the challenges and opportunities created by playful sonic e-textile TUI designs when working with autistic children that have a high level of support needs?

What follows is a reflexive discussion on a) the children's responses to the TUIs throughout the three studies, which addresses the main research question 1 (mRQ1), b) the design features that have been found to be the most supportive of social play and sensory regulation in this groups of children, which helps understanding better the mRQ3, c) the challenges and opportunities created by Mazi and Olly in regards to social play and self-regulation, which focus on providing answers to mRQ4, and finally it offers a reflection on the designs, methodology and approaches used, to address mRQ2. Within the field of CCI this information could inform the theory and development of other researches carried out within scholastic contexts around play, autism, and the role of technology such as playful e-textile sonic TUIs.

7.1 Children's responses to TUIs

By reflecting on the children's reactions to the TUIs throughout the three studies, the researcher aims to address the first of the main research questions; *How do groups of minimally to non-verbal autistic children respond playful TUIs*? (mRQ1). The three groups of children that participated in the three studies developed between 2018 and 2020, for this PhD responded positively to the TUIs and the sessions in general. This was exhibited through the children's facial expressions and emotional reactions, and it was reported by the teachers. For example, it was noted throughout the studies that children were happy (e.g. study 3 theme 6-Share emotions), switched on (e.g. study 1, theme 6, Alice and Tom), and engaged (e.g. Pete in study 1, Theme 5-Unexpected uses and T6-Share emotions; and Alice study 2 theme 3-Play to active sounds). In Study 1 under theme 6, it was observed by the dance teacher that one Joshua formed a relationship with Mazi (pg. 130). In study 3 under theme 1-Introduction to the TUI, Theo's TA reported that '*He was really excited to play with the toy*" but he "*didn't need my full support",* while under theme 2 Approaches she said that Theo was *"motivated [..] run towards Mazi and Olly with happiness"* (pg. 209). In study 3 (section 6.9 Findings) it was reported by the TA that "*Ray is asking for Olly Mazzi [sic] everyday. And he makes me write it on a piece of paper so that he can carry it with him*". Engaging in play seems to have also increased the verbal expression of some children, particularly in Study 3 (theme 3-Touch to activate sounds, pg. 211, 212, Anna and Steve) indicating that the TUIs afforded self-expression.

Throughout the studies, children approached the TUIs independently. For example, in Study 2, it was noticed that one of the younger children (Isaac) was the one that approached the most independently (theme 2, pg. 162) and exhibited the most collaborative play with Ben (theme 8-Play types, pg. 174). Considering these findings and those of Study 3, were younger children displayed more spontaneous social play dynamics than the others two groups, these results seem to suggest that younger autistic children (around 5 years old) might be more inclined to play independently and spontaneously than older ones (aged between 7-10). Research in this area is lacking, therefore further investigation would be required to confirm these findings as it could be that the activity was best pitched to younger children. Nonetheless, it is interesting to notice the contrasts with these results and those reported in the literature (Piaget, 1962) where older children's play is seen as more cooperative/competitive and independent. These studies seem to indicate that in groups of autistic children this same pattern might not apply.

However, it is suggested that chasing for example, is a form of play that autistic children are comfortable with, alongside rough and tumble, and Jordan (2003) found that those children that have been observed to display this type of play with others exhibit social skills that are not seen in different contexts. Therefore, because Isaac and Ben in study 2 liked chasing each other a lot (more even than the children in study 3), they might have exhibited more complex social play dynamic than the other children in their group for this reason.

Defining play is a controversial matter because researchers often prioritise "*extrinsic goals*" such as therapeutic or educational "*over the freedom and fun of play*" (Spiel and Gerling, 2020). In this research, play was considered an intrinsically engaging activity that has no other aims than that of being spontaneous, fun, and pleasant (Gadamer, 2004). Play shapes and influences many aspects of human development and since social interactions are experienced atypically by most autistic children (APA, 2013), it is believed that it is our responsibility as researchers to develop design strategies and methodologies which consider, embrace, and nourish a play environment for all. Therefore, it is believed that expanding the discourse around both free play and shareable interfaces, especially when working with more marginalised groups of children, such as minimally to non-verbal autistic children, could contribute to bridging the gap between educational and academic approaches to play.

By contributing to the development of positive social playful experiences during childhood, this work aims to contribute to enabling more children to become successful adults. As such, when designing socially engaging technologies for and with autistic children there is a need to expand the design space to be more inclusive and accessible. This is achieved by addressing and responding to the diverse needs of a broad spectrum of needs and preferences and through lowering the barrier of access to increasing participation. It can be therefore argued that when focussing on these values non-verbal autistic children have shown to respond well to playful e-textile sonic TUI design that reflected their preferences.

7.2 Design features supportive of social play and regulation

In order to address the research question 3 (*Which design features of the playful sonic e-textile TUIs presented in this PhD are supportive of social play and sensory regulation*?), the researcher reflected on the feedback that she received throughout the studies and on the observations that she made. For example, it was reported by the teachers that one of the things that seems to have scaffolded children's enjoyment, curiosity, toy engagement, and emotional regulation was an intangible thing, music. In study 1 the dance teacher stated that children displayed lovely 3-way interactions when playing music with Mazi such as reported in theme 4 "*there's* *[sic] lovely 2-3 ways interactions happening [sic] and children are enjoying it*". In study 2, the dance teacher said that Alice "*become unhappy"* when in day 4 she realised that there was no sound (T3), and in study 3 all children approached the TUI predominantly when the sound was on.

It was reported that the "*sounds stimulate(d) Theo curiosity*" (study 3 T3), and that Elodie "*enjoyed and loved it, specially with the sound on"* (study 3 T1). In study 3 (T3), the class teacher said, "*the sound caught their attention and therefore had an impact on their overall experience*" (T3). The new sound FX samples used in study 1 for the last two days, showed that also those gained Joshua's attention (T3 study 1). In study 2 it was reported that *"the vibrations from the music calmed*" Pete down (T6) and Alice became unhappy when she understood that Olly was broken and didn't play music, indicating that the music might have provided some sort of regulatory stimuli to some of the children. In study 1 Joshua went through the whole last testing session without holding the ribbon which the researcher was told he used to fiddle with as a regulatory strategy (see study 2 theme 6). Therefore, as suggested by Allen and Heaton the music might have been used by some children as a mood management strategy (Allen and Heaton, 2010).

Furthermore, in the third study children played more socially (i.e. parallel, associative and competitive play) when the music was on (see theme 8), indicating that it also encouraged social play activities. In study 3 the dance teacher said that the children preferred Mazi because "*it was easier to create sound*", while Olly was "*very tactile and sensory*" (T5). In study 2 (theme 4) however, she said that with Olly children could "*create music"* while with Mazi it was "*more cause and effect".* Therefore, with older children a more complex sound interaction could favour more creative outputs. All the children in the studies were non-expert musicians and this might have prevented some of them, particularly some of the younger group, to find their confidence to believe that they could be able to produce creative outcomes (Wu and Bryan-Kinns, 2019).

However, all children triggered the music by using the TUIs, some sang along (Pete study 2, Ray study 3 T6), others listened (Joshua study 1 in T3 and T6; Tom study 1 in T7; Ben and Isaac study 3 in T3) and the TUIs enabled musicking opportunities to flourish. Coined by Small (2011) the term musicking denotes any activity related to music such as listening and dancing. Olly and Mazi make an important contribution to the development of an approach for Musicking Tangibles for empowerment (Cappelen and Andersson, 2012) to be extended within the HCI and CCI communities, through providing a rich observational analysis and a detailed methodological approach. The results of the final study, suggest that the sounds evoked curiosity in the children and had a *honey pot* effect that positively impacted their experiences (Hornecker et al., 2007).

However, the dance teacher stated that Olly's physical affordances enabled more social play than Mazi (study 2 T2-Approach the TUI) perhaps due to its slightly bigger size, and the types of sensors used, which might have scaffolded more opportunities for social play dynamics. For example, in theme 5 (study 2) she stated that with Olly children "*could lay on the technology while the other could still play. While Mazi if you were laid on it, it was a bit difficult to play"* (T5-Unexpected uses). Ben's TA also observed that *"pulling was good for him [..]because he could go back a bit"* (study 2 T5). This could indicate that this type of sensors offered the children the opportunity to pull away from the main body of the toy, leaving more space for the others to keep using it for other purposes i.e. laying on it, pressing its top, balancing on and so on and enabling increased *fluidity of sharing* (Hornecker et al., 2007). In study 3 Tula's TA reported that the "*the round shape was inviting. The size was their size, they could reach it, it could hold them (especially Olly)"* (study 3 T5). Therefore, the size of the TUIs, the multi-user inputs, and the properties of the materials used all contributed to a positive play experience. Engaging in play seems also to have increased the verbal expression of some children, particularly in Study 3 (T3-Touch to activate sounds, pg. 210, Steve and Anna).

Social interactions might have also been facilitated by the circular configurations offered by the O-shaped interfaces (Kendon, 1990) and their shareable attributes (Hornecker et al., 2007). Some children, when given the chance, exhibited spontaneous genuine play marked by a sense of belonging. For example, in study 3 the dance teacher said that Olly and Mazi were "*A place to gather – an object of reference [..] Social interaction has definitely been facilitated as Mazi and Olly are motivating objects and the children gather and share space together which helps them communicate with each other (positive or negative)"* (theme 8 – Cooperative). In study 2 Isaac TA said that *"[Olly] was good because it was round. So, there were no edges, and there was access to everyone"* (T2) and added that Olly *"was soft, so it's really* *welcoming*". In study 3 (T5) Elodie's TA said that the *"material was good because it was soft and fluffy for them to kick push pull jump*". This affinity towards soft materials might be reinforced by the functional aspects of soft haptic feedback as this seems to also reduce feelings of uncertainty in neurotypical individuals (Van Horen and Mussweiler, 2014). Tula's TA also said that "*the material was soft, they probably liked it because they (Tula, Ray, Selina, Theo, Steve) laid on it. Most of them tried the ribbons, they liked the elasticity of this, especially Ray and Tula, she might also liked the colour of the ribbons*" (study T5).

Therefore, the different properties of each material, and their affordances including the colour, the felt, the types of sensors used, the soft somatic feedback, their sizes and the shapes, have encouraged social interactions that were supportive of child-led play and sensory regulation. This gives some evidence to answer mRQ3.

7.3 TUIs: Opportunities vs Challenges

The reflection below provides arguments for and against the playful e-textile sonic TUIs developed in this PhD and helps answering mRQ2 and mRQ4; *Can we design and evaluate playful sonic e-textile TUIs to provide sensory regulation and to encourage social interaction in nonverbal autistic children?; And* w*hat are the challenges and opportunities created by playful sonic e-textile TUI designs when working with autistic children that have a high level of support needs?*

One of the main opportunities generally offered by TUIs is their inherent physical and manipulative qualities that enable concrete, accessible and intuitive interactions. TUIs tackle some of the main challenges experienced by most autistic children such as sensory processing and abstraction of thoughts (APA, 2013). The designs of Mazi and Olly were evocative of social interactions as the teacher considered them to be "*A place to gather – an object of reference"* (study 3 theme 8, Cooperative). This could have been due to the large-scale, multi-user, shareable designs, which aimed at offering the best environment for the children to engage together with the TUIs, but also to the somatic stimuli that children received using their full bodies when interacting with such big TUIs. For example, Joshua's teacher noted that "*he requested deep pressure from Mazi and lifted Mazi onto his legs, as though to attain deep pressure and to create a blanket/ a form of comfort"* (study 1 theme 5), and Elodie TA's reported that she liked "*leaning over [Mazi] for deep pressure*" (study 3 theme 5). Children received deep pressure by interacting with the

TUIs in many ways. For example, in study 3, under theme 5, for Olly it was reported that Anna "*lay on the ground under the base— deep pressure*" and "*loves playing with the small silver buttons and make deep pressure, climbing, even hiding her feet under the fabric*" (study 3 theme 5); Elodie instead liked "*leaning over for deep pressure*" (study 3 theme 5). In study 2 (T5) on the other hand, it was reported that "*Isaac [..] he stepped into it. Put it around his waist [..] That was a lovely thing to see him getting some kind of regulation around his abdomen".*

Despite the fact that most of the children that participated in this research were non-verbal and generally received high level of support, they showed immediate and deferred imitation skills by looking at each other (T7-Share attention study 2, 2, 2; T8-Onlooker, study 2 and 3) and in the similar ways they used the TUIs (T5-Unexpected uses study 1, 2, 3) (Toth et al., 2006). Jordan (2003) suggested that lack of imitation is central "*to play and other deficits in autism*", therefore it was nice to see these skills being displayed when using the TUIs. The researcher believes that this multitude of features have created opportunities for positive and intrinsic play experiences and this sensory richness enabled object's appropriation and freedom of expression (Hornecker, 2012).

Some limitations have also emerged that highlighted the challenges of designing TUIs for autistic children. For example, as already mentioned in chapter 3.3 (positionality) and in the final discussion of study 2 (What was learned from the design), the researcher was the designer, maker and programmer of both Mazi and Olly. Coming up with these two fairly big design solutions was a time consuming and resource intense process and it required the researcher to think thoroughly about what she observed from the children and experiment with different materials to make the two artefacts. Combining electronic textiles with off-the-shelves equipment took time, while buying and experimenting with the new materials was a costly process which ate into the budget that the researcher had at her availability (£1000 for 3 years). That is also why, for example, she used an inflated therapy ball to make the main body of Olly instead of another soft-play dome as the one she used for the main body of Mazi (or even bigger than that). The researcher thought that not just the inflatable ball would have been cheaper than the soft-play dome used for Mazi but that, by deflating the ball, Olly could also have been moved and/or shipped from place to place more easily and comfortably than Mazi, which required two people to be transported. However, this solution created other challenges as it compromised the stability of the TUI i.e. the body was too wobbly. Nonetheless, children liked the wobbliness of the body and they enjoyed rocking on it by laying with their belly on its top, or by sitting on it, or by standing and balancing on it. Furthermore, in Study 2, the weights that were used by the researcher around the base to provide stability to the inflated ball, especially when the sensors were pulled, were not fixed at the base. Even when she addressed this issue in Study 3, by sewing some cotton pouches on the base where the weights could be placed, they did not provide enough stability to the ball. Luckily the children in study 3 were smaller than the others and didn't have enough strength to move Olly's body when they pulled the ribbons. Making two novel playful e-textile sonic tangibles that are large-scale can be not just time consuming but also rewarding. The researcher believes that designing the TUIs was an enriching process which emphasised the importance of going through an explorative phase in order to achieve the best possible outcome given the circumstances. Within the HCI community however as designers we tend to focus more on the final outcome rather than on how we get there i.e. the process.

Another design issue with Olly, especially in study 2 was that of having used long conductive threads to connect the sensors to the circuit and that's why in study 3 she remade the circuits and connections from scratch using hard components such as softcore wires. Although the wires integrated well within Olly's design she found challenging having to build two large scale technologies using entirely soft electronic components. Another similar challenge was presented by the circuit board, which was enclosed inside a little wooden box itself sandwiched between two weights. When stepping on it, the children could feel and while this didn't bother the children in study 2, for example, those in study 3 were found to be more curious about it. A similar point could be said about the speakers. The researcher thought that if the sound came directly from the source the children would have better understood the cause-effect interaction. However, she found it difficult to integrate it with the soft components of the TUIs. Thus, when designing large scale artefacts that are meant to be played with by more children, understanding how to design the technology and how to integrate hard and soft components in a coherent manner is crucial for building effective TUIs. The results however, show that the speaker on the body was beneficial in other ways i.e. it aided also self-regulation for Pete in study 2. In study 3, instead children were reported to have been distracted by it i.e. the on/off light on top of the speaker (Ray's TA, T5). Designers should consider that when working with younger children, these might tend to be more explorative than older ones.

The making of Mazi also presented some challenges. The researcher never hand-felted anything before so when making this TUI she was also doing it for the first time. She used two different felting techniques such as wet-felting and needle felting and at QMUL she didn't find a suitable shower room where she could have wet felted Mazi's body. Therefore, she did so at her place, in her bathroom's bathtub and garden. Felting takes lots of time, and although it was a delightful part of the design process, which the researcher fully embraced as a necessary part of the creative process, it was messy and took a long time. Because Mazi is quite big, the wool took a long time to dry, especially because the weather was not sunny in that period. Furthermore, she wet felted the bubbles (separately from the main body) by wrapping them around a few pairs of red tights that she found at a charity shop not thinking that they would have come out pink as the red dye was absorbed by the wool.

Thinking to save time (and money) for Olly she used industrial sheets of felt that she cut-to-measure to cover Olly's therapy ball. The thickness of the industrial felt sheet that she chose however, didn't allow her to speed up the process as much as she would have liked because issues with sewing such thick fabric replaced those encountered by the time-consuming process of felting the wool. Therefore, one of the challenges of making novel large scale TUIs was that of planning ahead how to manage time and resources accordingly.

Also storing them at the school was a problem in the first two studies that the researcher did not envision beforehand. Researchers wanting to build large scale TUIs should also consider the storing solution for when the TUIs are not used. The researcher stored them at QMUL for the first two studies, but this was unpractical and might have also compromised the stability of the interaction design.

Despite these limitations, the researcher learned that the materials chosen, and the type of sensors used for Mazi and Olly, have their own affordances and they all encouraged different types of interactions. This was possible thanks to their physical attributes and the "*multitude of incidental properties*" they afforded (Hornecker, 2012). By exploiting the intrinsic potentials of TUIs to offer concrete, direct and intuitive interactions, combined with the various sensory stimuli offered by the TUIs, which are more akin to human-human interaction, researchers could enable not just children's agency within the design processes beyond current PD approaches, and during a socially engaged play activity - mediated by a piece of technology, but they could also have a better understanding of the people they design for and with. The researcher suggests that these accounts can be used to inform the design principles and approaches of future development of playful e-textile sonic TUIs aimed at scaffolding social play while providing opportunities for self-regulation for non-verbal autistic children. This is achieved by tuning in to the needs of the children we design with and for.

7.4 Reflection

7.4.1 Methodology

The research, as it stands, demonstrates an in-depth mix of qualitative and quantitative data. The framework for observation developed by the researcher offered a useful lens through which examine the verbal and non-verbal interactions of the children, and contributed to addressing further mRQ2; *How can we design and evaluate playful TUIs for nonverbal autistic children within a scholastic context?* However, the data collection method used for the evaluation of Olly and Mazi evolved and expanded throughout the studies. The pre-studies observations fed into the designs of Mazi and Olly and facilitated children's self-expressions, participation and agency also during the design process.

In study 1, after the testing phase, the researcher didn't conduct any interviews, and this presented some issues. Some of the TAs did not complete the observation sheets when and how they were asked to, that is, they did not leave any comments related to the themes that they were asked to observe, but instead used mainly the 5-points rating scale they already used at the Garden. However, the ratings obtained throughout the studies from the 5-points scale, proved to be highly inefficient because it lacked explanations as to why a child was rated in a certain way. In the second study therefore, before the testing sessions began, the researcher explicitly asked the TAs to leave written notes in their observation's sheets. Yet, in study 2 the dance teacher and TAs were still asked to leave some generic notes rather than to leave a comment under each theme. Therefore, by the time that the last study started the researcher decided to ask them to leave a comment under each of the themes and this facilitated the analysis process. The researcher found that in the previous two studies the process of reporting the results was time-consuming due to the fact that she had to use her own interpretation of the notes to contextualise them within the themes. Note, that the researcher didn't just report the positive comments that the TAs and teacher left, instead she used most of them to a) bring the children alive, and, as already mentioned, b) to either confirm or contradict the more quantitative data that she collected from her video analysis.

The researcher wanted to have a holistic picture of the children's experiences and the framework for analysis offered her a broad view of how they reacted to the TUIs and to each other during the sessions. This however meant that she had to deal with lots of data, which not just was overwhelming, but it was also difficult to manage on her own. Unfortunately, other frameworks for observations within the HCI and CCI are specific to certain domains such as tangibles for learning (Marshall, 2007; Antle et al. 2007; Price, 2013), musical abilities (Kaur, Alias, and Mohamador, 2019), or VR (McVeigh-Schultz, Kolesnichenko, and Isbister, 2019), and they are used to inform the design of TUIs rather than to evaluate the experience of the children (Antle et al. 2013) or to support participatory design processes (i.e. IDEAS used in Benton et al. 2014). Other methods such as usability testing and user experience testing are either too focussed on system optimization or on generic UX aspects (Pettersson eta al., 2018). These are also often focussed on different types of interfaces such as screen-based ones i.e. mobiles, websites, games, software etc. (Ibid). This meant that the researcher had to develop her own framework for observation to evaluate the children's experiences in relation to their play and their self-regulation. This, which was inspired by the SCERTS Model, offers clear observational criteria that other researchers can use to identify and analyse children's non-verbal interactions (as well as their verbalizations) and it enables to gain a holistic overview of the children's experiences when using a TUIs for play.

However, the researcher thinks that the criteria for observations, or themes, used by her analysed in the video recordings could be reduced to further optimise the process. Although she has managed to address all the observed categories in the time-frame she set for herself, the framework as it stands contains many themes and sub-themes. For instance, the video analysis by the end of study 3 consists of 28 themes for observation (see Appendix G) some of which were found to be redundant. For example, once the researcher added T8-Play types, and its 13 sub-themes (from Unoccupied to Turn-taking, which include the other behaviours displayed by children) to the video analysis, the findings reported in T7-Share attention were redundant with the Onlooker type of play observed within T8.

Themes such as T5-Unexpected uses, T3-Touch to activate sounds, and in T4-Music making together, could be included as part of a more detailed analysis of T8-Play types, to reduce the number of observations. In addition, T6 was found to offer valuable insights on the moods of the children and consequently it's an important observational criterion when evaluating children's experiences that should also be added to T8 for future framework development. The framework's coding scheme is flexible and changeable depending on the children and it can be adapted to a situated analysis. A reduced version of the framework should be piloted for future studies.

The analysis does not provide intercoder reliability for the coding scheme as nobody other than the researcher validated the coding criteria applied to the video analysis. However, the results narrated throughout the studies, with teacher's quotes and observations, have helped to confirm or discredit the findings provided. It is also questionable the relevance and importance of such detailed quantitative analysis in the context of providing rich information of children's emotional responses, actions, self-regulation, and social experiences. The framework could therefore just be used as a useful lens, a guide, to carry out the observations during the testing phase and therefore to qualitatively examine children's non-verbal interactions.

Finally, the technologies were tested with small groups of children and the aim was not to generalise findings on the wider population. The numbers of participating children, which ranged between 5 to 7, replicated that of the number of children in a classroom often found at the Garden school. This was considered to be in line with the school's practices. Moreover, the heterogeneity and differences of the children, the compromises to be found when making one TUI for many children, and the size of the space, would not allow for bigger numbers of children within groups.

To conclude, a baseline assessment was not carried out in the first two studies as the dance teacher thought that children would have become distressed without music and it was difficult to convince her of the opposite. A baseline assessment would have allowed to see how children reacted to the TUIs with the music switched off first, and then to compare their reactions to when the music was on. However, the researcher did not want to cause any distress to the children, so she did not insist for this to happen in the first two studies. Once the dance teacher felt comfortable about trying the TUIs with their power off, for study 3, the researcher could better evaluate whether the sounds impacted the children's responses to the TUIs. Therefore, it's important to work well with the professionals that make studies possible.

7.4.2 Approaches

As reported by the TAs (e.g. in study 3, pg. 223), the free-flowing but semi-structured nature of the sessions enabled the children to be in control i.e. "*the session was free-flowing but still had a start, and end clearly differentiated, it was structured in a way. They were independent but staff was available for their needs. They all needed less prompt and it could have been positive experience for all of them"*. The prompts were reduced from study 2 and avoided in study 3, and the class teacher appreciated that the children were given the opportunity "*to explore an interactive musical toy using their body, in a relaxed and unprompted environment so they could use their initiative to enjoy and relax*" (T2-Approaches, pg. 207). She confirmed that this "*made the experience more child-led*" (T2, pg. 207). Therefore, the structure of the studies seems to have facilitated children's self-expression, agency and self-determination while still enabling them to use regulatory strategies to adjust and fulfil their sensory needs.

It is believed that the environment, and all the people part of the study equally impacted the children's experiences and the final outcome of this research, and it is difficult to analyse their influence in isolation. In Study 2 the researcher faced some challenges with how some TAs behaved which was something that she was not expecting. This resulted in there being too many TAs playing with Olly themselves, or working against the children's spontaneity. The issue was promptly addressed by the researcher, but other might be tempted to simply avoid having adult support and/or speaking up when the support does not match the expectations.

Although their prompts were eliminated by the time that the last study took place, the presence of the TAs was always welcome as they knew the children better than the researcher did. This helped ensuring the children's safety and enjoyment during the testing sessions but also it provided the children with the same level of support they received in their daily scholastic routines. Of course, the presence of the TAs was also crucial for the evaluation of the TUIs as they were able to give their opinion on the children’s experiences from an unbiased point of view.

Inspired by the literature and the children's observations, instead of having multiple smaller TUIs (as in i.e. Cappelen and Andersson, 2012) the researcher decided to design two large (around 70 cm in diameter) semi-spherical musical e-textile playful TUIs. This strategy of making one shareable tangible interface was used to invite children to join in the play together and enabled them to share the space, the object and the whole experiences. The concept of sharing a toy during a free playful activity is also not extensively explored in the field of HCI (Spiel and Gerling, 2020) nor within education (Wood, 2007). Furthermore, autistic children generally are described as if they are not interested in playing with others i.e. as reported by Ben TA’s in study 2 who said that the children have “*got the swing”* but they *“are not really playing with each other. They're kind of just on the swing*” (study 2, pg. 191). Hence, it was interesting to see that the children shared and responded positively to and played spontaneously with the two large-scale playful e-textile sonic TUIs and their peers. Making two large scale multi-users TUIs that children had to share to use, allowed them to gather together; Olly and Mazi were seen as an “*object of reference*” (pg. 234) and it was reported that they facilitated social interactions i.e. when the dance teacher in study 3 (theme 8-Play types, Cooperative, pg. 234) wrote that this enabled them to look at “*each other, laying together, and sitting together, turn-taking”*. Moreover, in place of offering many modalities of interactions (as in e.g. Kossyvaki and Curran, 2020; and Cappelen and Andersson, 2012) she focused on haptic and auditory stimuli. Limiting the output modality and focusing on what she knew the children liked the most, enabled her to account for and perhaps minimize occurrences of over-stimulation.

As Hornecker (2012) pointed out physical artefacts “*inherit a multitude of incidental properties (and affordance)*” from the materials that are used to make them, and this is both an opportunity for TUIs design but also a challenge as it makes it difficult for designers to actually restrict affordances to the ones desired by them. However, the “*potentially endless*” use that novel materials and physical interfaces have offer a rich sensory experience which can allow children to find different ways of appropriating the tangible for new or unexpected uses.In fact the researcher believes that the TUIs multifunctionalities e.g. the open and ambiguous designs (Eco, 1997; Gaver et al., 2003), allowed the children to be creative with their use of the technologies (Scheepmaker et al., 2018) and enabled freedom of expression, participation, and agency. This was achieved by adopting the principle of *Open work* into the design of the TUIs (Eco, 1997) to enable children's interventions, and self-expression and to allow the work to be completed by them. The concept of *Open work* resonates with those of ambiguity and design for pleasure detailed by Gaver (Gaver, 2002; Gaver et al., 2003) and was used as an inspiration for the designs of the TUIs of this PhD. The idea of *Open work* emphasized that of an open design rather than a finished one, which is therefore open to interpretations and appropriations and completed by the people that interact with it.

Therefore, the technologies but also the environment created, need to be open to enable children's appropriation of the artefact and of the space. This is achieved by e.g. giving them opportunities to receive needed sensory stimuli (Laurent & Fede, 2021), and finding ways to interact with the TUIs that are meaningful to them.

To conclude, researchers are suggested to gain a deep understanding of the people they'll work with to make informed design decisions that can be reflective of the children's likes and needs. They are also suggested to look at the experiences of children more *holistically*, in order to gain better understanding of their experiences and of the potentials of such interventions. As self-regulation, and especially emotional regulation, predicts prosocial engagement in autistic children (Jahromi et al., 2013), it was important in this research to develop digital ecologies that provided children with a varied palette of sensory stimuli which they could use to regulate their arousal levels (Laurent and Fede, 2021). Children in these studies employed different sensory-motor strategies such as jumping, spinning, running, climbing, balancing, touching, twisting, pressing and pulling. This perhaps indicates that the TUIs were effective also when the power was turned off. Playful e-textile sonic TUI designs therefore, can become *unfinished* toys (Baudelaire, 1853) that initiate children to a work of art that they can contribute without having the technology "*sacrificing the good qualities inherent to its class of toys*" (Raffle et al., 2004).

Technologies should enable non-verbal autistic children with high support needs to overcome the challenges they experience in unstructured and social environments and not exacerbate them (e.g. as in robotic-assisted interactions, VR and AR environments, and/or screen-based devices).

7.5 Future work

Future work should explore more deeply whether the approach developed throughout the three studies of this PhD can be used in different SEN settings across England and with different groups of autistic children than those attending the Garden school. With these objectives in mind, one could explore whether this approach, trialled with 5-10 years old, can be integrated within other specialised schools' curriculums. The aim would be to make the approach accessible and available to target groups by disseminating the findings through easily accessible resources for schools and academics such as guidelines to design the technologies, frameworks for planning and assessing, and teaching plans to engage older children in the design making process. This development could contribute to bridging the interdisciplinary gap in technological interventions for supporting social play in UK schools and potentially other settings. Furthermore, it has the potential of impacting teaching and academic practices and could contribute to influencing national play policies in England, particularly within the educational system.

As already mentioned, in order to optimise the researcher's time, resources and analysis, the evaluation framework developed for these studies could be improved and reduced. As previously suggested some Themes, such as T3, T4, T5 and T6 could be integrated within a more qualitative analysis guided by Theme 8.

In terms of sonic designs, it could be interesting to modify the characteristic of the sounds when touch is detected like tonality, pitch, or volume to allow for longer and more complex interactions. However, this should depend on the age/support level/likes of the children. Future research could explore different approaches to diverse musical outputs and analyse how these impacts the experience. For example, further explorations on the use of harmonious sounds vs dissonant sounds could shed some light on the beneficial effects of different types of music on social play and emotional regulation. Further testing to what extent, the sound generally impacted children's experiences would also be beneficial. For instance, it became clear that children were affected positively by the music, but it is still unclear whether few of them understood the cause-effect interaction and to what extent. A future study could have a similar style of music playing all the time with no interaction required by the children to see the reactions of the children to the TUIs.

A longer study where the TUIs are tested with and without sound could also be carried out in order to facilitate understanding around open questions, such as to what extent the children interacted with Mazi and Olly to play music rather than to play for the pleasure received by touching/pressing, pulling. Children were regulated and enjoyed the manipulative proprieties of the textiles and music was reported to contribute to their emotional regulation. However, other input modalities and interaction styles could also be explored further to understand i.e. the effect of music, but also to assess if some modality of interactions works best than others in sustaining social interactions and for longer times. It would also be interesting to explore other output modalities altogether, such as vibrations instead of sound, where children like vibrations.

Nonetheless, it could be that engagement is encouraged by a combination of factors that might be difficult to analyse in isolation. More research needs to be conducted on the round shape design as this work tests just this type of design. It should be investigated further whether the semi-spherical large-scale design provides better social opportunities than other shapes and TUIs. It is believed that a flat interface would not deliver a wide range of social opportunities like sharing, proximity, and eye contact as efficiently as a large shareable semi-spherical shaped TUI where everyone needs to gather around to and have same access.

Finally, further tests could look into whether there is a correlation between transitions of less social play types (such as unoccupied, onlooker, solitary) and more social plays (parallel, associative, competitive, cooperative) as in (Francis et al., 2018) to see if there is any connection between the play types. This could help explain their function further. It could be that for autistic children, moving between less social to more socially engaged play is fundamental to their regulation and enjoyment of the experience.

8 Concluding remarks

This thesis has provided an account of the benefits of using playful e-textile sonic tangible interfaces for scaffolding free play and self-regulation in groups of autistic children who like music within specialised educational contexts. It also highlighted design features that throughout the PhD have been found to be key factors for successful TUIs.

Among the key factors that supported social play and self-regulation it was found that a) a circular configuration allowed children to gather together around the TUIs giving them the same access rights, b) the principle of shareability enabled children to access and entry the TUIs with ease and aided collaborative music-making, c) multisensorial (but not overstimulating) and multifunctional aspects enticed children's curiosity and satisfied some of their sensory and emotional needs and d) alongside the principles of open and ambiguous designs they encouraged children's appropriation of the artefact, participation and self-expression.

Moreover, it was reported that the soft and malleable proprieties of the materials used in the design of Mazi and Olly facilitated a novel but comforting and enjoyable experience. The findings demonstrated that children liked the multifunctional proprieties of the TUIs and used them to make music, for deep-pressure and as a weight-bearing activity. The sensory stimulations afforded by Olly and Mazi were similar to those that children sought and/or liked during the data collection period - in the formative phase. This information was then fed into the design processes and reflected in the artefacts created. Additionally, although mixed feedback was received regarding the extent of some children's understanding of the cause-effect interaction, it was reported that the music contributed to the children's positive experiences and might have promoted emotional regulation. Therefore, it is suggested that for children who like music, e-textile sonic TUIs might be a good stimulus for social play and might contribute to a honey-pot effect that attracts children's curiosity and enables toy and social interactions. However, further studies would be required to understand to what extent the auditory output used in the three studies of this PhD impacted children's experiences and responses.

The provided accounts demonstrated how the approach developed throughout the PhD could be used by other researchers and educators interested in exploring the potentials of technology in supporting free, spontaneous, socially engaged play and self-regulation in minimally verbal autistic children. An inclusive digital ecology should embrace children's needs, likes, preferences, dislikes and triggers and this information should be fed into the design in order to ensure children's agency during the design process and the testing phase beyond current participatory design practices. The observational skills and experience of researchers, particularly those wanting to work with neurodivergent children, might influence design and evaluation outcomes. Researchers should develop and promote trusting relationships, and these should be built on mutual respect and esteem and by learning from the children.

Finally, the evaluation framework developed in this thesis could be used and adapted by other researchers interested in autism, play, and tangible technology as it offers a rich assessment with respect to different types of play, spontaneous and independent actions, social interactions, intrinsic motivations, and self-regulation.

By shifting the attention on supporting children's needs and self-regulation, and nurturing children's leisurely experiences through carefully designed open environments, instead of focusing on educative-goals, age-appropriate activities, and neurotypical similarities, researchers could positively affect children's experiences and lives and positively impact society at large.

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Appendix A: Mazi and Olly Wiring Diagrams and Schematics

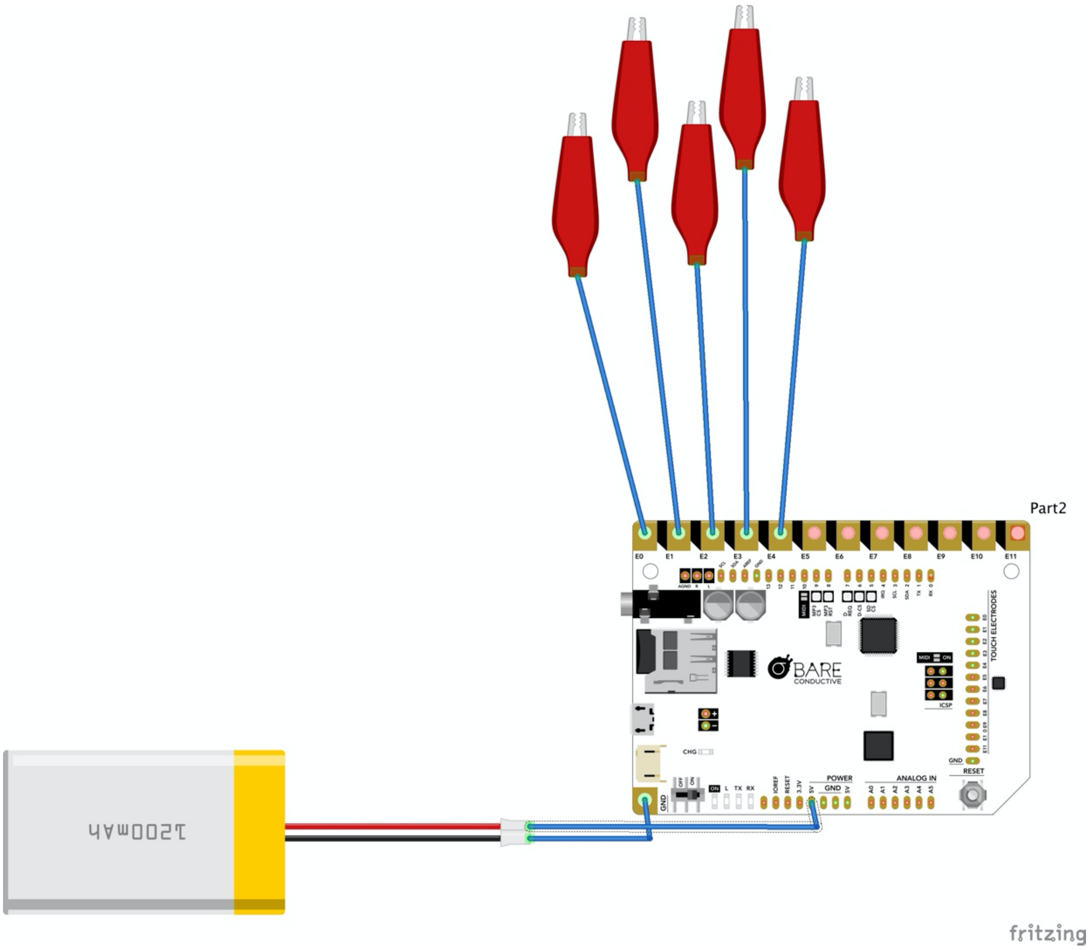


Figure A-0-1 Mazi Wiring Diagram

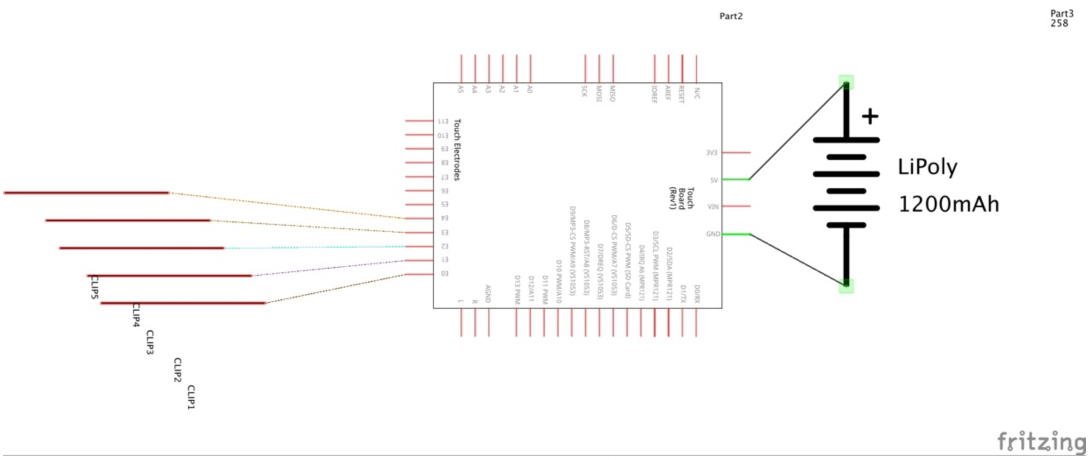


Figure A-0-2 Mazi Schematics

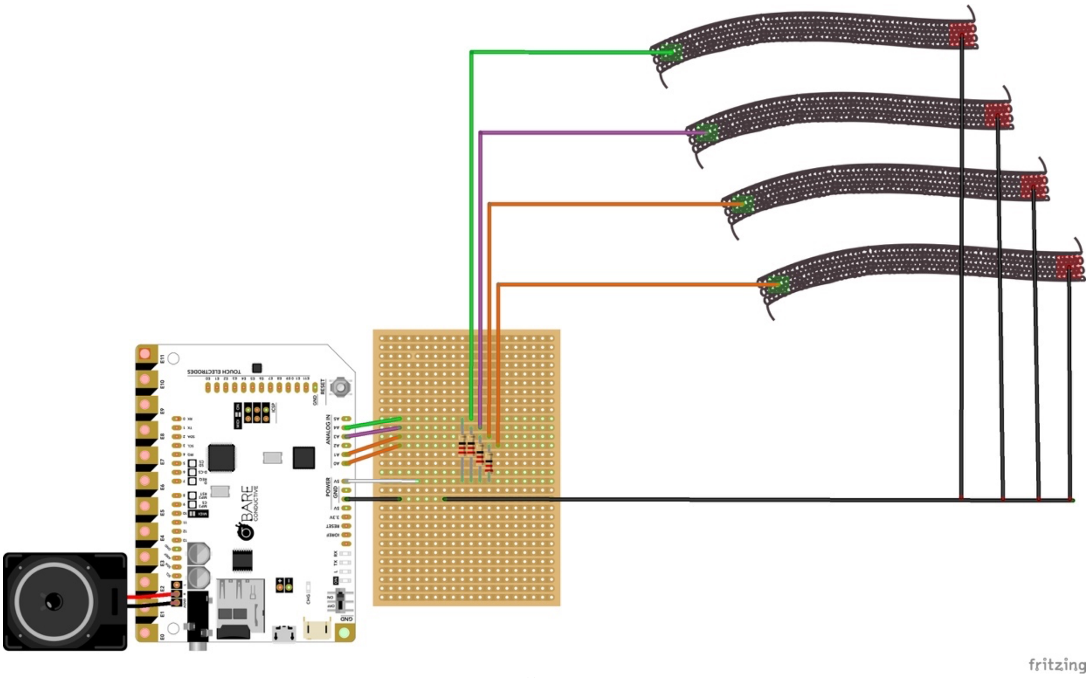


Figure A-0-3 Olly Wiring Diagram

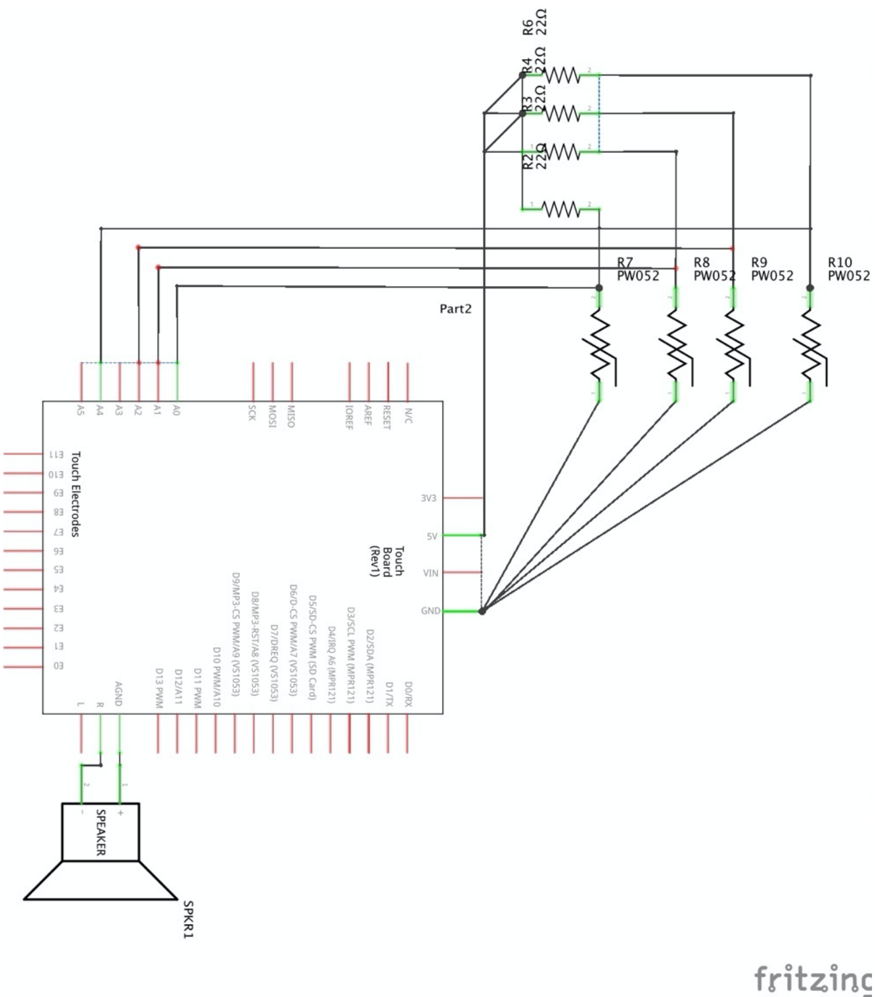


Figure A-0-4 Olly Schematics

Appendix B: Example of the Observation Sheets in Study 1

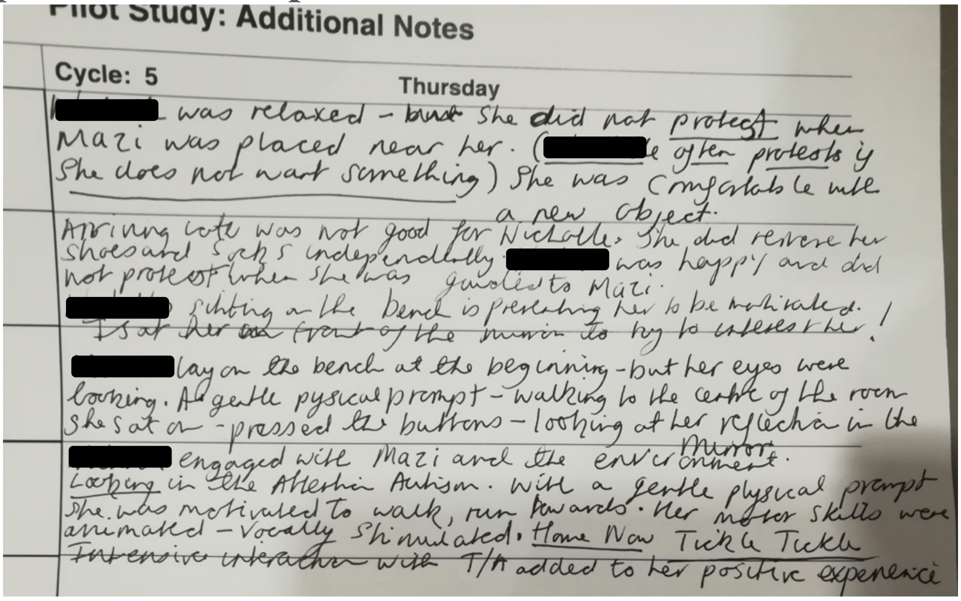


Figure B-0-1 Study 1, Dance Teacher Observation Sheets, Extra Notes, Alice

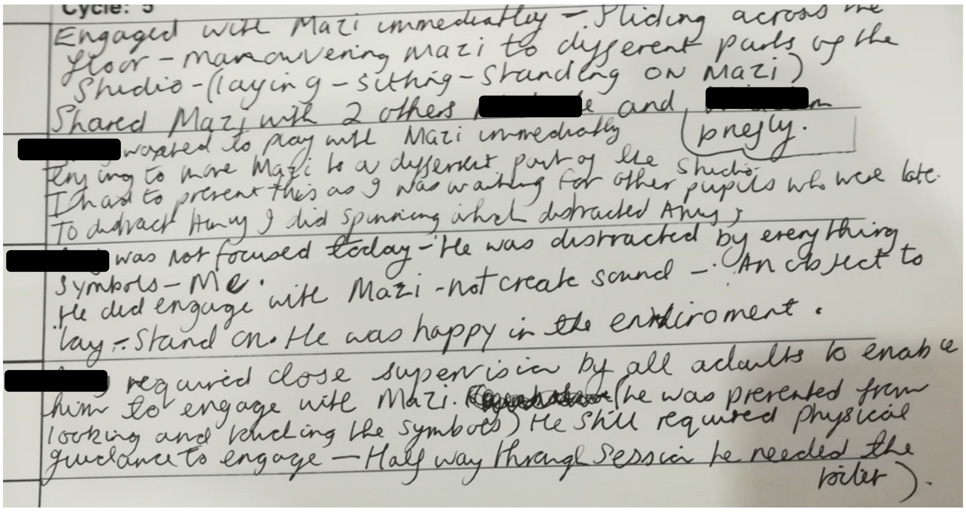


Figure B-0-2 Study 1, Dance Teacher Observation Sheets, Extra Notes, Pete

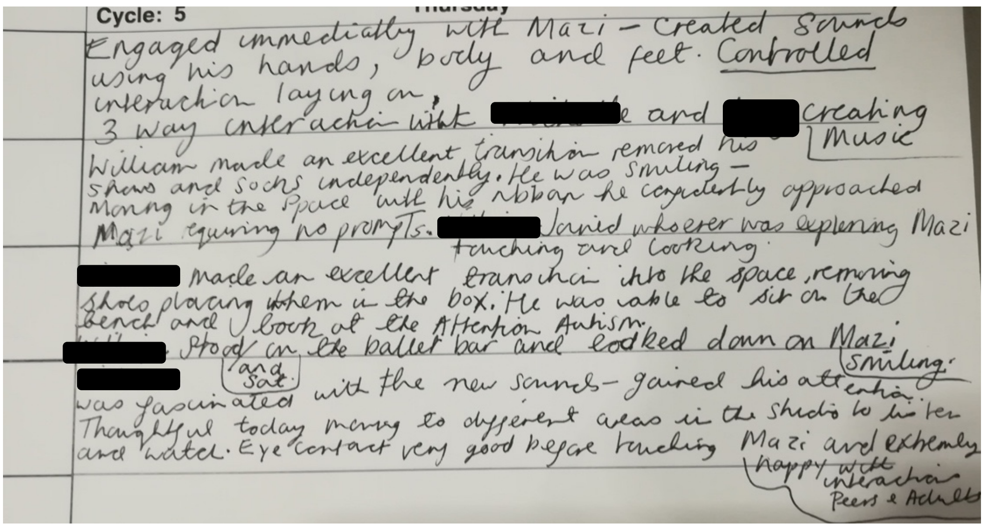


Figure B-0-3 Study 1 Dance Teacher Observation Sheets, Extra Notes, Joshua

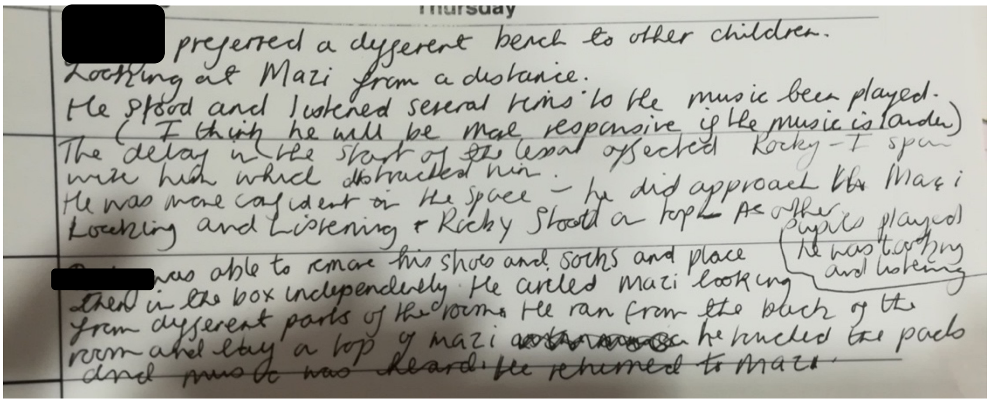


Figure B-0-4 Study 1, Dance Teacher Observation Sheets, Extra Notes, Tom

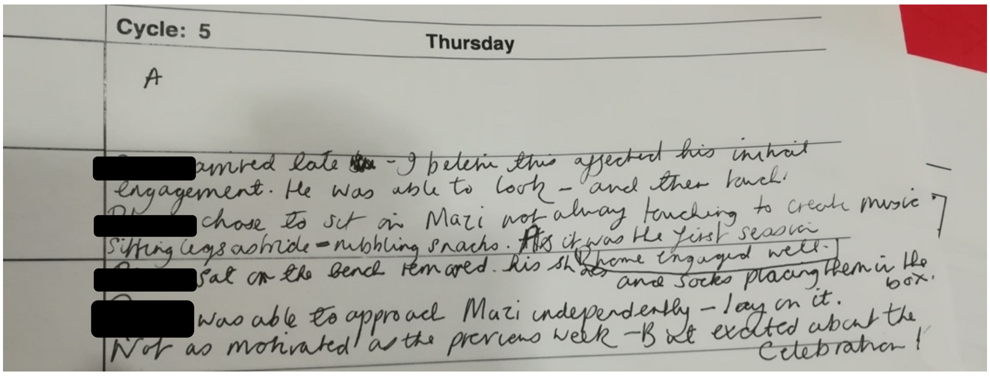


Figure B-0-5 Study 1, Dance Teacher Observation Sheets, Extra Notes, Leroy

Example of Transcripts of the Dance teacher's Feedback on Day 4
Joshua:
Joshua was fascinated by the new sounds - gained his attention. Thoughtful today moving to different areas in the studio to listen and watch. Eye contact very good before touching Mazi and extremely happy with interactions with peers and adults
Alice:
Alice engaged with Mazi and the environment. Looking in the Attention Autism (the beginning). With a gentle physical prompt she was motivated to walk and run towards.
Her motor skills were animated - vocally stimulated. "Home now". "Tickle Tickle". Intensive Interaction with TA added to her positive experience.
Pete:
Pete required close supervision by all adults to enable him to engage with Mazi. *he was prevented from looking and touching the symbols). He still require physical guidance to engage - half way through session he needed the toilet.

Example of Transcripts of the Dance teacher's Feedback on Day 5
Tom:
Tom Entered the room - looked around and smiled. He was able to remove shoes and socks. During the Attention Autism -under the cloth he approached independently - looked and touched.
Moments in the session he was 'SWITCHED ON' and confident in the space. Pupils who expressed their voice "screaming" isolated Tom. His TA felt he needed to leave.
Pete:
Was excited as he entered the studio room. removing shoes and socks. After exploring the space he was physically supported to observe the Attention Autism

activity. He was engaged and was able to look and listen
He required stretching today hanging and climbing on the curtain we allowed this as much as possible. He moved Mazi to the bar to enable him to climb - we ignored his behaviour times x3 he returned to the group (...?). Pete wanted to observe Mazi- people from up "high" "looking down". Pete requires the freedom to find his own way to explore Mazi- otherwise everything he does will be prompt!!

Alice:

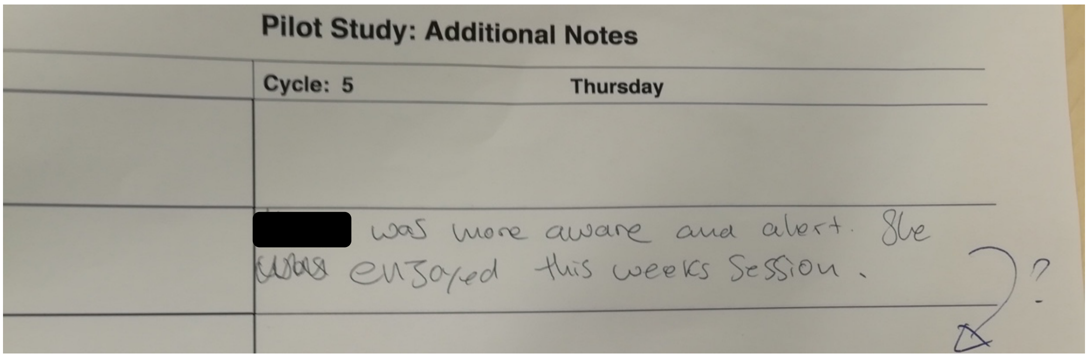
Motivated. switched on. vocal. happy. engaged. Alice was enriched by Mazi - enhancing her journey of discovery?
Alice is able to express herself in this session enabling her to develop confidently.

Leroy:

Leroy is aware of Mazi. He can touch and create sounds. He's more interested in adult interaction. He is not interested in playing as a group. He tries to encourage the adult away from the group to play his game.

Joshua:

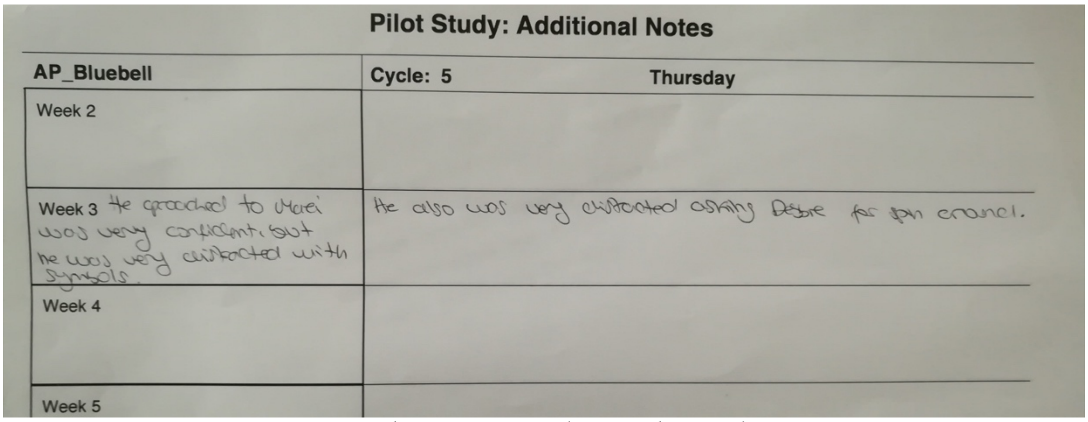
Confident - motivated - Joshua is at ease in the situation. He has formed a relationship with Mazi and he's able to touch engaged naturally- organically. He required some deep pressure at the beginning which showed he was relaxed- was bouncing around the space observing the others touching Mazi - joining the group- leaning- returning Joshua did not have an object (as he always requests) so what he achieved today was amazing



Pilot Study: Additional Notes

	Cycle: 5 Thursday
	[redacted] was more aware and alert. She ~~was~~ enjoyed this weeks session. ?

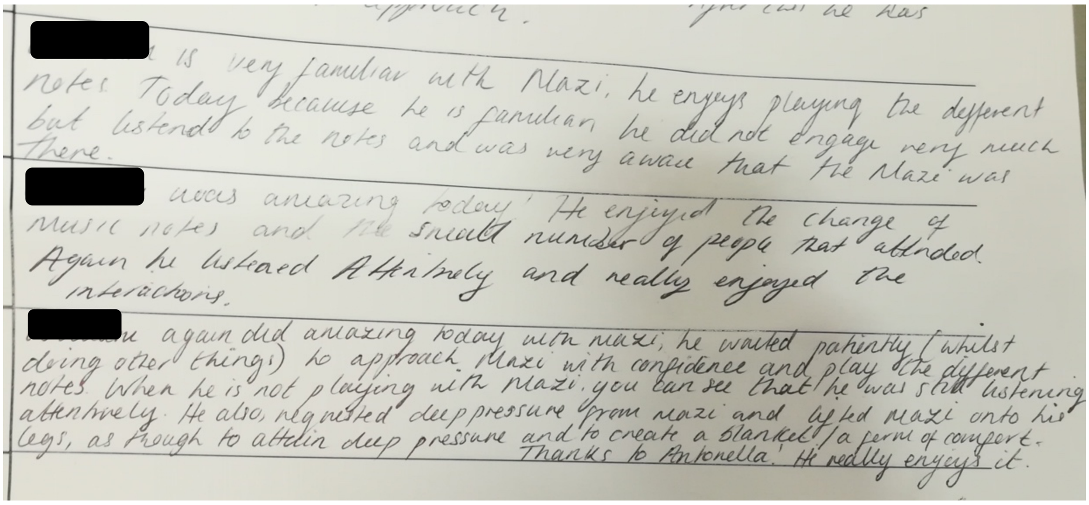
Figure B-0-6 Study 1, Alice's TA Evaluations sheets and Extra Notes



Pilot Study: Additional Notes

AP_Bluebell	Cycle: 5 Thursday
Week 2	
Week 3 He approached to Mazi was very confident, but he was very distracted with symbols.	He also was very distracted asking Debbie for his cranel.
Week 4	
Week 5	

Figure B-0-7 Study 1, Pete's TA Evaluations sheets and Extra Notes



[redacted] is very familiar with Mazi, he enjoys playing the different
notes. Today because he is familiar he did not engage very much
but listend to the notes and was very aware that the Mazi was
there.

[redacted] was amazing today! He enjoyed the change of
music notes and the small number of people that attended.
Again he listened Attentively and really enjoyed the
interactions.

[redacted] again did amazing today with mazi; he waited patiently (whilst
doing other things) to approach Mazi with confidence and play the different
notes. When he is not playing with Mazi, you can see that he was still listening
attentively. He also, requested deep pressure from mazi and lifted mazi onto his
legs, as though to attin deep pressure and to create a blanket / a form of comfort.
Thanks to Antonella! He really enjoys it.

Figure B-0-8 Study 1, Joshua's Evaluations sheets and Extra Notes

Appendix C: Example of the Observation Sheets in Study 2

Class: Snapdragon Name of child: NP	Area of learning	Cycle 5		Year: 2019		
Extra notes:	**Social Interaction and collaborative Play**	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
Week 2 [redacted] did not attend the whole Olly session because she was a bit upset during the transition (from the classroom to the dance studio) [redacted] was exploring the area around the Olly by walking, running and making sounds. [redacted] Also with an adult's support (full prompting) she sat close to the Olly and started pulling the clothes. Week 3: [redacted] with an adult's physical promt sat down close to Olly and started pulling slowly the clothes	Looks interested in the presentation of Olly (Debbie Attention Autism)	1	1	1	1	4
	Approaches Olly with confidence	2	2	2	•2	1
	Pull to activate sounds	2	2	2	—	1
	Plays notes together with peers or partner	3	3	3	—	2
	Shows use of Olly for else than playing notes (e.g. deep pressure; patting; squeezing; climbing etc)	3	3	3	3	1
	Share emotions: express appropriate emotions (pleasure/calm) and he/she is able to self-regulate	1	1	2	1	3
	Share attention: When not in Olly's proximity, shows attention towards others interacting with Olly and follows what's going on	2	2	2	2	4

Tracking according to independence see guidance document below

week 4: [redacted] was standing [redacted] next to the wall and she was looking [redacted] what [redacted] had been happening Olly's area. She was in a playful and happy mood

Figure C-0-1 Study 2, Alice's TA Evaluations sheets, Extra Notes and 5-points rating

Class: Ivy Name of child: AP	Area of learning	Cycle 5		Year: 2019		
Extra notes:	**Social Interaction and collaborative Play**	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
25.4.19. [redacted] was very curious about Olly and explored well. Amy enjoyed laying over the top and rocking. 2.5.19 [redacted] was a little dysregulated as he was awear that his class mates were going out however with prompting Amy was able to enjoy Olly for a time today. 9.5.19 [redacted] was happy and interacted well with Olly. He enjoyed rolling over Olly and tapping 14.5.19 [redacted] was happy bouncing on Olly even without the sound and he wanted to roll on Olly after the session. 23.5.19 [redacted] was very excited today but enjoyed bouncing on Olly.	Looks interested in the presentation of Olly (Debbie Attention Autism)	3	2	2	3	3
	Approaches Olly with confidence	3	3	4	4	5
	Pull to activate sounds	2	2	2	Ø	2
	Plays notes together with peers or partner	1	1	1	Ø	1
	Shows use of Olly for else than playing notes (e.g. deep pressure; patting; squeezing; climbing etc)	3	3	4	4	4
	Share emotions: express appropriate emotions (pleasure/calm) and he/she is able to self-regulate	1	1	2	2	2
	Share attention: When not in Olly's proximity, shows attention towards others interacting with Olly and follows what's going on	1	1	1	2	2

Figure C-0-2 Study 2, Pete's TA Observation Sheets, Extra Notes and 5-points rating

25/4/19 (1)

[redacted] was late so he didn't see the presentation. ~~But~~ 1WK
He walked around the space, looking Olly but without approach to him. He covered himself with the fabric, but he was looking it. As soon as [redacted] from the top of Olly, he sat in it and he started to show interest. He needed a little prompt from Dessie, but after that he joined the group. He interacted with Antonella, asking for tickle in his feet, and the he approached to Violet, putting his feet on top of Olly. He was calm, feeling in and enjoying the time.

2/5/19 (2)
2WK

In the beginning, [redacted] was in the corners, aware ~~about~~ about what was happening. But he wasn't approaching to Olly. After take off his ribbon, he showed more interest in Olly. In my opinion, ~~the fact that~~ because Amy was on top of Olly, [redacted] wasn't feeling comfortable in order to approach to it. When [redacted] moved from Olly, then he was approaching with confidence, sitting in it.
After that, he was playing with it, and with me asking for tickles in his feet. He sat down in Olly putting his feet in my hands. He was happy and he really liked it.

Figure C-0-3 Study 2, Joshua's TA Observation Sheets, Extra Notes, Day 1-2

7/5/19 (2)

In the beginning [redacted] was very distracted (3wk) although the 'hello' and 'attention autism' was sit on the bench following the activity.

Then he was sitting in the corner, asking for massage in his feet. Although myself and Sassie tried to encourage him, he refused to approach Olly.

After that, he was more convinced, playing and touching him. Then he felt comfortable and he also was enjoying other children's game.

He really enjoyed the session. He was very happy, smiling all the time. was a really lovely session with Olly.

16/5/19 (4wk)

~~He~~ He was very happy to go to the session. In 'hello' time he ran to Olly, ~~as~~ taking off the blanket and playing with him. After that, he approaches to Olly very confident. He tried to feel the speaker, removing the fabric. Then he played with it. He really enjoyed it. He also interacted with other students and TA's. He was so happy that he took his trousers off. He really enjoyed the session. I think he ~~is~~ was more confident with less students in the room. (3).

Figure C-0-4 Study 2, Joshua's TA Observation Sheets, Extra Notes, Day 3-4

Week 1

I was looking forward to see [redacted]s approach and reaction to Olly and the new situation as he likes his routine and any changes can trigger challenging behaviour. He amazed me with his brave initiation to go and explore Olly first of all kids in the middle of the room.

Week 2

Very pleased to see him joining peer's play, approach other kids who he didn't know. (Play chase with [redacted], approach William)

Week 3

After a slightly difficult day (changes in routine, little accident, less outside play) he was able to wait more on bench for „Hello" and spent a balanced time with play with peer and come back to Olly and pulling string. Very inspiring how he regulated himself and enjoyed the session while in early years playground he found it difficult to play with peers.

Figure C-0-5 Study 2, Isaac's TA Extra Notes, Day 1-3

Class: Bumblebee Name of child: EA	Area of learning	Cycle 5		Year: 2019		
Extra notes:	**Social Interaction and collaborative Play**	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
	Looks interested in the presentation of Olly (Debbie Attention Autism)	5	5	5	5	5
	Approaches Olly with confidence	5	5	5	5	5
	Pull to activate sounds	5	5	5	5	5
	Plays notes together with peers or partner	5	4	3	NO MUSIC	5
	Shows use of Olly for else than playing notes (e.g. deep pressure; patting; squeezing; climbing etc)	5	4	5	5	5
	Share emotions: express appropriate emotions (pleasure/calm) and he/she is able to self-regulate	4	5	5	5	5
	Share attention: When not in Olly's proximity, shows attention towards others interacting with Olly and follows what's going on	4	4	4	5	5

Extra notes:

Week 4

He didn't have [redacted] this week who he follows the most as they both like to chase each other. Also there was no music. He was still enthusiastic, initiative, approached more other TA's, teachers ([redacted]) and went back to Olly regularly. He could wait on the bench for celebration.

Week 5

[redacted] was relaxed and happy, interacted with everyone, all kids and TA's and Olly. Easily followed everyone on the move.

Figure C-0-6 Study 2, Isaac's TA Observation Sheets, Extra Notes and 5-points rating, Day 4-5

Class: ~~Ladybird~~ Peony Name of child: BM	Area of learning	Cycle 5		Year: 2019		
Extra notes:	**Social Interaction and collaborative Play**	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
Week 1 - very interested to start with but became distracted and left after 15 minutes Week2 - Managed to stay in longer. He played with olly in short bursts. Week3 - ~~B~~ He stayed for whole session. Mainly ran around with another child but came back to adult who came with him and interaction olly on and off	Looks interested in the presentation of Olly (Debbie Attention Autism)	4	3	3		
	Approaches Olly with confidence	5	5	5		
	Pull to activate sounds	5	5	5		
	Plays notes together with peers or partner	3	2	3		
	Shows use of Olly for else than playing notes (e.g. deep pressure; patting; squeezing; climbing etc)	2	0	3		
	Share emotions: express appropriate emotions (pleasure/calm) and he/she is able to self-regulate	0	2	5		
	Share attention: When not in Olly's proximity, shows attention towards others interacting with Olly and follows what's going on	0	2	3		

Figure C-0-7 Study 2, Ben's TA Observation Sheets, Extra Notes and 5-points rating, Day 1-3

[redacted] was disregulated on arrival - Screaming - distressed. (She went for a walk - toilet - drink - bubbles) On her return she was happier. Nichole required a physical prompt to Olly. She engage briefly smiling and interacting with Olly and adult. [redacted] chose to be at the perimeter of the others - dancing - and very vocal.

[redacted] made an excellent transition into the space removing shoes and socks - sitting on the bench and looking. She was engaged and looked at Olly in AA activity. [redacted] was very excited creating lots of vocal sounds. ~~Physical~~ physical prompt needed to approach Olly. [redacted] independently wrapped the lycra round her waist rocking back and forwards. Nichole was calm and relaxed at the end of the session

Class: Snapdragon Name of child: NP	Area of learning	Cycle 5		Year: 2019	
Extra notes:	**Social Interaction and collaborative Play**	**Week 1**	**Week 2**	**Week 3**	**Week 4**
[redacted] needed a physical guide to interact with Olly. The cloth was perfect for [redacted] to interact with pulling with 2 hands wrapping the cloth around her waist. [redacted] lay over Olly and engaged with an adult on the other side. WK	Looks interested in the presentation of Olly (Debbie Attention Autism)	1	ED	3	
	Approaches Olly with confidence	1	1	2	
	Pull to activate sounds	2	1	3	
	Plays notes together with peers or partner	2	2	3	
	Shows use of Olly for else than playing notes (e.g. deep pressure; patting; squeezing; climbing etc)	2	2	3	
	Share emotions: express appropriate emotions (pleasure/calm) and he/she is able to self-regulate	2	2	4	
	Share attention: When not in Olly's proximity, shows attention towards others interacting with Olly and follows what's going on	2	1	2	

Figure C-0-8 Study 2, Alice's Dance teacher Observation Sheets, Extra Notes and 5 points rating, Day 1-3

2. [redacted] followed the visuals Hello - AA - He was eager to touch Olly. [redacted] and [redacted] interacted in the space running, smiling enjoying the experience. [redacted] and [redacted] lay at the speaker touching and listening. [redacted] enjoyed the interaction with his T/A cuddles and tickles. [redacted] remained in the session he did not need to leave as he stayed regulated.

Wk 3 [redacted] made an excellent transition removed his shoes and socks sat down on the bench. He was engaged - focused and ready. [redacted] enjoyed his interaction with his T/A - warm embraces. He ran with [redacted] (who is not in his yr group new friend) [redacted] was able to sign More! running! [redacted] (this prevented a previous behavior - hitting to get attention from a pupil). [redacted] was able to communicate and [redacted] was able to understand.

Wk 4 Absent.

Wk 5 Absent

Figure C-0-9 Study 2, Ben's TA Observation Sheets, Extra Notes, Day 1-3

Example of Transcripts of the dance teacher's Feedback of Isaac
25/04/2019
Isaac was eager to interact with Olly. He pulled the cloth. placed his body inside the cloth. Elijah explored the cloth with Brian running around Olly.

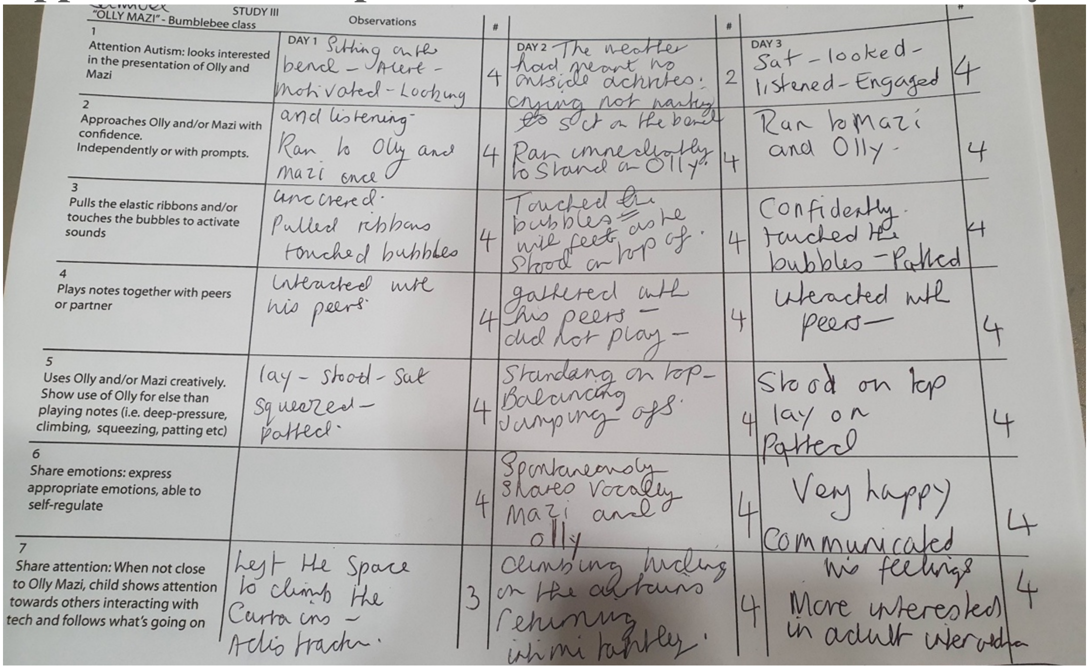
02/05/2019
Isaac transitioned into the space calmer - he was able to focus on the visual timetable even though he was eager to start the session. He self- regulated looking at the visual. Hello - AA. Elijah was motivated immediately to touch Olly. Isaac and Ben interacted with each other - running in the space and around Olly. Elijah remained focused in the session very positive. Interested in the speaker.

09/05/2019
Isaac MADE AN EXCELLENT TRANSITION into the space. removing shoes and socks - sitting on the bench and following the visual timetable. He was motivated to run to Olly after AA he touched the clothes gently creating sound.Isaac played with Ben (different ages - different class - different playground) he responded to Ben in a positive way - and Ben appreciated this. Isaac returned to Olly many times - touching Olly gently.

16/06/2019
Removed shoes and socks independently - he sat on the bench and was able to say "Hello" " Olly". Isaac was motivated to play with Olly bouncing -climbing on - placing the cloths over- leaning back and forwards. Isaac engaged with all of the boys in the session - following and interacting. he was calm and focused. clapping on Olly and creating sound.

23/05/2019
Isaac has had a few days of disregulation (moving fats with all transitions) today he listened to instructions responded to my simple sign (Wait) which is an enormous improvements. He is very social and likes the pupils he wants to interact and engage (chasing) he laughed a great deal expressing his joy. I feel his relationship with Olly is a fun one - he really likes the interactive nature of Olly pushing - pulling - laying on - sitting on. Pulling Joshua's trousers down was not too much and he was easily distracted. Ben's mood was good! He was less anxious than earlier in the day

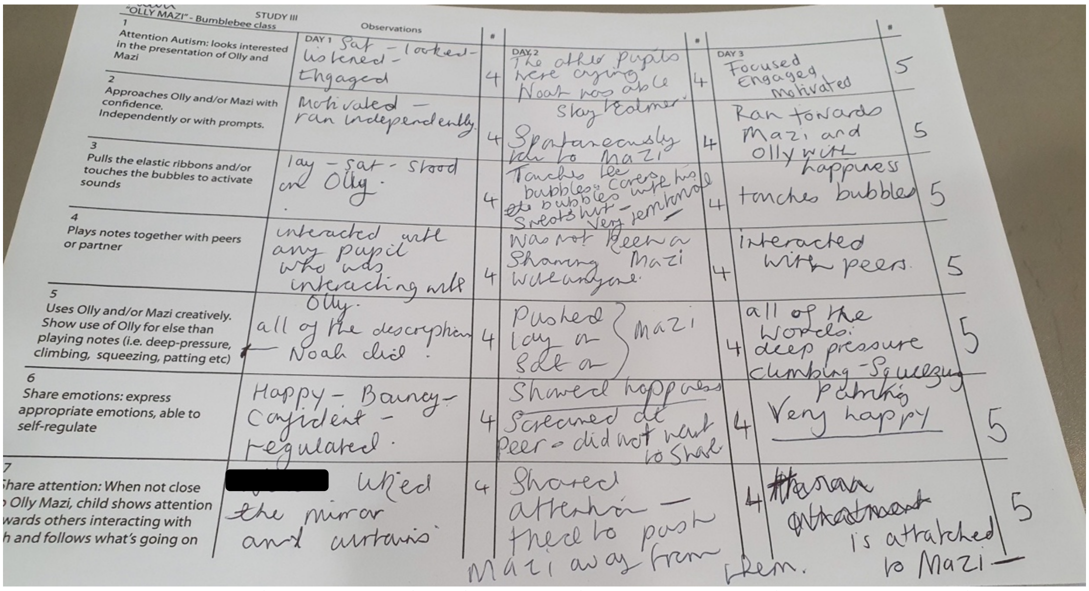
Appendix D: Example of the Observation Sheets in Study 3



"OLLY MAZI" - Bumblebee class — STUDY III — Observations

	DAY 1	#	DAY 2	#	DAY 3	#
1 Attention Autism: looks interested in the presentation of Olly and Mazi	Sitting on the bench – Alert – Motivated – Looking and listening	4	The weather had meant no outside activities; crying not participating	2	Sat – looked – listened – Engaged	4
2 Approaches Olly and/or Mazi with confidence. Independently or with prompts.	Ran to Olly and Mazi once uncovered.	4	Sat on the bench. Ran immediately to stand on Olly.	4	Ran to Mazi and Olly.	4
3 Pulls the elastic ribbons and/or touches the bubbles to activate sounds	Pulled ribbons touched bubbles	4	Touched the bubbles as he [illegible] feet as he stood on top of.	4	Confidently touched the bubbles – Patted	4
4 Plays notes together with peers or partner	Interacted with his peers.	4	gathered with his peers – did not play –	4	Interacted with peers –	4
5 Uses Olly and/or Mazi creatively. Show use of Olly for else than playing notes (i.e. deep-pressure, climbing, squeezing, patting etc)	lay – stood – sat squeezed – patted.	4	Standing on top – Balancing – Jumping off.	4	Stood on top lay on Patted	4
6 Share emotions: express appropriate emotions, able to self-regulate		4	Spontaneously shared vocally Mazi and Olly	4	Very happy Communicated his feelings	4
7 Share attention: When not close to Olly Mazi, child shows attention towards others interacting with tech and follows what's going on	Left the space to climb the curtains – [illegible]	3	Climbing holding on the curtains remaining [illegible]	4	More interested in adult interaction	4

Figure D-0-1 Study 3, Dance teacher Observation Sheets, Extra Notes and 5-points rating, Ray



"OLLY MAZI" - Bumblebee class — STUDY III — Observations

	DAY 1	#	DAY 2	#	DAY 3	#
1 Attention Autism: looks interested in the presentation of Olly and Mazi	Sat – looked – listened – Engaged	4	The other pupils were crying Noah was able stay calmer.	4	Focused Engaged motivated	5
2 Approaches Olly and/or Mazi with confidence. Independently or with prompts.	Motivated – ran independently	4	Spontaneously ran to Mazi	4	Ran towards Mazi and Olly with happiness	5
3 Pulls the elastic ribbons and/or touches the bubbles to activate sounds	lay – sat – stood on Olly.	4	Touches the bubbles, covers his the bubbles with his sweatshirt – Very emotional	4	touches bubbles	5
4 Plays notes together with peers or partner	interacted with any pupil who was interacting with Olly.	4	Was not keen a sharing Mazi with anyone.	4	interacted with peers.	5
5 Uses Olly and/or Mazi creatively. Show use of Olly for else than playing notes (i.e. deep-pressure, climbing, squeezing, patting etc)	all of the description Noah did.	4	Pushed lay on sat on Mazi	4	all of the words: deep pressure climbing – Squeezing Patting	5
6 Share emotions: express appropriate emotions, able to self-regulate	Happy – Bouncy – Confident – regulated.	4	Showed happiness Screamed at peer – did not want to share	4	Very happy	5
7 Share attention: When not close to Olly Mazi, child shows attention towards others interacting with tech and follows what's going on	[redacted] liked the mirror and curtains	4	Shared attention – there to push Mazi away from them.	4	~~[illegible]~~ is attached to Mazi –	5

Figure D-0-2 Study 3, Dance teacher Observation Sheets, Extra Note and 5-points rating s, Theo

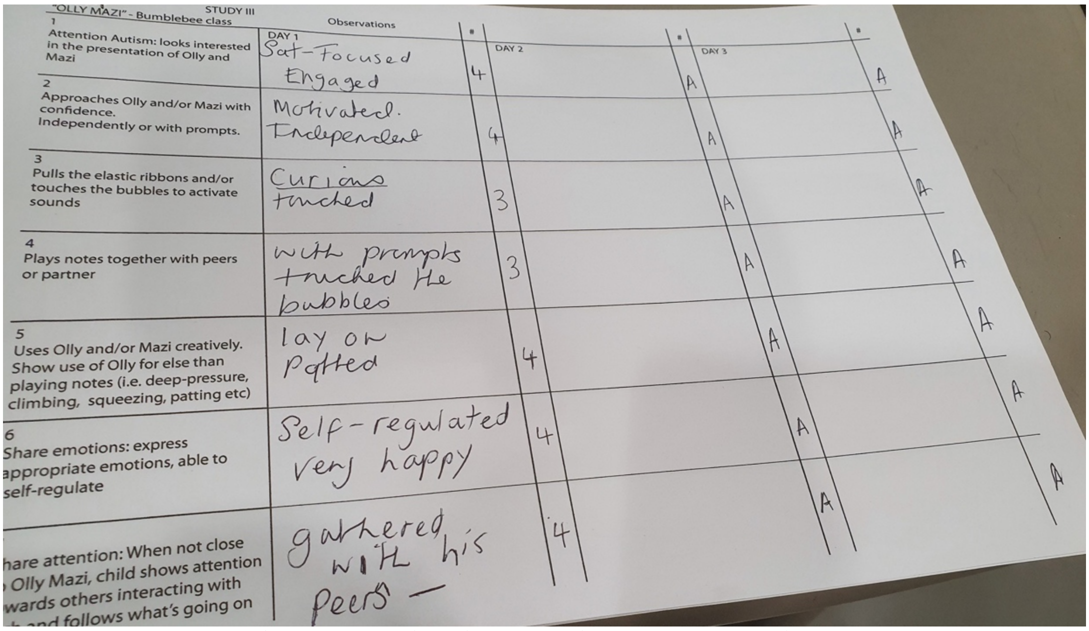


Figure D-0-3 Study 3, Dance teacher Observation Sheets, Extra Notes and 5-points rating, Steve

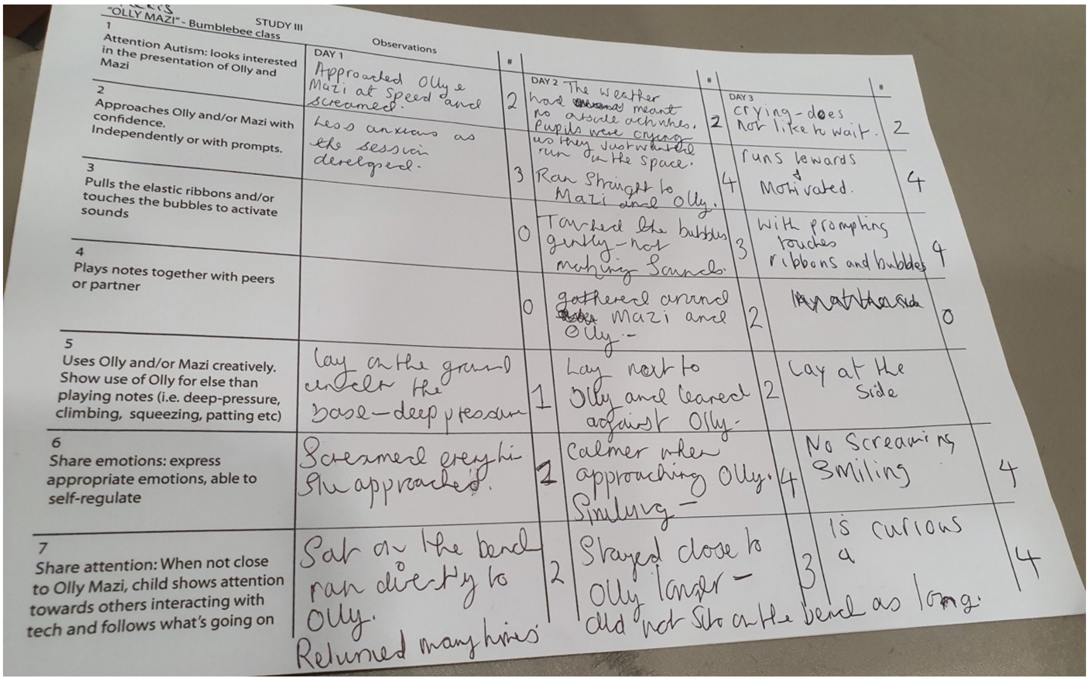
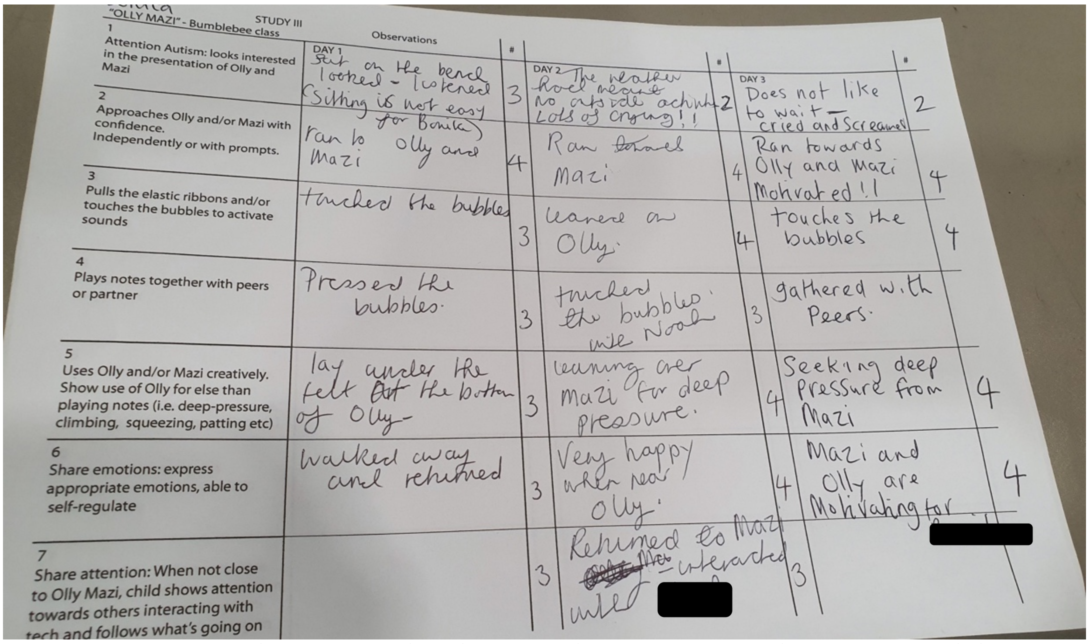


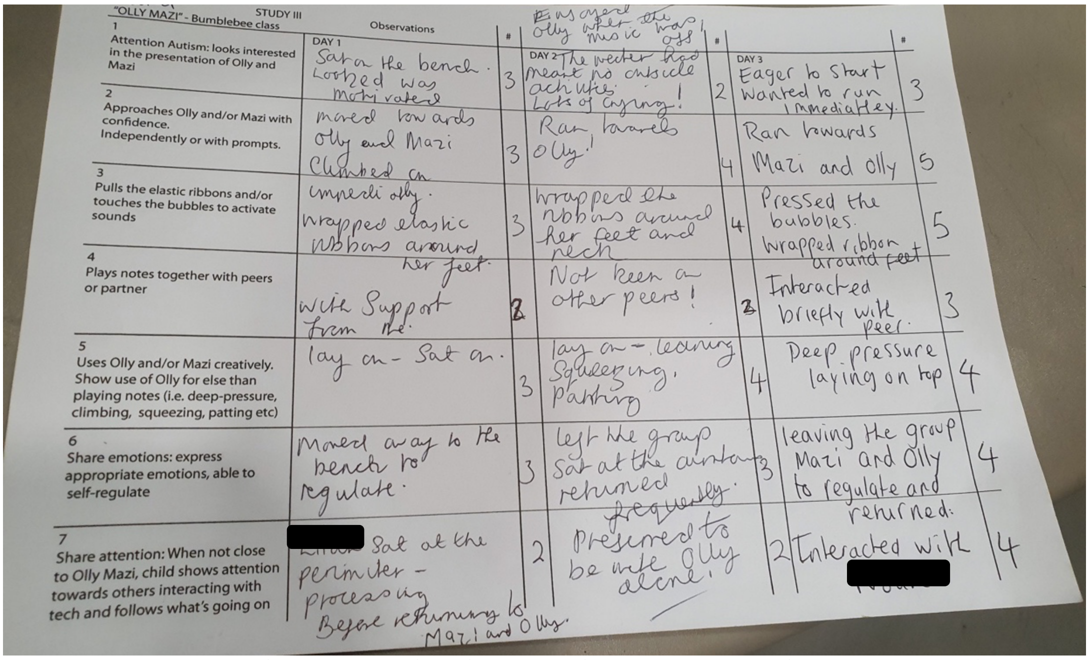
Figure D-0-4 Study 3, Dance teacher Observation Sheets, Extra Notes and 5-points rating, Steve



"OLLY MAZI" - Bumblebee class — STUDY III

	Observations DAY 1	#	DAY 2	#	DAY 3	#
1 Attention Autism: looks interested in the presentation of Olly and Mazi	Sat on the bench looked - listened (Sitting is not easy for Bonita)	3	The weather hoel meant no outside activities Lots of crying!!	2	Does not like to wait — cried and Screamed	2
2 Approaches Olly and/or Mazi with confidence. Independently or with prompts.	Ran to Olly and Mazi	4	Ran ~~toward~~ Mazi	4	Ran towards Olly and Mazi Motivated!!	4
3 Pulls the elastic ribbons and/or touches the bubbles to activate sounds	touched the bubbles	3	leaned on Olly.	4	touches the bubbles	4
4 Plays notes together with peers or partner	Pressed the bubbles.	3	touched the bubbles with Noah	3	gathered with Peers.	
5 Uses Olly and/or Mazi creatively. Show use of Olly for else than playing notes (i.e. deep-pressure, climbing, squeezing, patting etc)	lay under the felt ~~at~~ the bottom of Olly	3	leaning over Mazi for deep pressure.	4	Seeking deep pressure from Mazi	4
6 Share emotions: express appropriate emotions, able to self-regulate	walked away and returned	3	Very happy when near Olly.	4	Mazi and Olly are Motivating for [redacted]	4
7 Share attention: When not close to Olly Mazi, child shows attention towards others interacting with tech and follows what's going on		3	Returned to Mazi — interacted with [redacted]	3		

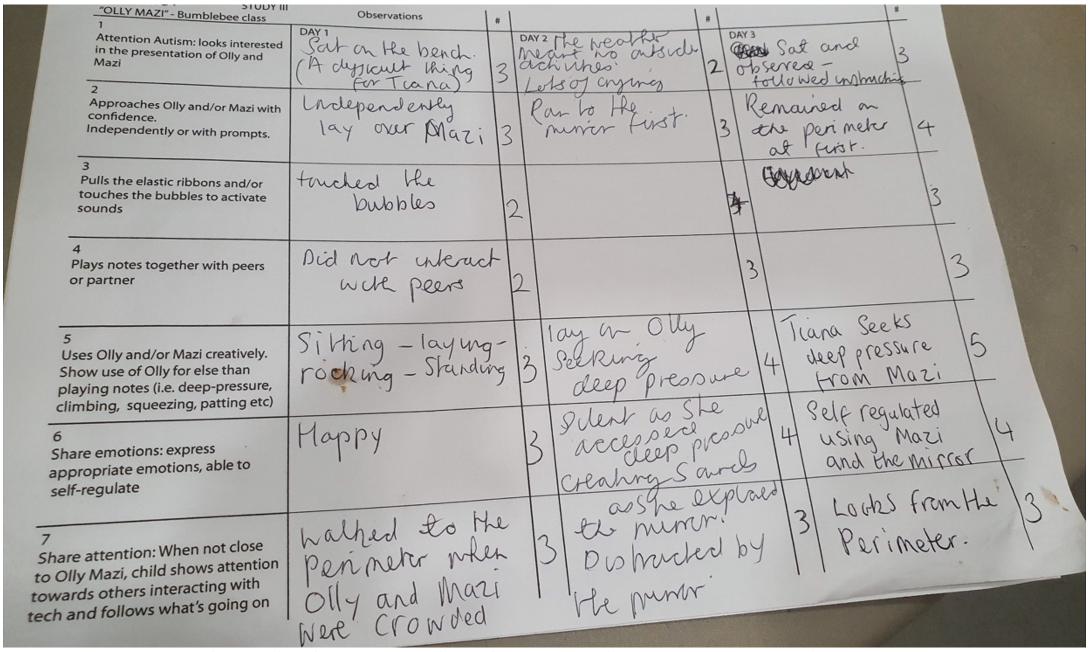
Figure D-0-5 Study 3, Dance teacher Observation Sheets, Extra Notes and 5-points rating, Elodie



"OLLY MAZI" - Bumblebee class — STUDY III

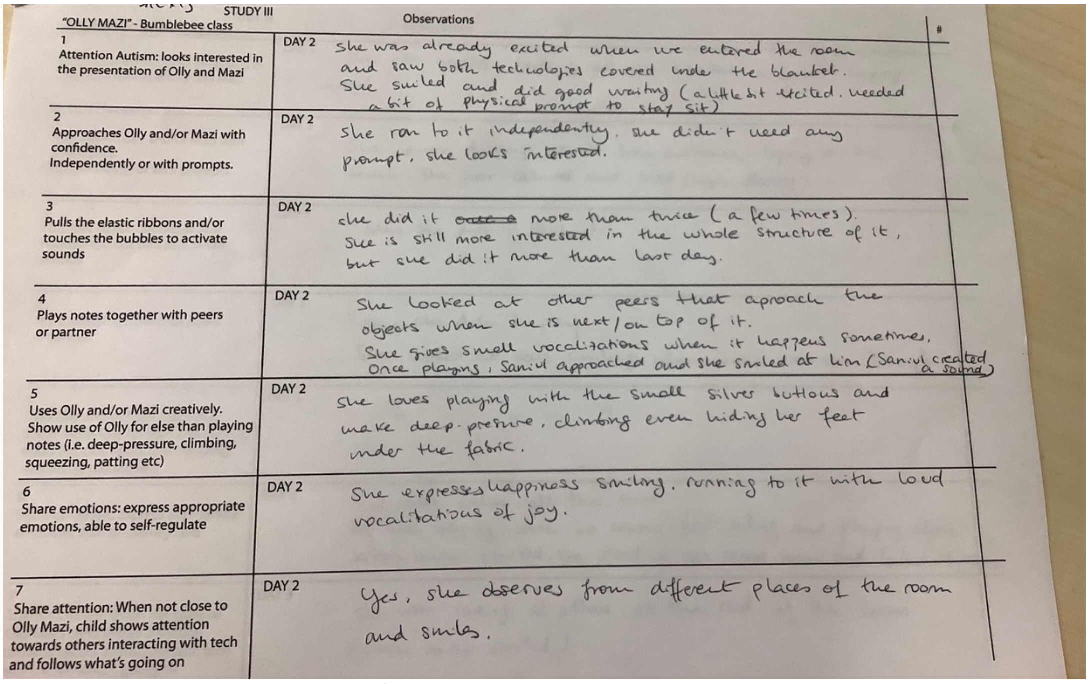
	Observations DAY 1	#	DAY 2	#	DAY 3	#
1 Attention Autism: looks interested in the presentation of Olly and Mazi	Sat on the bench. Looked was motivated	3	Enjoyed Olly when the music was off. The weather had meant no outside activities! Lots of crying!	2	Eager to start wanted to run immediately.	3
2 Approaches Olly and/or Mazi with confidence. Independently or with prompts.	moved towards Olly and Mazi Climbed on	3	Ran towards Olly!	4	Ran towards Mazi and Olly	5
3 Pulls the elastic ribbons and/or touches the bubbles to activate sounds	immediately. wrapped elastic ribbons around her feet.	3	wrapped the ribbons around her feet and neck	4	Pressed the bubbles. Wrapped ribbon around feet	5
4 Plays notes together with peers or partner	with Support from the.	2	Not keen on other peers!	3	Interacted briefly with peer.	3
5 Uses Olly and/or Mazi creatively. Show use of Olly for else than playing notes (i.e. deep-pressure, climbing, squeezing, patting etc)	lay on - Sat on.	3	lay on - leaning Squeezing, patting	4	Deep pressure laying on top	4
6 Share emotions: express appropriate emotions, able to self-regulate	Moved away to the bench to regulate.	3	left the group Sat at the curtain returned frequently.	3	leaving the group Mazi and Olly to regulate and returned.	4
7 Share attention: When not close to Olly Mazi, child shows attention towards others interacting with tech and follows what's going on	[redacted] Sat at the perimeter - processing Before returning to Mazi and Olly.	2	Preferred to be with Olly alone!	2	Interacted with [redacted]	4

Figure D-0-6 Study 3, Dance teacher Observation Sheets, Extra Notes and 5-points rating, Tula



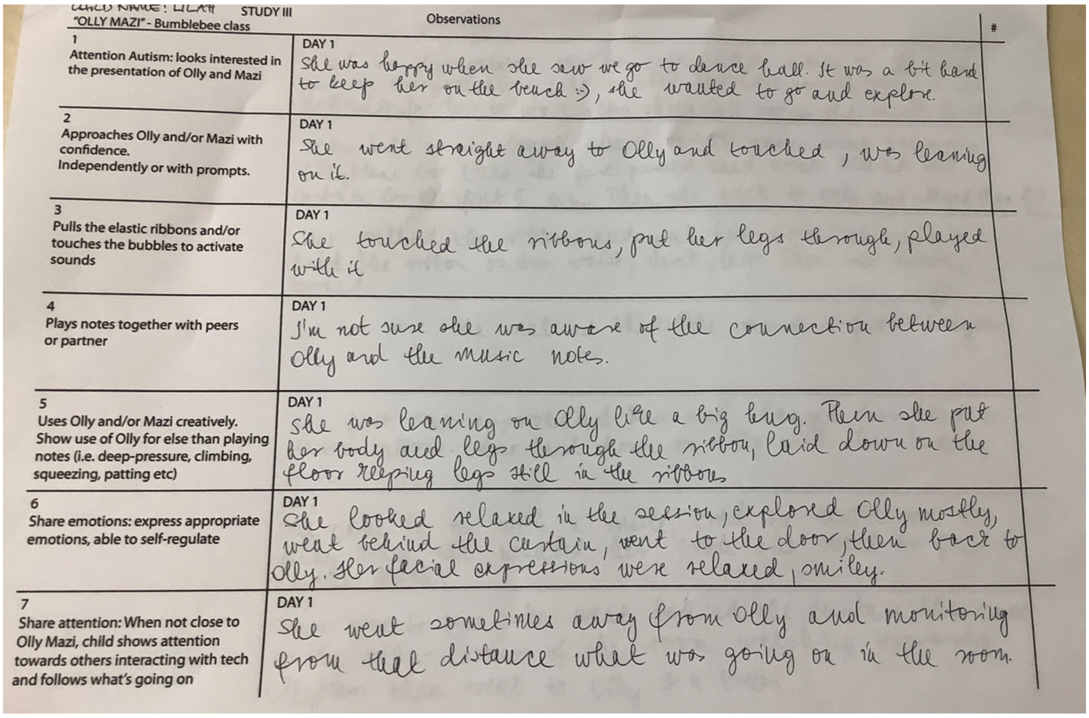
STUDY III "OLLY MAZI" - Bumblebee class	Observations DAY 1	#	DAY 2	#	DAY 3	#
1 Attention Autism: looks interested in the presentation of Olly and Mazi	Sat on the bench. (A difficult thing for Tiana)	3	The weather meant no outside activities. Lots of crying	2	Sat and observed – followed instructions	3
2 Approaches Olly and/or Mazi with confidence. Independently or with prompts.	Independently lay over Mazi	3	Ran to the mirror first.	3	Remained on the perimeter at first.	4
3 Pulls the elastic ribbons and/or touches the bubbles to activate sounds	touched the bubbles	2		~~4~~	[illegible]	3
4 Plays notes together with peers or partner	Did not interact with peers	2		3		3
5 Uses Olly and/or Mazi creatively. Show use of Olly for else than playing notes (i.e. deep-pressure, climbing, squeezing, patting etc)	Sitting – laying – rocking – Standing	3	lay on Olly Seeking deep pressure	4	Tiana Seeks deep pressure from Mazi	5
6 Share emotions: express appropriate emotions, able to self-regulate	Happy	3	Silent as she accessed deep pressure Creating sounds as she explored the mirror.	4	Self regulated using Mazi and the mirror	4
7 Share attention: When not close to Olly Mazi, child shows attention towards others interacting with tech and follows what's going on	Walked to the perimeter when Olly and Mazi were crowded	3	Distracted by the mirror	3	Looks from the Perimeter.	3

Figure D-0-7 Study 3, Selina's Dance teacher Observation Sheets, Extra Notes and 5-points rating, Day 1-3



STUDY III "OLLY MAZI" - Bumblebee class		Observations	#
1 Attention Autism: looks interested in the presentation of Olly and Mazi	DAY 2	She was already excited when we entered the room and saw both technologies covered under the blanket. She smiled and did good waiting (a little bit excited, needed a bit of physical prompt to stay sit)	
2 Approaches Olly and/or Mazi with confidence. Independently or with prompts.	DAY 2	she ran to it independently, she didn't need any prompt, she looks interested.	
3 Pulls the elastic ribbons and/or touches the bubbles to activate sounds	DAY 2	she did it ~~once~~ more than twice (a few times). She is still more interested in the whole structure of it, but she did it more than last day.	
4 Plays notes together with peers or partner	DAY 2	She looked at other peers that aproach the objects when she is next/on top of it. She gives small vocalizations when it happens sometimes. Once playing, Saniul approached and she smiled at him (Saniul created a sound)	
5 Uses Olly and/or Mazi creatively. Show use of Olly for else than playing notes (i.e. deep-pressure, climbing, squeezing, patting etc)	DAY 2	she loves playing with the small silver buttons and make deep-pressure, climbing even hiding her feet under the fabric.	
6 Share emotions: express appropriate emotions, able to self-regulate	DAY 2	She expresses happiness smiling, running to it with loud vocalitations of joy.	
7 Share attention: When not close to Olly Mazi, child shows attention towards others interacting with tech and follows what's going on	DAY 2	Yes, she observes from different places of the room and smiles.	

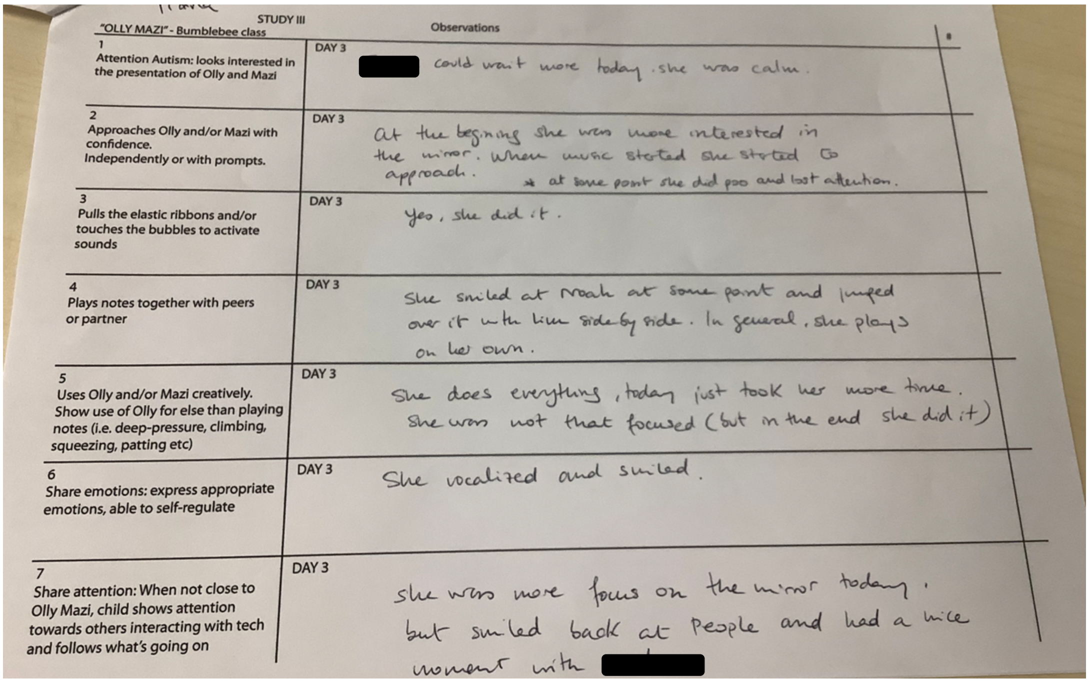
Figure D-0-8 Study 3, Anna's TA Evaluation Sheet, Extra Notes and 5-points rating, Day 2



CHILD NAME: LILAH STUDY III

"OLLY MAZI" - Bumblebee class	Observations
1 Attention Autism: looks interested in the presentation of Olly and Mazi	DAY 1 She was happy when she saw we go to dance hall. It was a bit hard to keep her on the bench :), she wanted to go and explore.
2 Approaches Olly and/or Mazi with confidence. Independently or with prompts.	DAY 1 She went straight away to Olly and touched, was leaning on it.
3 Pulls the elastic ribbons and/or touches the bubbles to activate sounds	DAY 1 She touched the ribbons, put her legs through, played with it
4 Plays notes together with peers or partner	DAY 1 I'm not sure she was aware of the connection between Olly and the music notes.
5 Uses Olly and/or Mazi creatively. Show use of Olly for else than playing notes (i.e. deep-pressure, climbing, squeezing, patting etc)	DAY 1 She was leaning on Olly like a big hug. Then she put her body and legs through the ribbon, laid down on the floor keeping legs still in the ribbons
6 Share emotions: express appropriate emotions, able to self-regulate	DAY 1 She looked relaxed in the session, explored Olly mostly, went behind the curtain, went to the door, then back to Olly. Her facial expressions were relaxed, smiley.
7 Share attention: When not close to Olly Mazi, child shows attention towards others interacting with tech and follows what's going on	DAY 1 She went sometimes away from Olly and monitoring from that distance what was going on in the room.

Figure D-0-9 Study 3, Tula's TA Evaluation Sheet, Extra Notes, Day 1



STUDY III

"OLLY MAZI" - Bumblebee class	Observations
1 Attention Autism: looks interested in the presentation of Olly and Mazi	DAY 3 [redacted] could wait more today. she was calm.
2 Approaches Olly and/or Mazi with confidence. Independently or with prompts.	DAY 3 At the beginning she was more interested in the mirror. When music started she started to approach. * at some point she did poo and lost attention.
3 Pulls the elastic ribbons and/or touches the bubbles to activate sounds	DAY 3 Yes, she did it.
4 Plays notes together with peers or partner	DAY 3 She smiled at Noah at some point and jumped over it with him side by side. In general, she plays on her own.
5 Uses Olly and/or Mazi creatively. Show use of Olly for else than playing notes (i.e. deep-pressure, climbing, squeezing, patting etc)	DAY 3 She does everything, today just took her more time. She was not that focused (but in the end she did it)
6 Share emotions: express appropriate emotions, able to self-regulate	DAY 3 She vocalized and smiled.
7 Share attention: When not close to Olly Mazi, child shows attention towards others interacting with tech and follows what's going on	DAY 3 she was more focus on the mirror today. but smiled back at people and had a nice moment with [redacted]

Figure D-0-10 Study 3, Selina's TA Evaluation Sheet, Extra Notes, Day 3

Example of Transcripts of the Dance teacher's Feedback of Tula

Day 1

T1 sat on the bench. looked was motivated
T2 moved towards Olly and Mazi climbed on immediately
T3 wrapped plastic Ribbons around the feet
T4 with support from me
T5 lay on -sat on
T6 move away to the branch to regulate
T7 the perimeter — processing before returning to Olly and Mazi

Day 2
T1 engaged Olly when the music was off
T2 Ran towards Olly
T3 wrapped the ribbon around their feet and neck
T4 not keen on other peer
T5 lay on - leaning- squeezing- patting
T6 left the group Sat at the curtain. returned frequently
T7 preferred to be with Olly alone

Day 3
T1 eager to start wanted to run immediately
T2 ran towards Maisie and Ollie
T3 press the bubbles wrap the ribbon around fee
T4 interacted briefly with peer
T5 deep pressure- laying on top
T6 leaving the group Mazi and Olly to regulate and returned
T7 interacted with Noah

Appendix E: Post Study 3 questionnaires samples

<u>Questionnaire form for TAs:</u>
TA name:
Initials of child accompanied:
Date of questionnaire:

A. CHILDREN's EXPERIENCES

1. Did the child you worked with interact with Olly and/or Mazi?
2. Did they interact more with Olly, with Mazi or equally with both technologies?
3. If they interacted more with one technology or they interacted with both equally, could you think of why?
4. Did the children interacted with each other?
5. If yes, do you think that Olly and/or Mazi have facilitated the social interactions of children?
6. If yes, in what way?
7. Do the children usually interact between them in other school settings?
8. Were the children regulated throughout the sessions?
9. Can you explain how and why you think so?
10. Do you think the overall experience of the child you worked with was positive, negative, surprising, annoying, neutral? Can you expand on that?

B. DESIGN AND INTERACTIONS

1. Do you think the child(ren) you accompanied understood the cause-effect interaction with the technologies i.e. do you think they understood that if they pulled Olly or touched Mazi they produced sounds?
2. If so, please explain why you think this
3. Do you think that the sound affected the experience of the child(ren) you worked with?
4. If yes, in what way? Can you write some examples?
5. Do you think the child you accompanied liked the fact that there was music involved or did not care about it?
6. Was there anything in particular that your child liked or disliked about Olly and/or Mazi?
7. Do you think the sound affected the overall experience of every child in the classroom, no one or someone in particular?
8. If so, was that positively or negatively or how?
9. Do you think they liked the design (i.e. materials, shape, size) of Mazi?
10. Do you think they liked the design (i.e. materials, shape, size) of Olly?
11. Can you explain why that might or might not be the case?
12. Which one of the two technologies the child(ren) you accompanied preferred?
13. Can you explain why you think so?

C. GENERAL

1. Did you find any issue with the design/technology, the structure of the activity, the environment and/or the approaches used?
2. Did you notice anything different in the way children behaved?
3. Was there anything that you particularly liked or disliked about the study?
4. Was the level of prompts you gave to the child(ren) you accompanied different from usual?

5. Did that affect the experience of the children in any way?
6. How do you think the child(ren) you accompanied experienced the sessions overall?

Questionnaire form for Dance Teacher:
Name:
Date of questionnaire:

A. CHILDREN's EXPERIENCES

1. Did the children interact with Olly and/or Mazi?
2. Did they interact more with Olly, with Mazi or equally with both technologies?
3. If they interacted more with one technology or they interacted with both equally, could you think of why?
4. Was there any child than played with Olly and/or Mazi more than the others?
5. If yes, could you think why is that?
6. Did the children interacted with each other?
7. If yes, do you think that Olly and/or Mazi have facilitated the social interactions of children?
8. If yes, in what way?
9. Do the children usually interact between them in other school settings?
10. Were the children regulated throughout the sessions?
11. Can you explain how and why you think so?
12. Do you think the overall experience of the children was positive, negative, surprising, annoying, neutral? Can you expand on that?

B. DESIGN AND INTERACTIONS

14. Do you think the child understood the cause-effect interaction with the technologies i.e. do you think they understood that if they pulled Olly or touched Mazi in certain points they produced sounds?
15. If so, please explain why you think this
16. Do you think that the sound affected the experience of any/some of the child(ren)?
17. If yes, in what way? Can you write some examples?
18. Do you think the children liked the fact that there was music involved or did not care about it?
19. Was there anything in particular that any child liked or disliked about Olly and/or Mazi?
20. Do you think the sound affected the overall experience of every child in the classroom, no one or someone in particular? Can you write the initials of who you think was affected most and why do you think that is?
21. If so, was that positively or negatively or how?
22. Do you think they liked the design (i.e. materials, shape, size) of Olly?
23. Do you think they liked the design (i.e. materials, shape, size) of Mazi?
24. Can you explain why that might or might not be the case?
25. Which one of the two technologies the children preferred?
26. Can you explain why you think so?

C. GENERAL

7. Did you find any issue with the design/technology, the structure of the activity, the environment and/or the approaches used?

8. Did you notice anything different in the way children behaved?
9. Was there anything that you particularly liked or disliked about the study?
10. Was the level of prompts given to the children different from usual?
11. Did that affect the experience of the children in any way?
12. How do you think the children experienced the sessions overall?

TA COMPLETED QUESTIONNAIRE SAMPLE

Initials of child accompanied: Theo, Selina.
Date of questionnaire: 29/05/20
A. CHILDREN's EXPERIENCES

1. Did the child you worked with interact with Olly and/or Mazi?

N.L.- Child shows curiosity to the objects, explore both of them Olly and Mazi
T.A.- Child wasn't interesting with objects in the beginning of the session, she liked to explore environment that she usually has others activities in. With the time as she saw others playing with Olly Mazi, she went to see and explore as well

2. Did they interact more with Olly, with Mazi or equally with both technologies?

N.L.- He show equally interest in Olly and Mazi
T.A.- She shows more interest in Olly

3. If they interacted more with one technology or they interacted with both equally, could you think of why?

N.L.- He likes both of the technologies, in my opinion, he like the sound effect after an action (pull, press),
T.A.- If she show interest, in my opinion, it was more about swinging on it, touching the textures

4. Did the children interacted with each other?

Children did interact with each other.

5. If yes, do you think that Olly and/or Mazi have facilitated the social interactions of children?

N.L. – in general he wasn't very happy to share with any objects that she was playing particular moment, but that resulted children were interacting
T.A.- depend on her mud, when upset she didn't like to play alongside others, when happy and explore objects didn't mind other children next to her

6. If yes, in what way?

N.L. – in general he wasn't very happy to share with any objects that she was playing particular moment, but that resulted children were interacting
T.A. – mostly when she lied on the Olly, other children tried to have their turs as well. She was happy to have it for herself, sometimes she looked around and laugh.

7. Do the children usually interact between them in other school settings?

N.L.- he is a child that he is very social, he like to have interactions at any bases: eye contact, physical contact, if desire something he able to ask verbally.
T.A. – She like to be independent, doesn't show much interest to other students, but she interact when she think other student chase her

8. Were the children regulated throughout the sessions?

N.L.- he seems to be very happy when play with Olly and Mazi
T.A. – when she get upset, she wasn't interested to Olly, Mazi;

9. Can you explain how and why you think so?

N.L.- even when he gets upset Olly or Mazi helped him to distract and divert to back to play again with it
T.A.- when She gets upset its hard for her to get over it and being distracted by any objects. E.g. when she fell she stood against the mirror and she was looking at herself how she fall again and again

10. Do you think the overall experience of the child you worked with was positive, negative, surprising, annoying, neutral? Can you expand on that?

It was very nice experience to see how children explore new object with so many different sounds, shape and texture. I could see Olly and Mazi make on them big impression. Students like to touch it (even pull the textures out), touching, lie down on it and swing.

B. DESIGN AND INTERACTIONS

1. Do you think the child(ren) you accompanied understood the cause-effect interaction with the technologies i.e. do you think they understood that if they pulled Olly or touched Mazi they produced sounds?

N.L.- I think he understood cause- effect of Olly and Mazi
T.A.- I think she doesn't understand cause-effect

2. If so, please explain why you think so

N.L.- he play with Mazi and Olly by touching buttons and pulling the textures.
T.A.- She didn't put attention to press the buttons at all, in my opinion, her fun was to swing on Olly when lie down on it and then she explore with the textures. I think she like more physical sensations then cause-effect results.

<u>DANCE TEACHER COMPLETED QUESTIONNAIRE SAMPLE</u>

Initials of child accompanied: ALL
Date of questionnaire: 29.4.20
A. CHILDREN's EXPERIENCES
1. Did the children interact with Olly and/or Mazi?

The children interacted with Mazi and Olly.

2. Do you know if they interacted more with Olly, with Mazi or equally with both technologies?

Mazi was more popular at first as less motor skills are required to get a response. Once the skill of holding the ribbon were mastered pupils were able to interact with Olly.

3. If they interacted more with one technology or they interacted with both equally, could you think of why?

Mazi was more popular due to design the pupil can receive a response quicker with their Body ex. Sit on, lay on, stand on.

4. Do you know if the children interacted with each other during the sessions?

All children shared space in close proximity apart from 1 (T)
All children had subtle interactions – touching Mazi or Olly at the same time (B and S) (L and N)
N and L played a chasing game naturally together (they do spend time out of school)
N was possessive with Mazi and moved him away from other children – 3 children followed (S, L, R).
5. If yes, do you think that Olly and/or Mazi have facilitated the social interactions of children?

6. If yes, in what way?

A place to gather – an object of reference: Looking at each other, laying together, and sitting together, turn taking. Social interaction has definitely being facilitated as Mazi and Olly are motivating objects and the children gather and share space together which helps them communicate with each other (positive or negative)

7. Do the children usually interact between them in other school settings?

In dance it is different interactions as we move quite quickly between activities – more direction. Mazi and Olly is a moves at a slower/ relaxed pace which enables more time for the children to find a peaceful place.

8. Were the children regulated before/after coming to the sessions? Or was there any difference in behaviours on the day the sessions happened?

The pupils were very upset in the first session as we had requested they sit on the bench for Attention Autism – once they were released to explore they became regulated.
The distress did not continue in the next sessions pupils waited and self-regulated with the support of the staff.
The second session the children had spent the day in school due to the weather and were not keen on sitting on the bench for the Attention Autism – not as

much crying and distress. (I felt they were aware of what was going to happen next)
The children were very chilled and relaxed after each session and we had no issues with (Behaviour/transition)

9. Can you explain how and why you think so?

I think children were very motivated with Mazi and Olly and the sensory input they received was meaningful and fulfilling.

10. Do you think the overall experience of the children was positive, negative, surprising, annoying, neutral? Can you expand on that?

The first session amazed me of how engaged the children were especially as they are Early Years and have only been in the school since late September.
They were interested and excited in what was happening in the space
The atmosphere was calm.
Happiness and joy in learning new experiences.

B. DESIGN AND INTERACTIONS

11. Do you think the children understood the cause-effect interaction with the technologies i.e. do you think they understood that if they pulled Olly or touched Mazi they produced sounds?

3 children (N, S, R)
1 child needs more time to adapt to new experiences (L)
The sensory pupils were unaware (B, A, T)

12. If so, please explain why you think this

The children who are more aware have some understanding of cause and effect (N, S, R)
The sensory pupils were unaware and needed more time. (B, A, T)

13. Do you think that the sound affected the experience of the children?
Yes

15. If yes, in what way? Can you write some examples?

The sound excited some children who are quite lively and animated.
In comparison the quieter pupils were calm and relaxed.

Appendix F: Examples of Annotations and Code Analysis

	start	duration	
Intro	03:52.3	01:03.9	attention autism Debbie
End	25:01.9	03:28.1	finish and celebrations
C1 Intro to Mazi	03:53.2	00:21.7	looks at Mazi and Debbie saying to sit down and peeC5 sitting down.While Song starts
C1 Intro to Mazi	04:19.2	00:01.3	eye contact with Debbie
C1 Intro to Mazi	04:23.5	00:00.9	looks at Mazi.Debbie has C2proached the cloth
C1 Intro to Mazi	04:49.1	00:05.3	redirected by TA back to the bench she looks at mazi
C1 C2proaches Mazi with confidence	11:14.8	00:20.0	Debbie PP prompt her and she positively stayed toucing and laying her head on top pod. Also s
C1 C2proaches Mazi with confidence	11:39.8	05:33.0	C2 takes C1 off Mazi and slides Mazi aC3y. Debbie PP +VP C1 to go back to Mazi and C1 does
C1 C2proaches Mazi with confidence	20:27.3	01:39.0	Mazi gets slided in front of where she's sittin in the bench.she smiles
C1 Touches to activate sounds	11:53.3	00:04.0	PP.top pod while she goes down on the floor
C1 Touches to activate sounds	12:18.9	00:06.0	she independently and spontaneously played yellow pot repeteadly
C1 Touches to activate sounds	12:25.2	00:01.0	indep.spont.kept playing though C2 took Mazi aC3y
C1 Touches to activate sounds	15:52.3	00:32.0	indep.spont.afdfer TA plays
C1 Touches to activate sounds	23:06.4	00:01.5	indep.spont.plays one pod.once
C1 Touches to activate sounds	23:45.7	00:03.9	indep.spont.plays one note repeteadly.all together.smiles
C1 Plays notes together with partner/peer	15:52.3	00:32.0	Ta plays notes together
C1 Plays notes together with partner/peer	23:45.7	00:03.9	plays alongside TA
C1 Uses Mazi other than for playing sounds	11:16.8	00:16.0	lays upper body on it. strokes the body of Mazi.look at her reflection on Mazi
C1 Uses Mazi other than for playing sounds	11:53.3	00:14.0	lay on it with upper body.knees on the floor. touches/strokes body and top pod
C1 Uses Mazi other than for playing sounds	12:07.5	00:11.2	sits next to it and rips off little pieces of felt.she hold them in her hands andlooks at them
C1 Uses Mazi other than for playing sounds	12:33.3	03:02.0	slides across floor.looks at her reflection while touching Mazi.Lay head on it and hug top pod. to
C1 Uses Mazi other than for playing sounds	16:54.6	00:22.7	takes piece of felt off body
C1 Uses Mazi other than for playing sounds	21:47.3	00:21.0	touch with foot
C1 Uses Mazi other than for playing sounds	23:04.7	00:17.9	touches with one hand. spontanepously
C1 Uses Mazi other than for playing sounds	23:44.5	00:09.4	touches/press with both hands
C1 Uses Mazi other than for playing sounds	24:32.4	00:42.4	touches with both feet. lays her legs on it
C2 Intro to Mazi	03:52.3	00:06.6	at timetable looking at symbols.turn around as mazi leaves the storage but Debbie puches him
C2 Intro to Mazi	04:11.6	00:25.6	looks at the otheC5 singing from the the mid of the room. spins a couple of time and goes to C
C2 Intro to Mazi	04:37.3	00:20.8	LOOKS AT DEBBIE UNCOVERING MAZI.TA PP to sit as he attempts to stands just after Debbie t
C2 C2proaches mazi with confidence	03:56.1	00:02.8	goes toC3rds Mazi but Debbie tells him to sit down
C2 C2proaches mazi with confidence	04:28.7	00:08.5	C2proaches but gets redirected to sit on the bench
C2 C2proaches mazi with confidence	04:58.0	00:48.0	C3nts to stan to go toC3rds Mazi bytu TA PP him to sit. He manages to go and get hold of Mazi
C2 C2proaches mazi with confidence	05:54.4	00:21.9	Debbie VP that is time for Mazi.takes it to the opposite side of the room

Figure F-0-1 Study 1, Example of Annotations used for Code Analysis (T1 Intro-T5 Creative uses)

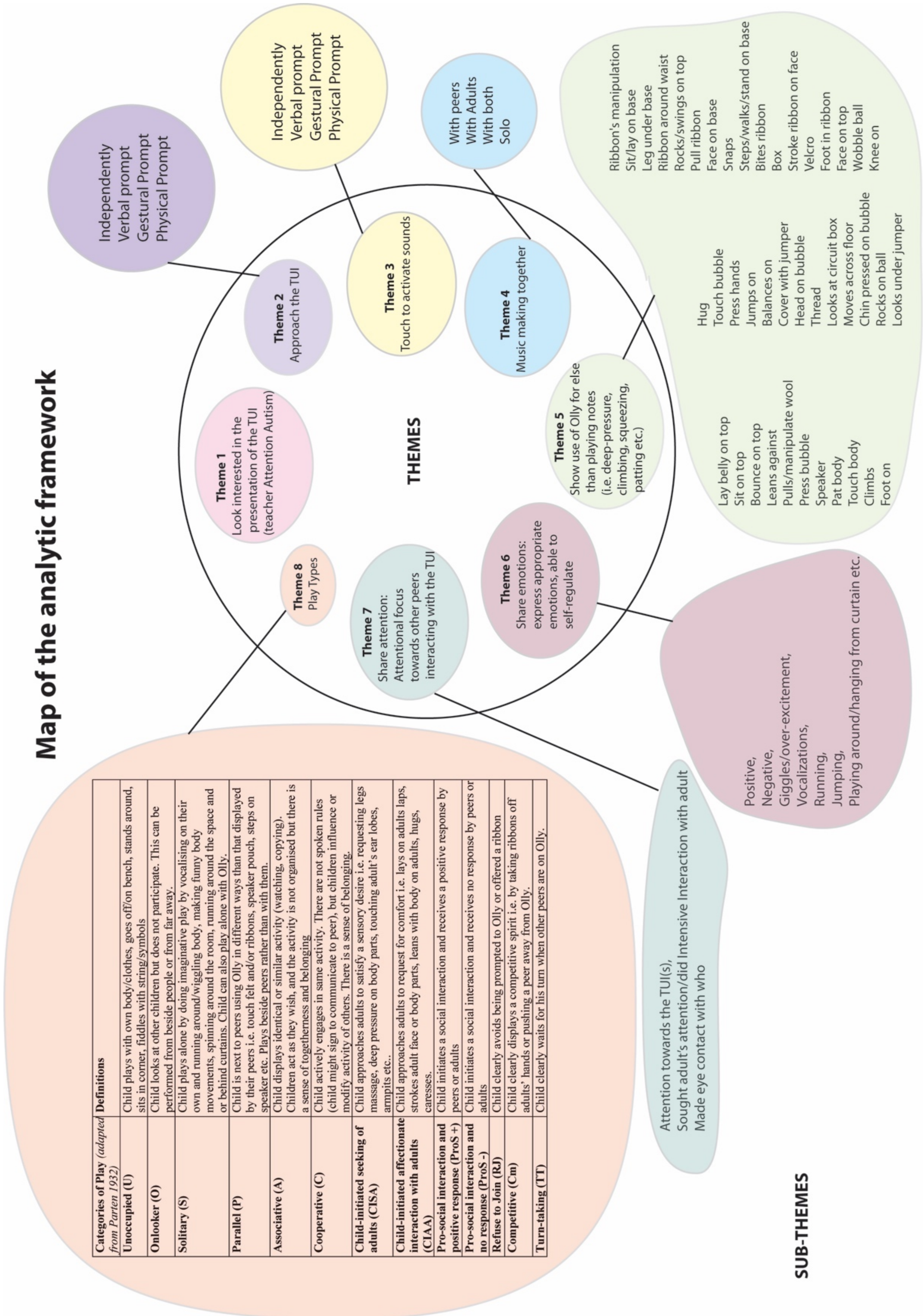
1	Variables	Start time	End time	Duration	Descriptions	
2	Intro	00:02.5	00:11.6	00:09.1	hello	
3	Intro	00:11.6	00:25.0	00:13.4	curtain	
4	Intro	00:25.1	01:04.0	00:38.9	AA	
5	Intro	03:58.0	04:03.0	00:05.0	lights down	
6	Intro	07:26.4	07:30.1	00:03.7	lights down and up again	
7	Intro	20:38.1	20:48.3	00:10.2	blue keeps plaing even though E is not touching anymore	
8	Intro	21:08.6	21:12.2	00:03.6	blue kepts playing. tipped over	
9	Intro	21:14.6	21:34.6	00:20.0	blue keeps playing the same note.no one touches it. E is sat on O but not playing	
10	Intro	21:35.4	21:43.2	00:07.8	blues keep playing	
11	Intro	21:45.5	22:23.6	00:38.1	blue keeps playing though no one is touching it	
12	Intro	22:33.2	22:36.2	00:02.9	light down.then up again	
13	Intro	25:02.7	25:20.2	00:17.6	countdown	24:16.3
14	Intro	25:29.8	25:32.1		sitting on the bench	
15	**Intro Total**			00:52.3		
16	NP Intro to Olly	00:02.0	00:11.3		wears ear defenders	
17	NP Intro to Olly	00:11.3	00:14.1	00:02.8	looks down.legs/feet	
18	NP Intro to Olly	00:14.1	00:16.2	00:02.1	closes eyes. puts head close to J's chest	
19	NP Intro to Olly	00:16.2	00:16.6	00:00.3	glimpses at J	
20	NP Intro to Olly	00:16.7	00:19.8	00:03.1	face covered by J's moving	
21	NP Intro to Olly	00:19.9	00:23.2	00:03.3	moves head forwards.touches J's arms with both hands. puts face on it. strokes mouth	
22	NP Intro to Olly	00:23.2	00:25.4	00:02.2	looks at D finishing to open curtain and O	
23	NP Intro to Olly	00:25.6	00:26.8	00:01.2	puts one leg on J's leg	
24	NP Intro to Olly	00:26.9	00:28.2	00:01.3	looks at D/O while puts other leg on J	
25	NP Intro to Olly	00:28.3	00:30.0	00:01.7	squeeses/manipulate J's arm.face very close.eyes closed	
26	NP Intro to Olly	00:30.0	00:30.7	00:00.7	glimpses at D and O.smiles	
27	NP Intro to Olly	00:30.7	00:31.4	00:00.8	holds on onto J.looks on pavement towards d and O	
28	NP Intro to Olly	00:31.4	00:32.2	00:00.8	glimpses at D	
29	NP Intro to Olly	00:32.3	00:35.0	00:02.7	moves head far from arm.looks at O/D.big smile	
30	NP Intro to Olly	00:35.1	00:37.0	00:01.9	suqeeses eyes while smiles.face up	
31	NP Intro to Olly	00:37.0	00:38.0	00:01.0	holds onto J's arms which she's moving to hold E	
32	NP Intro to Olly	00:38.0	00:41.3	00:03.3	looks towards pavement.smiles.holds J's arm.	
33	NP Intro to Olly	00:41.4	00:43.7	00:02.3	squeeses eyes.holds on to J's arms.puts face close.smile	
34	NP Intro to Olly	00:43.7	00:46.4	00:02.8	looks at O.smile	
35	NP Intro to Olly	00:46.4	00:50.3	00:03.9	presses chin and cheek against J's elbow and arm. closes eyes	
36	NP Intro to Olly	00:50.3	00:54.9	00:04.6	looks at O and E in its proximity.bbig smile	
37	NP Intro to Olly	00:54.9	01:00.1	00:05.2	mouth on J's elbow.manipulate arm	
38	NP Intro to Olly	01:00.1	01:01.7	00:01.6	smiles, looks at O	
39	NP Intro to Olly	01:01.7	01:02.6	00:00.9	smiles, looks towards pavement O's direction	
40	NP Intro to Olly	01:02.6	01:04.0	00:01.4	smiles, looks at O	
41	**NP Intro to Olly Total**			00:51.8		
42	NP Approaches (	03:20.7	04:40.0	01:19.3	PP by D	
43	NP Approaches (	08:46.0	10:33.0	01:47.0	PP by D	
44	NP Approaches (	13:38.8	14:18.0	00:39.2	as E follows her on bench she moves towards O.Indep and spont	
45	NP Approaches (	20:37.1	20:57.0	00:19.9	PP by D	
46	NP Approaches (	21:51.5	25:29.5	03:38.0	PP by D	
47	**NP Approaches Olly with confidence Total**			07:43.5		
48	NP Touches to a	23:04.9	23:24.8	00:19.9	SOLO. INDEP.keeps on the move making little steps as if to actively keep playing	
49	NP Touches to a	23:24.9	23:37.0	00:12.1	SOLO.INDEP.D shows N E just in front and puts while she pulls back up the ribbon which dropped	
50	NP Touches to a	23:37.2	23:41.5	00:04.3	SOLO.PP.pulls back with ribbon around waist	
51	NP Touches to a	23:41.5	24:11.9	00:30.4	SOLO.INDEP.roocks back and forth as if to play actively and independently. holds onto D	
52	NP Touches to a	24:12.1	25:15.4	01:03.3	SOLO. INDEP.gets closer and puts ribbon around neck. manipulates with hands and pulls back. i	

Figure F-0-2 Study 2, Example of Annotations used for Code Analysis (T1 Intro-T3 Touches to play)

						Music OFF From mm 2:10	Music ON From mm 9:02	FINISHED OFF at mm 28:31
Al Social Play	0:18:10	0:18:12	0:00:02	Comp with No as	M			
Al Tot Comp			**0:00:02**					
Al Social Play	0:16:08	0:16:12	0:00:04	Onlooker. glimpses around in room while standing on bench 1				
Al Social Play	0:04:25	0:04:31	0:00:06	Onlooker				
Al Social Play	0:06:54	0:07:01	0:00:07	Onlooker				
Al Social Play	0:13:55	0:13:59	0:00:04	Onlooker as D PP her to the mid of room				
Al Social Play	0:14:49	0:15:03	0:00:14	Onlooker as she giggles body on bench 1				
Al Social Play	0:13:01	0:13:08	0:00:07	Onlooker as she ists on benhc				
Al Social Play	0:27:16	0:27:20	0:00:03	Onlooker as she its on bench 1				
Al Social Play	0:06:00	0:06:07	0:00:07	Onlooker as she sits				
Al Social Play	0:25:57	0:26:20	0:00:23	Onlooker as she sits on bench				
Al Social Play	0:02:28	0:03:18	0:00:49	Onlooker as she sits on bench 1				
Al Social Play	0:03:51	0:03:59	0:00:08	Onlooker as she sits on bench 1 and holds toy				
Al Social Play	0:05:01	0:05:12	0:00:10	Onlooker as she sits on bench and fiddles iwth little toy				
Al Social Play	0:11:08	0:11:26	0:00:17	Onlooker as she sits on benhc 1 and fiddles with her toy thingy				
Al Social Play	0:17:15	0:17:18	0:00:03	Onlooker as she stand on one corner of bench 1				
Al Social Play	0:19:53	0:19:56	0:00:03	Onlooker as she walks to O				
Al Social Play	0:22:03	0:22:09	0:00:06	Onlooker as she wlaks back and satnd beside O				
Al Social Play	0:12:19	0:12:41	0:00:22	Onlooker as sits on bench 1 and fiddles with thingy in her hands				
Al Social Play	0:22:33	0:22:39	0:00:06	Onlooker ass he stands by wall. Sa is playing music on m with tA				
Al Social Play	0:22:47	0:22:49	0:00:02	onlooker ass he stands on bench 2 and takes off thing her mouth. seems to look towrds Li and No arou				
Al Social Play	0:20:34	0:20:39	0:00:05	Onlooker ass he stands on bench. moves as soon as Li runs close				
Al Social Play	0:19:16	0:19:19	0:00:03	Onlooker at No sat on bench and D coming in from office door				
Al Social Play	0:25:27	0:25:29	0:00:02	Onlooker glimpses at peers as she reaches end of bench and turs aroun d				
Al Social Play	0:27:05	0:27:10	0:00:04	Onlooker seems to looks at li who wlaks across curatin side				
Al Social Play	0:17:40	0:17:45	0:00:04	Onlooker to No. as if suddenly back in room she turns to No as he stands on bench too then jumps off				
Al Social Play	0:18:09	0:18:10	0:00:00	Onlooker to Sa and No who just jumped on bench one at each side				
Al Social Play	0:21:34	0:21:37	0:00:02	Onlooker toward No and TA. No had just got hold of TA hands and wlaked her to M. ta point at M an				
Al Social Play	0:05:48	0:05:50	0:00:02	Onlooker. glimpses ta peers				
Al Social Play	0:06:21	0:06:34	0:00:12	Onlooker. as she sits on bench 1 in featal position				
Al Social Play	0:18:16	0:18:20	0:00:04	Onlooker. at D sliding M across floor and in front of Al				
Al Social Play	0:14:05	0:14:10	0:00:04	Onlooker. first toward D as she come and picks up that plastic thingy and then towards peers around (				
Al Social Play	0:06:14	0:06:16	0:00:02	Onlooker. glimpses around when liad on bench				
Al Social Play	0:11:43	0:11:46	0:00:03	Onlooker. glimpses at D and Sa playing music on M in front of bench 1 where she's sitting while fidd				
Al Social Play	0:27:50	0:27:52	0:00:02	Onlooker. glimpses at group as she reaches ned of bench 1				
Al Social Play	0:10:42	0:10:45	0:00:03	Onlooker. glimpses at OM				
Al Social Play	0:10:55	0:11:05	0:00:09	Onlooker. glimpses at peers around/maybe OM. not sure				
Al Social Play	0:25:22	0:25:25	0:00:03	Onlooker. glimpses at peers from standing on ebnch 1				
Al Social Play	0:24:43	0:24:46	0:00:02	Onlooker. glimpses at Sa and TA making music on O				
Al Social Play	0:11:51	0:12:09	0:00:18	Onlooker. looks around as she wiggles body on bench and sits with legs up on bench				
Al Social Play	0:23:15	0:23:19	0:00:04	Onlooker. looks at peers around room as she stands on bench 2				
Al Social Play	0:13:12	0:13:45	0:00:32	Onlooker. seems to be looking at peers especially Bonbon as she gets PP to bench				
Al Social Play	0:24:32	0:24:38	0:00:06	Onlooker. seems to look at No sliding M across floor				

Figure F-0-3 Study 3, Example of Annotations used for Code Analysis (T8 Play Types)

Appendix G: Analytic codes: all themes and subthemes analysed



Categories of Play *(adapted from Parten 1932)*	Definitions
Unoccupied (U)	Child plays with own body/clothes, goes off/on bench, stands around, sits in corner, fiddles with string/symbols
Onlooker (O)	Child looks at other children but does not participate. This can be performed from beside people or from far away.
Solitary (S)	Child plays alone by doing imaginative play by vocalising on their own and running around/wiggling body, making funny body movements, spinning around the room, running around the space and or behind curtains. Child can also play alone with Olly.
Parallel (P)	Child is next to peers using Olly in different ways than that displayed by their peers i.e. touch felt and/or ribbons, speaker pouch, steps on speaker etc. Plays beside peers rather than with them.
Associative (A)	Child displays identical or similar activity (watching, copying). Children act as they wish, and the activity is not organised but there is a sense of togetherness and belonging
Cooperative (C)	Child actively engages in same activity. There are not spoken rules (child might sign to communicate to peer), but children influence or modify activity of others. There is a sense of belonging.
Child-initiated seeking of adults (CISA)	Child approaches adults to satisfy a sensory desire i.e. requesting legs massage, deep pressure on body parts, touching adult's ear lobes, armpits etc..
Child-initiated affectionate interaction with adults (CIAA)	Child approaches adults to request for comfort i.e. lays on adults laps, strokes adult face or body parts, leans with body on adults, hugs, caresses.
Pro-social interaction and positive response (ProS +)	Child initiates a social interaction and receives a positive response by peers or adults
Pro-social interaction and no response (ProS -)	Child initiates a social interaction and receives no response by peers or adults
Refuse to Join (RJ)	Child clearly avoids being prompted to Olly or offered a ribbon
Competitive (Cm)	Child clearly displays a competitive spirit i.e. by taking ribbons off adults' hands or pushing a peer away from Olly.
Turn-taking (TT)	Child clearly waits for his turn when other peers are on Olly.

Figure G-0-1 Illustration of the map of the analytic codes generated through the studies