Mazi: Tangible Technologies as a Channel for Collaborative Play

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ABSTRACT

This paper investigates how haptic and auditory stimulation can be playfully implemented as an accessible and stimulating form of interaction for children. We present the design of Mazi, a sonic Tangible User Interface (TUI) designed to encourage spontaneous and collaborative play between children with high support needs autism. We report on a five week study of Mazi with five children aged between 6 and 9 years old at a Special Education Needs (SEN) school in London, UK. We found that collaborative play emerged from the interaction with the system especially in regards to socialization and engagement. Our study contributes to exploring the potential of user-centered TUI development as a channel to facilitate social interaction while providing sensory regulation for children with SENs.

CCS CONCEPTS

• Human-centered computing→ **Human computer interaction;** *Haptic devices; Collaborative interaction;* → **Interaction Design;** *User centered design*;

KEYWORDS

Children, Autism, Tangible User Interfaces, Social Interaction, Sensory Integration, Play, Smart Textiles

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1 INTRODUCTION

Play is a fundamental part of human existence, and is especially important for children's development [31, 32]. However, children with Special Educational Needs such as autism often find it difficult to engage in play especially with others. Cognitive, behavioral, and technological approaches have been developed over the years to support children with a range of abilities to engage in playful and social interaction. In this paper we explore how a particular form of interactive technology – tangible interaction [9] – might offer increased opportunities for play. TUIs provide a mean for supporting collaborative play and more generally social communication [6, 10] [24]. For collaboration to happen intuitively a principle of shareability should be implemented in the design of TUIs. As explained by Hornecker et al. [11] 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]. However, despite the potential benefit of TUIs for supporting play and communication [17] recent studies on functional social skills development target children with low support needs and Asperger and are particularly focused on VR, AR, robots and computer vision [37, 36, 41]. As children with autism, especially those in the lower end of the spectrum, have difficulty with abstraction of thoughts, we explore in this paper how physical interaction might enhance the possibility of sharing positive experiences between children. This paper investigates how haptic and auditory stimulation can be playfully implemented as part of an accessible form of interaction that would stimulate children participation during leisure and recreational time in indoor spaces. Our research offers four contributions: 1) we present an exploration and study of an e-textile sonic TUI

called Mazi developed to support collaborative play in a group of children with autism; 2) we provide evidence of its impact on a group of five children with high support needs autism; 3) we present an evaluation framework inspired by curriculum-based assessment; 4) lastly we provide design considerations for developing TUIs to support social interaction among children with high support needs.

2 BACKGROUND

The first child with autism found in literature was Donald T. in an article published in 1943 by Leo Kanner titled *Autistic Disturbances of Affective Contact* [29]. The meaning of autism has since become an umbrella term to define behavioral traits. Today is understood that autism has a genetic and biological component to its origins [1]. Children with autism often present common characteristics identified in the dyad of impairment [34]. The dyad affects areas related to:

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

Along with cognitive challenges, many children with autism may find it difficult to self-regulate, self-express, self-organize and to process the many sensory inputs that we receive from social and environmental interactions. This may explain why what is typically considered a positive activity such as play which is usually unstructured and free can at times be a demanding task for many children with autism. It is commonly agreed that play is good for children's cognitive and social development [31, 32] as it promotes and affects areas related to language, problem solving, creativity, memory, self-regulation and executive functioning through the exploration and manipulation of toys [4]. Furthermore, there are many positive outcomes associated with playing with augmented tangible objects [21, 22, 24] and a creative use of objects through playful experiences has proved beneficial for the acquisition of social skills [23]. However, it is thought that unstructured dynamics drive more solitary play in children with autism [30]. This might be due to a language or communicative barrier that prevents these children from approaching peers "appropriately".

2.1 Strategic interventions

Approaches used to enable and encourage pupils with autism to reach their full potentials include: the Picture Exchange Communication System (PECS) [6], a system of cards used by people to communicate meaningfully; the Social Communication, Emotional Regulation and Transactional Support (SCERTS) [7, 23], an educational framework based on core challenges faced by children with autism; contemporary Applied Behavioral Analysis (ABA), an approach used to influence behavior; Intensive Interaction [12] that teaches the fundamentals of communication and Attention Autism [39] to develop joint attention skills. This paper draws on the strategies used in the Special Education Needs (SEN) School where our study takes place which uses 'evidence-based approaches' including PECS and SCERTS. The SCERTS defines three communicative stages for children with autism: 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 [33]. The children in our study were at Social and Language Partner stages. Another approach used is Attention Autism, a practice developed by speech therapist Gina Davies used in UK SEN settings to promote children's attention through fun and visually stimulating activities [39]. It is divided in four stages (the bucket; attention builder; turn-taking and re-engaging attention; shifting and re-engaging attention) and each of them aims at improving children's participation and to become more competent social partners. Lastly, Intensive Interaction was first developed by Nind & Hewett in 1994 [12] for people with profound learning difficulties and communicative problems and it targets social interaction's development for those individual that are nonverbal or preverbal by adapting the partner's traditional way of communicating to that of the individual with autism. The 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" of the English education system [40] ensuring that all pupils receive the same level of teaching.

2.2 Technology based approaches

TUIs have been deployed in SEN settings to support learning skills and for health and wellbeing benefits [8, 5, 22, 18, 15, 16, 25, 37]. Kientz et al. provide a taxonomy of development of interactive technology for children with autism that includes: Personal Computers and the Web; Video and Multimedia; Mobile Technologies; Shared Active Surfaces; Virtual and Augmented Reality; Sensor-Based and Wearable; Robotics; Natural User Interfaces [13]. For example Farr et al. [22] made a comparative study between neurotypical children and children with autism on the social effects of using construction TUIs vs physical construction

toys during a playful activity. The developed TUI, called Topobo, was made of assembling parts for building different creatures while the physical toy was made of Lego pieces. The study demonstrated that providing the children with playful activities within a structured task the TUI was soliciting more parallel and collaborative play than solitary play when compared to the Lego toys. Other researches on TUIs for high support needs children with autism either focus on tabletop interactive devices [21, 18, 17] or tablets [19, 21]. Most recently Zhiglova [20] presented an interactive textile carpet concept to support storytelling through the use of detachable soft fabric shaped characters, and speculates on the potential social benefit that such carpets could have for children with high support needs. Previous sonic interaction technologies are either in support of therapeutic interventions on a 1:1 basis i.e. SoundBeam [2] and Polipo [5]; or they target accessible instruments for musical expression and promotion of general well-being [3, 25]. However, more recent studies on social skills development for children with autism focused on VR, AR, robots and computer vision in general [36, 37, 14, 41]. This may be due to the increased availability of such tools and the fact that mild autistic individuals are more able to develop compensation strategies and transfer this type of interaction to real life situations. For example, the work of Mora-Guiard et al. [37] on full-body interaction aimed to foster relationships between a child with autism and a neurotypical peer. The full-body interaction system projected the children's respective avatars onto the floor in a virtual environment and through handling a physical object the people 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 focusing on socialization, collaboration and user engagement. On the other hand, [14] found that deploying a VR avatar system in a pediatric inpatient-care context when compared to a physical plush robot decreased the social opportunities among peers. Our work expands on [14] and takes a different approach from the above mentioned studies in that it highlights the challenges with representation and abstraction of thoughts faced by children with autism and aims to address them by introducing a simple interaction that is accessible to direct observation and manipulation.

3 DESIGN

We found no research that looks at stimulating collaborative play and social skills through a sonic textile-based TUI for children with high support needs autism. In order to address this we designed a sonic TUI called Mazi to facilitate social interaction while providing sensory regulation for this population. Mazi allows people to play up to five sounds polyphonically and was designed with *entry* and *access points* in mind: the former represented by the shape of the piece, the type of interaction it offers and the colors used; and the latter denoted by characteristics such as the disposition of the colored 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 colored bubbles to activate the sonic outputs. Its current design was informed by our personal observations, field notes, recordings of interviews of staff members (with P.E. Teacher, Dance Teacher, OT) and by the parents feedback as discussed in this section.

3.1 Formative research: requirements gathering

In order to inform Mazi's design we spent two months creating a rich profiles of five children. For two to three weeks each child was observed during Dance and Physical Education (PE) lessons and field notes taken. PE lessons were chosen because the PE Hall allowed us to see what type of apparatus and physical materials the children used the most. Teachers, Teaching Assistants (TAs), and Occupational Therapists were interviewed to develop the rich profiles of the children. A meeting with all the parents which lasted roughly 90 minutes and where we explained the study and received feedbacks, was organized before the study commenced by the Head Teacher and four of the five children's relatives attended. Before the study commenced, each classroom was given a folder with a copy of the lesson plan, pen, tracking sheet, rating point guideline, extra notes sheet, extra symbols and Objects of References (OoR). For the latter, the first prototypes made out of felted half tennis balls to resemble the shapes of the bubbles designed on Mazi were used (Figure 1). The design principles that we wanted to address were: 1) build on children's past experiences and preferences; 2) support self-regulation; 3) encourage social activities.

Figure 1: OoR prototype used for transitions and timetable

3.2 Iterative prototyping

Given the exploratory nature of the study and the short timeframe we focused on developing just one TUI. During the observations we noted that four out of the five children used the therapy balls when doing P.E. more than any other equipment (e.g. trampoline, basketballs, obstacles, rings). Therefore the TUI was designed to resemble a round soft and bouncy shape similar to a therapy ball (Figure 2). Also, the round shape provided good collaborative and self-regulatory affordances. Indeed, researches within the workplace have suggested that a circular configurations facilitate natural communicative and collaborative mechanisms [10] providing a mean for socialization.

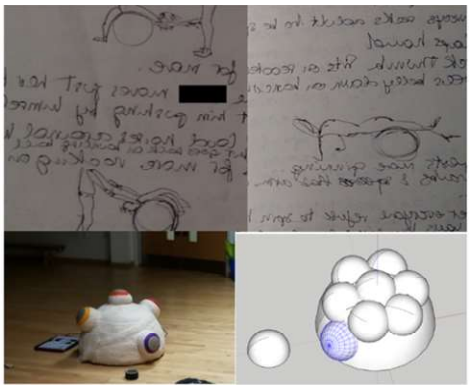

Figure 2: 3D sketch of first ideas; Mazi final (changing speaker)

The physical materials were chosen to be resilient and to provide a mean for deep-pressure through the soft yet quite rough texture. A mix of bright primary and secondary colors in keeping with colors used in the school were chosen to help attract attention to the active sensor areas. To develop the digital aspects of Mazi we used Bare Conductive Touch Board [38] in MIDI mode. [38] It is a circuit board that uses capacitive sensing to detect proximity and touch and it allows to play up to 64 sounds polyphonically. We connected the circuit board to five pieces of Silver Jersey Fabric sewn on top of the colored bubbles by using conductive thread. For the bubbles, we enclosed five inflated balance hedgehogs with two layers of 5mm thick polyester wadding, we dry-felted layers of merino wool fiber over it and lastly sewn patches of conductive jersey on top to make them interactive. The main frame of the installation was a soft-play piece of equipment covered in wool roving with fibers felted onto it. Cables and circuitry were all been covered in felt, and Mazi was battery powered (3.7V 1.200mAh Lipo battery cell) in order to make the installation stand-alone (Figure 2). We opted for a Lipo battery 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 whom 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 risk of damage. Alongside being fire retardant and self-extinguishing, felt is also chemical retardant and has thermal insulating properties. For the first 3 weeks each of the bubbles represented a note of an acoustic piano. We've used a pentatonic scale based on C major (specifically the 1st, 3rd and 6th grades of the C major Scale) as this generally allows for harmonic series of notes to be played without dissonant intervals even by untrained musicians - studies [26, 27, 28] demonstrate that children with autism prefers harmonious to dissonant sounds. From week 4 we changed the notes following the teacher's suggestions and used instead a combination of sound FX because it sounded more "*fun*".

4 STUDY PLANNING AND METHOD

The study was planned as a user-centered design approach working closely with the school's therapists and teachers, whom in-depth knowledge of children, alongside the researcher's previous experience in working at the school, facilitated a rich collection of the children's profiles. It spanned over a period of 5 weeks (the scholastic cycle included 6 weeks in total) and took place every Thursday afternoon in the Dance Studio of a state special school based in North East London, UK, for girls and boys aged 2 to 16. The duration of each session was flexible but usually was around 30 minutes. 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 when they wished. We also worked collaboratively with the Dance Teacher and each child's Teacher and TA during the formative stage of the research to implement goals, define a plan for the study, and redefine the objectives of the entire research. Further discussion with the Occupational Therapist helped finesse the plans.

4.1 Participants

The pupils attending the school, have a diagnosis of autism that follows the Diagnostic and Statistical Manual of Mental Disorders version five (DSM-5) [34]. The first area of assessment in the criteria of the DSM-5 is Social cognition represented in the SCERTS approach by: 1) the inability of sharing processes of attention (joint attention); and 2) by the inability to produce, follow and understand verbal and embodied communication (symbol use). The children were recruited for the study under the advice of the Head Teacher

following this selection criteria: a) diagnosis for ASD; b) aged between 4-10; c) children in the lower level of the spectrum; d) children that respond well to music. Queen Mary University's Ethics of Research Panel fully approved the research and the parents of participating children signed the informed consent forms. Children were also free to not participate if they expressed so by showing signs of dislikes or dysregulation. In this paper we'll refer to the children as C1 for Child 1, C2 for Child 2 and so on. One child was a girl (C1). From each child's Individual Education Plan (IEP) we were able to ascertain their current SCERTS communication stages. Two of the children were at SCERTS SP stage (C3 and C4) and the other three (C1, C2, C5) were at LP stage.

When looking at the pupils Performance scales which assess the performance level of children below the national curriculum and consist of *eight level* of increasing difficulty, ranging from P1 to P8, C1 was mainly at P-level 3 and 4; C2 ranged between P-level 6 and 8; C3 was at P-level 4; C4 corresponded to P-level 2; and lastly C5 ranged between P-level 4 and 5. The children's individual Positive Behavior Support Plans and further discussion in various meetings with Teachers and TAs enabled us to determine each child's current likes, dislikes, triggers and their responses to triggers/events. This detailed information was used when planning the TUI design and the set-up of the room. Every child attended each session with the TA they normally worked with on that day to avoid disruption in their routines. C1 and C5 were both accompanied by one TA, while every other child was assisted on a one-to-one basis. C2 attended the first lesson alongside his Teacher instead of his usual TA and arrived unaccompanied in week 4. C1 and C5 both in the same classroom, have attended the session with their 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.

4.2 Study set-up

The video footage were 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 point of view. Unfortunately the iPad, did get switched off a few times during the sessions, leaving us just two points of view for 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 in 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 take it out just before Attention Autism started. When all the children had taken their shoes and socks off, the *leader*, with the support of visual cues sequenced on a timeline, introduced the session saying hello to everyone and welcoming the technology by saying "*It's time for Mazi*". Then she usually sat on the floor on her knees just 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*", to capture the attention of the children. Following Attention Autism practices every TAs started singing along 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 or it was up to the leader to decide if to invite first the adults, to model the interaction, and then the children to try out the technology (Figure 3). To signal that the session was finished the leader would usually start a count-down from 5, to give enough time to each child to process what came next, and then covered the technology using the same big cloth used at the beginning.

Figure 3: Children playing with Mazi

It was decided by the leader that the researcher had to be part of the experience as two of the children knew her from the previous years that she had worked at the school, so she was introduced to all of the children (the first day) and invited to take the *lead* to congratulate 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 we waved goodbye. The parents were given some pictures extracted from the video recordings alongside written feedback every day after the study. This was a way for us to share what we had observed during each gathering and it has been particularly welcomed by the parents.

4.3 Evaluation

The children's progress was measured in respect to seven research themes defined according to the school's assessment method and inspired by the SCERTS Model. The Dance Teacher and each TA were asked to weekly fill a tracking sheet, where they individually rated children against five themes. The leader and the first researcher have tracked all five children, whilst each TA tracked the child(ren) they worked with. The first five themes below were part of the weekly tracking sheets, while the last two were from in depth video analysis. The themes (T) observed are as follow:

T1 *Attention Autism*: Shows focus during Mazi's presentation

T2 *Approach Mazi*: Willingness to be around Mazi's proximity

T3 *Plays to activate sounds*: Engaged in the cause-effect interaction with the sonic outputs

T4 *Play together*: Willingness to play with Mazi together with peers or adults

T5 *Uses creatively*: Interest in using Mazi for else than playing sounds

T6 *Share emotions*: Express appropriate emotions and is able to self-regulate (pleasure/calm)

T7 *Share attention*: Attentional focus towards others interacting with Mazi

The rating followed a 5 points rating system which was the one currently adopted by the school and based on the level of independence of the children. Additionally, in each tracking's folder there was an *extra* sheet where all the TAs and the leader were asked to write their weekly observations and impression in respect to the child's experience and reactions. Lastly, after each sessions the first researcher and the leader exchanged feedback about the activity, and notes were taken to help improving the experience along the way.

Video analysis was carried out using ELAN software where we applied a mix of deductive and inductive thematic analysis following a qualitative inquiry approach inspired by Heath et al. [35]. The researcher was always present throughout the five sessions. This helped addressing one of the main purpose of the study which was that of stimulating independent and spontaneous play. The frequency of three types of behaviors such as independent (I), gestural/verbally prompted (GP/VP) and/or physically prompted (PP) have been checked for each of the pupils against two categories (T2, T3). In T4 we further looked if the children played together with their peers or with the adults, while in T5 we checked the rate of occurrences of different actions performed by the children when using Mazi other than for activating sounds. The main actions emerged are:

a. Presses
b. Uses with feet
c. Sits on or next to
d. Strokes
e. Jumps/Climbs
f. Lays on with whole body or by the side
g. Pats
h. Slides across the floor
i. Shows interested towards/touches one of the speakers

In T6 we looked at four behaviors noticed through the analysis and driven by the themes. These were: *positive or negative emotions, giggles/over-excitement* and lastly instances of *vocalizations*. Finally, in T7 we looked at if the child: *shows attention towards Mazi*; or *seeks adult attention/does Intensive Interaction with adult.*

5 FINDINGS

The findings will be discussed in details by providing quantitative and qualitative data from the video analysis. The results of the 5 points system are not reported due to the low level of agreement between the raters (68.18%) and inconsistent completion by teaching assistants. As the school personnel did not have any allocated time to evaluate and rate the sessions (or watch the video recordings) this approach presented some challenges. Some TAs filled the tracking sheet the day after or the week after, or asked someone else to do it for them when they did not attend the session (this happened just once). All the TAs were particularly involved in the sessions and played with different children over time. It was difficult to discern the level of accuracy in their tracking sheets, and unfortunately this meant that the ratings haven't been taken into account for precision measures. The length of each session changed over time. The total amount of time of all the five sessions, was of 119:05 minutes. The duration of Attention Autism (AA) calculated over the sum of the total sessions equals to 6:98 minutes. For those children who were not present for all the sessions their evaluations have been done over the sum of the times they attended.

5.1 Theme 1: Attention Autism

To check children's attention we coded pupil's gaze and behaviors during AA. Generally the video analysis suggests that AA captured the children's attention and overall worked well as a practice to introduce Mazi to the group. This is demonstrated by the percentage of time that the children have looked towards this part of the activity and in the case of C1 it equals to 78.5%. A low rate of occurrences shows that

C1 was among the children to be able to stay focused for longer throughout the five weeks.

C2 also attended all the sessions and showed the highest percentage of interest towards this part of the activity (80.6%). This result was quite impressive as it was reported by his teacher that in class "*is the one that doesn't look, like, all the others are there and he's the one that is all over the place; he might..have one minute but he's the one that most seeks your, your, the tapping, or sucking his thumb or he has one of those sensory cushion..but Attention Autism he's the one*".

C3 throughout the five weeks demonstrated an interest equal to 70.8% of the time. Although not the highest score, this was a positive results for him especially when considering what's been reported in the interviews by his teacher and TAs: "[C3] is *over-responsive to sensory environments…He often overreacts because the environment is very stimulating for him*'.

C4, was absent in day 4 and left after 17 minutes in day 3. It's worth noticing that in day 1 his 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 C4 is the child that exhibited less interest towards this part of the activity (45.7%), in day 3 and day 5 he went towards Mazi as soon as the song of AA ended. In the former (day 3) he helped the leader uncovering Mazi and leaned on it while smiling and making eye contact with the leader; and in the latter he climbed on Mazi as soon as the leader removed the cover. The leader wrote after day 5 that "*C4 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 towards Mazi or the leader during AA, C4 was paying attention to what was happening within the presented activity.

Lastly, C5 attended just three sessions and exhibited an interest towards AA that corresponds to 61.6% of the time. From the information gathered about C5 we knew that he's a very curious boy and this showed throughout the weeks and also during AA as he sometimes would have looked at people passing by the corridor or moving around the room and turn back his attention to Mazi after few seconds.

5.2 Theme 2: Approach Mazi

Here we observed moments whether the child was in near proximity of Mazi even though they were not necessarily interacting with it. The overall time that C1 spent approaching Mazi corresponds to 33.5%. Most of that time she has been physically prompted but over time, especially after week 3, her confidence increased and she started to approach and play independently. Prompts were diminished throughout the five weeks and the last day was the first day that she played with Mazi just spontaneously.

C2 approached the TUI mostly independently (11.5%) but the last weeks he required prompting. The overall time he spent approaching Mazi is equivalent to 18.6% and day 4 was the session where he received more physical prompts. C2 was the only child that over time showed diminished interest towards the tangible. However, in 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 Mazi by the teacher and has been span around as a diversion. As we can read from the leader and TA's extra notes of that day, this distracted him: "*[C2] 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 in day 3 the extra notes of his TA reads: "*He was distracted because of the symbols. He also listened one song very exciting for him before Mazi time. He could have been over-excited because of that*". As confirmed by the interview with his teacher C2 "*is a very visual child...loves pictures*". He would in fact often take two or three symbols off the timetable and observe them throughout the session. We interpreted this 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 creative uses for it, like climbing and laying on it.

In regards to C3 it was reported that he didn't 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 (25%) play. C3 required very little PP 0.5%, and VP (6.1%) to approach Mazi.

On the contrary, C4 spent 14.3% of the time in Mazi's proximity, of which a total of 11.4% was done with PP while 1.9% was independent. Although he was absent one day and left earlier in day 3, his confidence and his tolerance towards 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 C4 and making noise...[C4] Appeared to increase in confidence with Mazi as weeks progressed.*

Interestingly C5 always approached Mazi independently and it is worth remembering that he's among the youngest of the group. His approaches lasted for 30.9% of the three sessions he attended.

5.3 Theme 3: Plays to activate sounds

Within the times that the pupils approached Mazi, we measured how long each child has spent playing with Mazi by touching the different bubbles to activate sounds. C1 activated the sonic outputs for 2.6% of the time of which 1.9% was done playing independently; 0.5% with physical prompts; and 0.2% with verbal or gestural prompts. Day 4 is the session she played independently for longer, but she still received some prompting; while day 5 even if she played just for few seconds she played just independently. 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.

C2 played for 1.8% of the time, including 1.5% independently, 0.2% receiving VP and 0.1% with physical prompts. When playing sounds he usually patted the bubble's tops as to receive some sort of deep pressure which he usually satisfied by holding and patting/pressing a TA's hand. Especially in day 1, he also smiled after touching the bubbles.

The pupil that engaged the most with the sonic feature of Mazi was C3. He spent 5% of the time activating sounds of which 4.5% were independent actions and 0.5% required VP. He didn't show any preference towards any specific sound but smiled several times throughout the sessions after playing the bubbles. He would sometimes play the sounds while his TA was singing in the background. From day 1 the leader noticed that he: "*Engaged immediately with Mazi. Created sounds using his hands, body and feet…*". After we changed the sounds and uploaded the new samples in day 4 the leader observed that: "*C3 was fascinated by the new sounds - gained his attention.*".

C4 played the least with Mazi. He played for a total of 0.5% of time, of which 0.3% was done independently and for 0.2% he required PP. Although it was reported by the TAs working in his classroom that C4 "*Responds much better to sounds"* the TA that accompanied him to the sessions with Mazi wrote: "*C4 enjoyed climbing on Mazi, not sure how much he responded to sounds."* from previous meetings his teacher said that: "[C4] *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*". Possibly to fully enjoy the sonic feature C4 needed more time.

Lastly, C5 spent a total of 3.8% of the time playing sounds and the majority of this percentage was done independently (3.2%) but 0.3% required VP and 0.3% was done by receiving PP. Especially the first day he tried and played all the different notes. The last day he initiated instances of explorative and collaborative play with two TAs better discussed in the following paragraphs.

5.4 Theme 4: Plays together

Here we observed if the child would play together with adults, with peers or competitively. Generally, the leader stated that "*there's lovely 2-3 ways interactions happening and children are enjoying it.*" and that we "*should be happy already about the spontaneity and independence that's happening"* as children generally receive a big amount of prompting. When combining the percentages of playing together with adults (0.8%) and with peers (0.3%) C1 spent an overall time playing together of 1.1%. The observations reveal that several times she's being playing notes independently and sometimes collaboratively. C1 really started expressing herself and initiating interactions with Mazi from day 3 and with adults from day 4, suggesting that Mazi was a good social stimuli for her.

C2 played sounds with adults and played competitively with peers for the same amount of time (0.6%). When displaying competitive behaviors he would have slid Mazi across the floor away from the rest of the group. He also played with peers for 0.3% of the time demonstrating some sharing abilities and awareness towards the concept of working together by saying the word "*together*" as he went towards Mazi and exchanged few notes with an adult.

C3 played together with others for 4.2% of the time. This was particularly impressive because it was reported by his teacher that it was difficult to engage him in unstructured activities. The leader in the extra notes wrote after day 2:"*..He was smiling. Moving in the space with his ribbon; he independently approached Mazi requiring no prompts. C3 joined whoever was exploring Mazi touching and looking.*" Like the previous two children, he has played sounds together mostly with adults (3.6%), followed by 0.6% of time where he played with peers and competitively (0.7%). As other children, he 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, C4 played sounds together with an adult just once (0.1% of the time). We were informed by his teacher that he would "*not initiate interaction with peers*" and the *leader* confirmed that it would take him some time to get used to new situations and people. However, during the study there have been several instances where he made eye contact with peers and we noticed that he smiled while looking at them in two occasions. His mom's commented during a meeting that he started making and

sustaining eye contact with her just recently, so we valued this result.

C5 performed several sonic exchanges while playing with adults and generally spent 1.4% playing with TAs and 0.4% of the time he played alongside peers. He also did some competitive play (1.1%) especially with C2. During the last day, while two of the TAs were keeping the rhythm, one by clapping and the other one by patting on Mazi, C5 activated two sounds simultaneously for a prolonged period of time (more than few seconds). The leader and his TA interpreted this as him wanting them to play his game on his own rules writing in the extra notes that C5 "*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*". Contrarily, we believe that C5 was exercising his coordination and motor skills and considered certain dynamics (like the TA moving Mazi away towards another child) might have accidentally interrupted what was potentially a collaborative moment between the child and the adults playing along.

5.5 Theme 5: Uses creatively

Within the approach time theme 5 describes how long a child spent interacting with Mazi but to play sounds. Nine main actions emerged from the video analysis and the rate of occurrences were counted and are listed below in descending order:

1. Lays on it: 53 instances
2. Sits on it or next to it: 48 instances
3. Slides across the floor: 29 instances
4. Presses: 27 instances
5. Climbs/Jumps on it: 24 instances
6. Using with feet: 23 instances
7. Shows interest in speaker: 23 instances
8. Strokes: 9 instances
9. Pats: 6 instances

A figure (Figure 4) of children's likes/dislikes is provided at the end of this paragraph, to facilitate the reader to decode the creative behavior of the children. Aside from playing sounds, C1 spent 18% of time interacting with Mazi and the action she performed the most were: *lays on it* (14); *using with feet* (11); *presses* (6); *sits on it*, *strokes*, interest towards *the speaker* and *slide across floor* (5 instances each); *pats* (3); and lastly *jumps or climb* (1). She would often lay on it and look at herself and Mazi in the mirror.

C2 has interacted with Mazi other than to play sounds for most of his approach time (11.2%.). The actions he performed the most were: *lays* (14); *jumps or climbs* on it and *slides across floor* (13); sits (4); *presess*, *pats* and shows interest towards the *speaker* (1 instance each). C2 never displayed touching with feet and stroking.

C3 used Mazi for 18.3% of his approach time. He mostly performed: *laying on it* (19 instances); *interest in the speaker* and *pressing* (16); *sitting on* it (14); using with *feet* (10); *jumping or climb*ing on it (6); *sliding across floor* (4); *stroking* (2) and he never exhibited patting. C3 patted just when playing music on the bubbles.

C4 used Mazi creatively for 3% of the times of the combined sessions he attended and displayed the following actions: *sitting on it* (6); *climbing/jumping on it* (4); *pressing* (3); *pat*ting and *using with feet* (each 2); *stroking* and *laying on it* (1). C4 never performed *sliding* Mazi across floor and *touching the speaker*.

Lastly, C5 used Mazi but for playing sounds for a total time of 19.4%; again most of the time of his approaches. He would usually sits 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: *sitting on it* (1); *sliding across floor* (7); *laying* on it (6); and he *pressed* and *stroked* once. He also showed *interested in the speaker* (1).

Child	Likes	Dislikes
C1	Quite, tidy places; singing; edible messy play; drawing; dancing; mirror; bubbles; tickles	Noisy and crowded places; unexpected sounds; fast and close movements
C2	Puzzles, reading, words, visuals, routines, numbers, letters, shapes, joking, deep pressure, TV characters	Sit still; focus; noisy environments
C3	Manipulate fabric and ribbons, deep pressure, time at the corner, dry texture, mirror, rocking	Wait; noisy environments; wet clothes; new people and textures; transitions
C4	Hula hoops; trampoline; therapy ball; deep pressure, denim jeans; nursery rhymes; vibrations; dry food, climbing	Messy play; wet texture; shoes and trousers on; loud noises; changes in routines; not having my space
C5	Shows; people; movements; things happening; chewy tube; soft toys; running; music; dancing; chasing; straw; eating tiny things	Fans; waiting; sharing toys and adult attention; sitting for long; transition if not ready

Figure 4: Children's likes and dislikes

5.6 Theme 6: Share emotions

Sharing emotions is one of the key development areas tracked within the Social Communication domain of the Joint Attention section of the SCERTS. Therefore we believe it was important for us to check the emotional state of the children during the study. C1 exhibited more positive emotions than any other child (20.5%) but she also expressed negative emotions for 2.3% of the time and she often vocalized (18%). The negative emotions were always displayed when she was PP to interact with Mazi by vocal moans accompanied by smiles. It had been observed even during dance and P.E that C1 needs lots of prompting to participate during structured and unstructured activities. However, on day 5 the leader feedback reads: "*Motivated. switched on. Vocal. Happy.*

Engaged. C1 was enriched by Mazi… C1 is able to express herself in this session enabling her to develop confidently".

C2 expressed 17.1% of vocalizations, displayed signs of giggles/excitement (14.2%) and showed self-regulated positive emotions like smiles and laughs for 1.7% of the time. The feedbacks of the leader after session 4 reads: "*C2 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 physical guidance to engage - Half way through session he needed the toilet."* Preventing him to look at the symbols might have increased the instances of over-excitement of that day which we noted being particularly high. However he also came unaccompanied that day and needed the toilet half-way through the activity so is difficult to isolate one single cause.

C3 expressed positive emotions for a total of 4.1% and half-way through the sessions he started vocalizing (1.7%). He is non-verbal and when vocalizing he always produces abstract sounds with his voice. Comments from the leader after the last session reads that C3 was: "*.. at ease in the situation. He has formed a relationship with Mazi and he's able to touch engaged naturally- organically. …C3 did not have an object (as he always requests) so what he achieved today was amazing*". After day 3 she wrote " *Eye contact very good before touching Mazi and extremely happy with interactions with peers and adults"*

C4 and C5 were the only pupils that expressed negative emotions that were usually represented by distress. These might have been due to the fact that they were the younger of the group and unable to fully self-regulate their emotional states yet. In the case of C4 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 amount of time that C4 has expressed his emotions are described as follow: positive 4.4%, negative 1.8%, vocalization 0.06%. Peculiarly, C5 hasn't exhibited any particular reaction to the environment 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. In day 5 he was more expressive and displayed a range of emotions among which 4.7% were positive; 2.1% were negative; 0.6% were displays of excitement; and 6.2% vocalizations. His negative emotions were due to the fact that he wanted to play with his TA but after a while he was prevented to do so. Nonetheless, he returned to a calm state and managed to self-regulate independently and in a short period of time.

5.7 Theme 7: Share attention

The last aspect we observed was if the children shared their attentional focus towards Mazi and peers interacting with it or if they sought the attention of the adults when not in Mazi's proximity. C1 *Shared Attention* for 16.7% and spent 13.6% of the time doing *Intensive Interaction with adults.* In day 4 and 5 for a total 37.4% of the 13.6% spent doing *II with adults*, C1 initiated Intensive Interaction with the researcher.

C2 has spent 14.9% of the time sharing attention while 4.7% he *sought the attention of adults.* During the first day, C2 has not showed any interest towards Mazi when not in its proximity. Contrarily, in day 2 his attention increased as he also spent less time approaching Mazi. Every day after day 2, and especially in day 3 he has been seeking adult's attention and insisted on being span by the leader. This is thought to have contributed to lower his overall interest towards approaching Mazi for the next days.

C3 spent 11.6% of the time *Sharing Attention*, and 8% *seeking adult's attention.* In day 4, he engaged in *Intensive Interaction* with the researcher for 22.3% of the time that he spent *seeking adult's attention.* After the last day the leader wrote: *"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".*

C4 was also particularly seeking the attention of the leader in day 2 after he had been span around alongside C2, whilst in day 5 the time spent with adult was mostly due to doing *Intensive Interaction* with one particular TA that was not usually working with him. This pupil had been described as been generally very solitary so II was a good practice for his social skills development. It can also be noticed by the footage that in several occasions he stopped and appeared to listen to the sounds being played by others. He spent 15.43% of the time sharing attention and 6.42% seeking adult's attention.

Finally, C5 shared his attention for 8.9% of the time and unlike the others he mostly *sought adult's attention* (10.2%). During one of the three sessions he was holding a straw which we noted distracted him for the whole activity and the extra notes of his TA reads that: *"C5 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 play time he "*demands*" two adults to play hide and seek with him and he likes to guide the TA's actions and "*to feel in control*". Also, in the playground he would not interact with any equipment. During the study he explored Mazi's sonic features and interacted with it in several occasions independently, collaboratively and competitively.

6 DISCUSSIONS

All of the children, apart from one, increased (not progressively) or maintained a "high level" of independence while interacting with Mazi throughout the five weeks. The teachers facilitated the activity and encouraged children's joint attention and exploration by gradually reducing the prompts. However, teachers' reported children's level of engagement with Mazi beyond their facilitation. E.g. teacher stated *"...C3 is at ease in the situation. He has formed a relationship with Mazi and he's able to touch engaged naturally- organically"* and *"Motivated. switched on. vocal. happy. engaged. C1 was enriched by Mazi - enhancing her journey of discovery."*

The simple auditory affordances were intended to support children's understanding of cause-effect interaction, and the polyphony of Mazi was to make it possible for multiple children to act at the same time thus reinforcing opportunities for collaborative play. This was supported by observations of children's smiles after the sounds played as an effect of their own actions, and e.g. as quoted by the TA "*C3 enjoys playing the different notes*". When not in direct proximity of Mazi we also noticed sharing attention skills supported by Mazi e.g. teacher said "*Looking at Mazi from a distance. He [C4] stood several times and listened to the music being played*" and C3 *"...was listening attentively*". When we proposed the different sounds, the leader noticed that C3 *"was fascinated by the new sounds"* and she continued saying that this *"gained his attention*". After day 4 the feedback of his TA reads: "*C3 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.*" All of them smiled after listening to the audio and all of them apart from C4 explored all the sounds of both set of samples. C1 exhibited a high curiosity towards the new sounds by exploring them independently and for longer than the harmonious notes but we cannot pinpoint if the interactions have been affected by the change in the samples used or if the child gained more confidence as the time passed. Generally all the children that approached Mazi, at first played at least one of the sounds and then explored other uses. Their engagement with the sonic feature shows increased independent instances over the weeks and we suggest that the cause-effect feature captured children's attention as demonstrated by their reactions.

In terms of physical affordance, the large circular shape supported instances of parallel and associative play by providing a focal point for collaboration and togetherness as evidenced by eye contact amongst peers around Mazi. The various bubbles acted as area of access points for each child allowing for sharing opportunities and socialization around the artefact where more parallel and associative play than solitary and unoccupied behaviors were noticed. The size of the tangible provided turn taking opportunities and sharing skills allowing people to appreciate and acknowledge each other's proximity. Children were able to lift Mazi and keep it on their thighs while sitting on the floor, as it happened with C3 during the last day.

The affordance of the object intuitively prompted the actions that the initial idea behind the experience intended to stimulate like laying on Mazi to apply pressure on the children's body parts, and some that the researcher didn't anticipate like sliding the tangible on the floor to move it across the space or lifting it. These actions suggest that Mazi not just was versatile but provided a weight-bearing activity and deep pressure. Deep pressure, also known as swaddle therapy, has been proved to reduce anxiety even in those individuals without sensory processing disorders. This might explain why C3, as reported by the leader, during the last session was for the first time able to go through the whole length of the activity without holding a ribbon: "*C3 did not have an object (as he always requests) so what he achieved today was amazing*". Sensory integration alongside rewarding the children with something they like it's also an important factor for developing effective TUIs as this would enable the children to autonomously regulate their emotional states. We are not sure how much the use of felt influenced the children behavior but, like a plush toy, the use of textile could potentially reduce stress and anxiety and might help with social exclusion [14]. All the children explored the texture by touching it for a prolonged period of time.

Our focus with Mazi was to allow children to develop basic social skills in the real world and in context, it didn't required children to follow any particular rules 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, the adults were not allowing much time for playing in solitary mode and were prompting a shared use of Mazi when necessary. The inclusive and supported setting promoted participation skills more than in unstructured format like play time, while reducing the adult's prompts facilitated independent and spontaneous instances of play as shown by the results. The chance of error was minimized by the use of harmonious sounds, the versatility of the TUI and its affordance. Children were free to move around the environment and to move Mazi with them if they felt it necessary. The mobility aspect of the tangible seems to have been crucial for encouraging socialization and collaborative activities as demonstrated by the children's behaviors. For further studies it will be interesting to modify the characteristic of the sounds when

touch is detected like tonality, pitch or volume to allow for longer interactions. However, further research needs to be conducted on the round shape to investigate if the design provides better social opportunities than other shapes. We believe that a different shape would not deliver a wide range of social opportunities like proximity, joint attention and eye contact as efficiently as a round shape TUI where everyone needs to gather around to. Unfortunately the timescale that we were working on didn't allow us to develop a baseline assessment which may have improved the results. For the next study we are planning 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 off) and compare those with few minutes of footages with the technology on.

7 CONCLUSIONS

As with other user-centered approaches we encourage researchers to invest extended time getting to know the children they want to work with and to gain an in-depth knowledge of their level of abilities and preferences. When working with groups of children with autism we suggest focusing on aspects such as T5 (Uses creatively), T6 (Share emotions) and T7 (Share attention) if considering collaborative activities such as play. We found that technologies aimed at stimulate social interactions in this population should be sturdy, versatile, user-centered, able to reduce anxiety, engaging, simple and possibly mobile. To conclude, it should be noted that we compared behaviors displayed within sessions and are not sure about the transferability of these performances to other contexts nor of the long-lasting effect. Nonetheless, we believe that this approach could be used to encourage playful activities among children also in other educational contexts like i.e. play-time, and also by designers for SEN spaces. Lastly, the length of the study was too short to confirm scientific validity and it is hard to isolate the confounding variables that might have affected certain actions.

However, the study gave positive results and further research will be undertaken in the months to come in collaboration with the same school.

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