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Designing Accessible Interfaces to Enhance Collective Musical Engagement for and with Children with Autism

THÉO JOURDAN, Sorbonne Université, CNRS ISIR, France

ALEJANDRO VANZANDT-ESCOBAR, Association BrutPop, France

BAPTISTE CARAMIAUX, Sorbonne Université, CNRS ISIR, France

Accessible Digital Musical Interfaces (ADMIs) aim to enhance the inclusivity of musical practice by supporting users with diverse needs. This paper focuses on the design and use of ADMIs for and with autistic children. While previous research has highlighted the developmental benefits of ADMIs in therapeutic and educational settings, their potential to foster social interaction and collective musical engagement outside of these contexts remains underexplored. Through an 18-month Action Research collaboration with two non-profit organizations (NPOs) that facilitate creative activities for autistic children, this study investigates the development of ADMIs that support inclusive and collective musical experiences and examines how iterative design processes can respond to the social and relational dynamics specific to group settings involving autistic participants. Our findings highlight the requirements of ADMI design for this context and the evolving role, sometimes ambiguous, that these interfaces play in enabling shared musical engagement. We also reflect on the methodological and ethical challenges of conducting research within NPO environments and promoting the children's autonomy through open forms of participation, reappropriation and workshop flexibility.

CCS Concepts: • **Human-centered computing** → **HCI design and evaluation methods**; *Collaborative and social computing theory, concepts and paradigms*; *Accessibility systems and tools*.

Additional Key Words and Phrases: Qualitative research, Accessible Digital Musical Instrument, Collective musicking, Children, Action Research

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1 Introduction

In recent years, there has been growing interest in designing musical instruments and interfaces which aim to overcome barriers to musical engagement, also called musicking [72], faced by disabled people. The research field of Accessible Digital Musical Instruments (ADMI) [33] promotes the accessibility of musical control interfaces and instruments through the design of bespoke solutions and by adapting existing tools. The scope of ADMI is broad, addressing the needs of users with a variety of disabilities¹. Research into the design of ADMI for, or with groups of autistic

¹Or, as Frid said, with a variety of abilities, “*people being disabled only by two things: people’s perceptions and their environment*” [33]

Authors’ Contact Information: [Théo Jourdan](mailto:theo.jourdan@sorbonne-universite.fr), theo.jourdan@sorbonne-universite.fr, Sorbonne Université, CNRS and ISIR, Paris, France; [Alejandro VanZandt-Escobar](mailto:alejandrovanzandt@zandwerk.org), alejandrovanzandt@zandwerk.org, Association BrutPop, Paris, France; [Baptiste Caramiaux](mailto:baptiste.caramiaux@sorbonne-universite.fr), baptiste.caramiaux@sorbonne-universite.fr, Sorbonne Université, CNRS and ISIR, Paris, France.



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users² is however not well represented in the field. In a recent literature survey, Frid showed that ADMI research considering autistic people as the target users accounts for only 8.4% of all ADMI research, and the majority of the ADMIs were designed to be used by a single person and not for a collective musical practice [33], and frequently focuses on musical tasks. Autistic children can have diverse forms of communication, hypo- and hypersensitivity to sounds that can trigger anxiety, and special interests, routines and rituals that may be used to manage anxiety and stress. These behaviors can lead to social exclusion and consequently social isolation [5], which can create challenges in fostering creative interactions among the group. Considering design at a collective level, with several children able to experience musicking, creates a need for adaptable interfaces and interactions designed that should not only consider the individual specificity of each user of the group but also question the importance of the context and environment.

Researchers within the CSCW community have developed a range of tools and methodological approaches to address these challenges, particularly through participatory design involving autistic participants. Research in these areas emphasizes that participation cannot be reduced to method adaptation alone, but unfolds within collective contexts shaped by relationships, institutional settings, material arrangements, and power asymmetries [41, 47, 51]. Prior HCI and CSCW research has shown that designing with autistic children requires rethinking assumptions about communication, creativity, autonomy, and collaboration, and attending carefully to embodied, sensory, and relational forms of engagement [26, 26, 74]. Frameworks such as IDEAS [7] and D4D [8], along with approaches like Co-Design Beyond Words [83] and Expanded Proxy Design [60], demonstrate that meaningful participation is possible when design processes are carefully structured, supported, and allowed to remain flexible. At the same time, scholars have stressed that such frameworks are not prescriptive solutions, but must be interpreted and adapted in situated, long-term practice [32].

This shift toward contextual, collective, and relational perspectives in PD and CSCW also raises important methodological implications for ADMI research. Recent research in ADMI has explored participatory design methods in which people with disabilities are involved in the design of musical interactions so that these interactions incorporate their specific characteristics [58, 70, 78, 84]. However, Duarte et al. [27] have shown that the development and design of ADMIs often prioritize physiological “needs” over social and cultural considerations, underscoring the need to move toward design approaches to ADMI that are better grounded in the social model of disability. This points to the necessity of reframing ADMI design around “*musicking*” as articulated by Small et al., framing musical practice not as a solitary interaction between an individual and an interface, but as a collective activity that encompasses diverse forms of participation beyond instrumental performance alone, “*whether by performing, by listening, by rehearsing or practicing, by providing material for performance, or by dancing*” [72].

In this article, we lay out a participatory design approach in the context of the design of ADMI following an ecological perspective, enabling their integration for specific groups of autistic children who we worked with in collaboration with two non-profit organizations (NPOs). It offers an empirical account of how participatory design frameworks are enacted in practice, how collective participation is sustained despite heterogeneous communication modes, and how design can support not the stabilization of use, but the ongoing reconfiguration of participation. Our research questions are twofold:

- RQ1: How is the interface design process shaped to remain responsive to the breadth of participation among autistic children?

²The choice of the terminology between *autistic users* and *users with autistic spectrum disorder (ASD)* is currently an active discussion in the scientific and associative communities [73], we decided to acknowledge the term *autistic users* as this is the term used in the associative environment in which the research was conducted.

- RQ2: How do forms of participation and engagement emerge and evolve over time within collective musicking activities?

In order to investigate these questions, we organized a series of workshops over a year and a half in collaboration with two local NPOs that work with autistic children and have developed a musical practice which encourages people with no musical training or who are self-taught to play music in an experimental form [19, 46]. Throughout these workshops, we iterated on the design of the interfaces deployed in the workshops. These iterations were based on our observations, exchanges with members of the NPO, and forms of communication by the children we learned to understand. Positioned at the intersection of CSCW research on participatory design with autistic children and design of ADMIs, our contributions are twofold. First, we identified design insights to promote collective musicking by attending to sonic material (recording strategies), interaction (balancing active and passive engagement, enabling multi-user scenarios), and interface qualities (low-cost, mobile, and adaptable designs). Second, complementary thematic analysis of stakeholder interviews further revealed key factors supporting autonomy, through open forms of participation, reappropriation, and workshop flexibility, as well as the importance of designing responsively to relational dynamics, including dynamic role-taking and nonverbal communication.

The paper is structured as follows. Section 2 reviews related work on participatory design with autistic children and ADMIs for collective musicking, situating our contribution within CSCW and HCI research. Section 3 describes our methodological approach, including the action research framework, the collaborating non-profit organizations, and the data collection and analysis methods. Section 4 presents the outcomes of the three iterative design cycles, detailing the workshops and comparing the different interfaces designed. Section 5 provides a thematic analysis of stakeholder interviews, offering longer-term and reflective insights into the design process and its impacts. Finally, Section 6 discusses the implications of our findings for participatory design, autonomy and power relation in collective musicking contexts, before concluding with directions for future research.

2 Related Work

This section firstly situates our work within prior research on participatory design with autistic children, highlighting existing ethically attentive and flexible approaches that move beyond verbal communication and individual adaptation, attend to infrastructural conditions and support participation as a situated and evolving socio-technical accomplishment. Secondly, we review existing literature on ADMIs for collective musicking, showing that while most work focuses on individual access and therapeutic or educational music use, emerging approaches call for ecological and participatory ADAMI designs that better support collective participation and inclusive musicking.

2.1 Participatory design with autistic children

Participatory Design (PD) is both an approach and a normative stance that argues for the direct involvement of people affected by technologies in their design [12]. Motivations for adopting PD range from pragmatic concerns such as improving the fit between technological features and users' needs to more idealistic agendas related to empowerment, democratization of innovation, and the co-construction of alternative futures [51]. In HCI-related research, PD has been shown to be particularly relevant when designing technologies for groups whose lived experiences and life-worlds are distant from those of designers and researchers, and who are historically marginalized in design processes [41]. Autistic children constitute a prime example of such a group [73]. Designing with autistic children involves navigating a complex design context shaped by unequal power relations [15], diverse modes of communication [26], and the

presence of multiple stakeholders such as parents, teachers, therapists, and carers. These conditions require participatory approaches that are not only methodologically rigorous but also ethically attentive, empathetic, and flexible.

As a result, a growing body of HCI research has sought to adapt PD methods to better engage autistic children and account for their specific modes of interaction and participation. In a critical review of the HCI research on technologies for autistic children, Spiel et al. [74] examine how such research conceptualizes the agency of autistic children. Rather than focusing on technological effectiveness or usability, the authors analyze the purposes these technologies serve and the power relations they enact. The article advances an alternative critical position informed by participatory sense-making, neurodiversity, and critical disability studies. In this way, De Jaegher calls for a *participatory sense-making*, but emphasizes that shared understanding is not a given, but emerges through interaction and may be challenging when participants assign meaning based on different perceptual and sensory grounds [26]. For autistic individuals, repetitive behaviors, preferences for sameness, attention to detail, and specific sensory routines can serve as strategies for structuring the environment, regulating sensory input, and creating a sense of safety. While such behaviors may appear restrictive or opaque to allistic people, they often carry rich meaning for autistic individuals and should be interpreted contextually and with care [26].

This has important implications for participatory design, where conventional assumptions about communication, creativity, and collaboration may not hold. Methodologically, many researchers have therefore avoided relying exclusively on self-report when working with autistic children. Instead, researchers frequently adopt indirect perspectives, drawing on observations, ethnographic accounts, or proxy reports from parents and caregivers [4]. Others conduct retrospective interviews with autistic adults to gain insights into childhood experiences [22]. However, these approaches also risk marginalizing children’s own forms of expression, particularly given that an estimated 30% of autistic children are minimally verbal, communicating through non-speech sounds, echolalia, gestures, or embodied action rather than spoken language [76]. In response to these challenges, several participatory approaches have been developed to better support engagement beyond verbal communication. Metatla et al. introduce “*Expanded Proxy Design*”, an approach in which children are enabled to design for others by engaging with non-human proxies (e.g., objects or characters) that embody aspects of marginalized experiences, thereby supporting empathy, perspective-taking, and participation when direct communication or shared experience is limited [60]. Wilson et al. propose “*Co-Design Beyond Words*”, a child-led approach that foregrounds moments of interaction, micro-level social instances of connection, coordination, or mutual attention as central design resources [83]. Rather than treating communication difficulties as a limitation, this approach values embodied interaction, timing, and affect as meaningful contributions to the design process. By attending closely to micro-interactions, designers can uncover design insights that would otherwise remain invisible in traditional PD methods.

Designing with autistic children, particularly within participatory design processes, cannot be reduced to adapting methods or interfaces to individual needs. Participation unfolds within broader infrastructures composed of social relations, institutional settings, material arrangements, and ongoing forms of coordination involving different stakeholders [47]. From a CSCW perspective, this highlights the importance of attending to infrastructural conditions that shape how participation is made possible over time [14]. Prior work on infrastructuring emphasizes that participatory design extends beyond co-designing artefacts to the collaborative shaping of socio-technical arrangements, including practices, roles, routines, and organizational constraints [48]. In community and non-profit contexts [59], these infrastructures are often characterized by limited resources, reliance on volunteers, shifting personnel, and existing technologies that cannot easily be replaced [49, 80]. As a result, participatory design necessarily involves negotiating responsibilities, expectations, and continuity within these settings [59]. Taking infrastructure seriously thus foregrounds the need to

design with existing organizational arrangements, rather than around them, and to treat participation as an ongoing, situated accomplishment supported by socio-material conditions rather than a one-off methodological intervention [20, 53].

Thus, more structured participatory frameworks have also emerged. The IDEAS approach developed by Benton et al. builds on the TEACCH intervention program to provide concrete structures and supports to involve autistic children in PD activities [7]. IDEAS emphasizes predictable environments, clear spatial organization, and scaffolding strategies that reduce cognitive and sensory overload. Building on this work, the same authors later proposed the D4D (Designing for Diversity) framework, which articulates two complementary strategies for participatory work with neurodiverse populations: structuring the environment and providing additional supports, while simultaneously stressing the importance of understanding both cultural patterns and individual specificities [8]. Crucially, later reflections by Frauenberger et al. demonstrate that participatory design with autistic children rarely follows a fixed methodological script. In their long-term *OutsideTheBox* project, they describe how initial attempts to apply established PD methods gradually evolved into a more fluid, adaptive practice, characterized by the blending of diverse methodological building blocks and an expanding design repertoire [32]. Rather than adhering to a stable framework, the design process became increasingly responsive to how participation unfolded over time, underscoring the importance of methodological flexibility and reflexivity in long-term collaborations.

2.2 Designing ADMI for collective musicking

Research on Accessible Digital Musical Interfaces (ADMI) has traditionally focused on enabling access to music-making for people with disabilities through the design of bespoke instruments or the adaptation of existing musical tools. Prior work has addressed a wide range of users, including people with physical disabilities [3, 9, 39, 52], profound and multiple learning difficulties [28], and individuals with complex needs [81]. This work has been facilitated by the increasing availability of open-source and low-cost DIY technologies (e.g. Arduino³, Bela⁴), which allow for fine-grained adaptation to individual users and contexts [67].

Although there is still no commonly accepted framework for the design and evaluation of ADMIs following Lindertorp et al. [56], partly due to the diversity of uses and users grouped together in this research, some of the contributions identified certain key features. Adaptability and customization, user participation, iterative prototyping, and interdisciplinary development teams were considered as necessary by Frid [34] for ADMIs in general. From educational perspectives, following Förster et al. [35] additional requirements such as robustness, intuitive interaction, and low barriers to entry have been highlighted, particularly in Special Educational Needs contexts, where discovery-based learning and aesthetic experience are central.

Historically, much ADMI research has also conceptualized disability primarily at the level of the individual, aligning with a medical model that frames accessibility as a response to physiological or cognitive impairments. This framing has tended to prioritize functional compensation while overlooking the social, cultural, and contextual dimensions of musical engagement [34, 57]. In response, more recent work has begun to incorporate sociocultural perspectives and usage context, aligning ADMI design with the social model of disability [56]. From this perspective, barriers to musical participation are understood not only as individual limitations but as emergent properties of non-inclusive environments, tools, and practices [42].

³<https://www.arduino.cc/>

⁴<https://bela.io>

Within this evolving landscape, research specifically addressing ADMIs designed for or with autistic people remains limited. Existing work has predominantly focused on music therapy or educational settings, often employing traditional acoustic instruments and targeting clinical or developmental outcomes [23, 75]. Recent research studied the impact of musical improvisation on autistic children [10, 25], involving musical sessions in a clinical setting, using traditional instruments (typically acoustic instruments). A recent literature review showed that there are few studies specifically dedicated to the design of musical interface with autistic people, and specifically for musicking (access to music-making) and creative expression rather than for therapeutic context [33]. Recently, Nonnis et al. [64] has begun to address this gap by designing tangible and embodied interfaces that support nonverbal interaction, social play, and sensory engagement among autistic children, explicitly challenging deficit-based perspectives and medicalized goals.

Parallel to these developments, initiatives and organizations dedicated to inclusive music-making, such as community-based programs and adaptive music collectives including Drake Music Project [62], OpenUp Music [63] and Adaptive Use Musical Instruments (AUMI) Project [2], have increasingly emphasized the participation of neurodivergent people in both musical practice and design processes. This has led to greater adoption of participatory design methods within ADMI research, including ethnographically informed design, Research through Design, and long-term iterative collaboration [6, 64]. However, most ADMI research, even when participatory, continues to prioritize individual interaction between a user and an instrument, with limited attention to collective musical engagement following Feng et al. [30]. Studies examining social interaction mediated by ADMIs are comparatively rare and are most often situated in therapeutic [30] or school-based contexts [35, 56], where collective activity is developed toward predefined outcomes such as stress reduction or skill development [30].

Experiences of social exclusion and isolation are particularly prevalent among autistic people [43, 45], underscoring the importance of designing for collective participation and social inclusion. From this perspective, designing ADMIs for groups requires an ecological approach that extends beyond the interface itself. This includes attention to spatial arrangements, facilitation practices, supporting roles, environmental conditions, and the broader organizational and cultural structures within which musical activities take place. Our work builds on and extends this body of literature by examining ADMIs within collective, community-based musicking practices involving autistic children. Rather than focusing on isolated user–artefact interactions, we situate ADMIs within a broader sociotechnical ecology that includes participants, volunteers, organizational practices, and evolving forms of coordination. In doing so, we contribute to emerging efforts in ADMI and CSCW to understand musical interfaces not only as accessible tools, but as sociomaterial mediators of participation, engagement, and collective creative experience.

3 Method

3.1 Description of the local non-profit organizations and the national context

We collaborated with two non-profit organizations (NPO) active in [CITY], France: *BrutPop* and *J’imaginerais*, who have different goals and ways of operation but who both work extensively with autistic children, teenagers and young adults. Here we firstly present the social situation of the children participating in the NPO’s activities, and then present the two NPO and the organization of the collaboration.

3.1.1 Social situation of the children. The children present at the NPOs’ activities and therefore during the research project, because they have been diagnosed with autism, are excluded from mainstream educational and cultural environments and are therefore placed either in day hospitals, various residential centers, SEND (Special Educational Needs and Disabilities) schools, or “without solution” meaning they stay in their families when there are no places

available in these specialized residential center. These centers are also seen as a means of excluding children diagnosed with autism, following a document produced in 2019 by Catalina Devandas-Aguilar, United Nations special rapporteur about the rights of persons with disabilities in France [55]: *“The Special Rapporteur is extremely concerned about the very high number of persons with disabilities living in institutions across France. Approximately 100,000 children and 200,000 adults with disabilities reside in a broad range of institutionalized settings (...) Although these institutions differ in size, name and set-up, they all restrict liberty, segregate and isolate individuals from their communities, deny their choice of and control over living and support arrangements and significantly restrict their day-to-day decisions.”* (see p.12 of the document).

In the context of artistic practices, French law mandates equal access to arts education through institutional obligations to provide accommodations or compensations, and, since 2005, promotes the concept of “cultural rights”. However, ambiguities in the legislation and insufficient support for policy implementation present significant challenges within many centers. Traditionally, artistic education and practice have been situated within institutions, where professionals often serve dual roles as both caregivers and arts educators. Although gradual, a process of “de-institutionalization”, the transfer of responsibility for these activities to specialized external organizations, is currently underway [1]. This shift is beneficial in separating care objectives from personal development goals, an advancement supported by the activities of the BrutPop and J’imaginerai associations.

3.1.2 BrutPop. Established in 2009 [18], the NPO is a network of artists dedicated to developing accessible musical practices, with a focus on overcoming access barriers faced by autistic people and mentally or psychologically disabled people. BrutPop aims at providing access to musical expression, going against the vein of music and disability necessarily means music therapy. It explicitly emphasizes access to musical expression as a cultural right, distinguishing its approach from the therapeutic objectives that are often prioritized at the intersection of musical practice and disability.

The NPO conducts year-round sound workshops within residential facilities, designs customized instrumental solutions, and organizes or participates in events at the intersection of art, disability, and the role of emerging technologies in this context. Their initiatives are grounded in the principles of alternative digital communities, particularly the ethos of open-source sharing. In alignment with these values, the NPO is committed to fostering the dissemination of low-cost resources, developed collaboratively with individuals with disabilities, to promote accessibility and inclusivity. In particular, the NPO envisions how alternative and experimental approaches to both musical aesthetics and ways of socialising and making (open-source, DIY, etc.) lay the groundwork for a more generally inclusive space than if they are operating to start with within a more normative or traditional artistic space.

3.1.3 J’imaginerai. The NPO offers autistic children and adolescents the opportunity to engage in artistic, cultural, and sporting activities in [CITY]. J’imaginerai’s three main objectives are: *“Awakening young people: freeing the imagination, developing creativity, stimulating curiosity by learning about new media; Integration: socialisation through the group, encounters between young people and the community, whether aware of the disability specificities or not; Autonomy: interactive workshops, involvement in the life of the group, acquisition of autonomy through meeting and exchanging with others, valuing children”* [46]. J’imaginerai primarily serves children aged 6 to 18, whether from private family settings or various residential treatment centers for disabled persons. Groups of up to six participants, each one accompanied by a volunteer, are organized based on the children’s age and cognitive abilities. This personalized, ‘one-on-one’ approach to supervision, along with tailored activity planning, provides opportunity for the children’s individual development. Participation is flexible, with different children involved on different days, and families are not required to commit their children to extended periods of involvement. Young autistic people also take part in the life of the group by preparing

meals for example, which is an important part of socialisation and the acquisition of independence. The volunteers who assist with these activities are often students, resulting in a natural turnover as they are unlikely to remain with the NPO for several years.

3.2 Positioning ourselves

The research carried out and presented in this article is based on the point of view of three non-autistic persons. Two authors (first and last) are researchers in HCI, with a specific research interest in artistic and musical practices. The second author is a member of the NPO BrutPop, a teacher, and a music artist. As non-autistic people undertaking an action research project (see below) with autistic children and reflecting on that specific experience, our research do not aim at making conclusions on autism in general. However, we rely on the support of NPO members who may have longer-term and deeper relationships with the participants and can provide more insights on the children specifically.

Our approach to autism, neurodivergence, and disability is informed by the understanding that the children we work with are not inherently defined by their autism. Rather, they are positioned within NPO due to being administratively or medically labeled as autistic, which leads to their exclusion from mainstream educational and cultural environments. This exclusion creates barriers to musical engagement and fosters social isolation.

3.3 Adopting Action Research methodology

Action Research (AR) integrates theory and practice to address significant organizational, community, and social issues in collaboration with those who experience them. The process combines action with reflection in a continuous cycle of co-generated knowledge [24]. Thus, AR is characterized by an Action Inquiry process that involves a cyclical approach, where practice is continuously improved by systematically alternating between taking action in the field and inquiring into it. This cyclical process involves working closely in collaboration with stakeholders through three phases per cycle: Plan, Act and Reflect. During the planning phase, stakeholders collaborate together to develop a comprehensive action plan. In the action phase, the research activities are carried out, observations are recorded to document the effects of the actions, stakeholders are interviewed, and the collected data are summarized and analyzed. In the reflection phase, stakeholders review the outcomes, articulate the lessons learned, and identify areas for improvement for future research cycles. The outcomes from one cycle are used as the basis for the continued exploration of practice in the next cycle. This iterative process makes it suitable in design and has been used in the field of HCI (see for instance [31, 40, 69]).

In our study, we followed an approach based on AR for its generative nature. Our aim was to start from a research intention, which is the design of sound and music interfaces to foster collective musical expression with autistic children, and to study the emerging process through our field experiments. AR facilitates the creation of new artifacts, and reflects on these artifacts as a means of obtaining information about human experiences and the social and interactional contexts that surround them. Through collaborative musical activities, we not only gathered information about the children's experiences and preferences, but also engaged with them as co-participants in the design process.

3.4 Description of the field work

The project was initiated with the aim of investigating the design of interfaces to foster collective musical expression within situated contexts, particularly in relation to diverse user groups and individuals with specific needs. The AR methodological framework facilitated the establishment of a collaboration with the BrutPop association, whose core activities center on the development and delivery of diverse music workshops from the design of DIY instruments to set up musical sessions. Subsequently, a partnership was initiated with J'imagerais, identified as a relevant field for

research because the NPO is already an ecosystem where different people interact, volunteers and autistic children from different backgrounds and with very varied profiles. The two NPOs had already worked together in the past, and share the same set of values, particularly in terms of their approach to disability and the inclusion of autistic children, which seeks to move away from a medical and institutional approach. J'imagerais operates through a collaborative model involving both regular and occasional contributors to facilitate creative activities for children. Within this framework, we established an ongoing partnership as regular contributors, organizing activities over what became an 18-month period. Members of J'imagerais, including the founder, interns, and volunteers, were actively involved, driven by interest in the research underpinning the initiative. They have participated in the action research cycles at each stage, including the planning and organization of workshops, as well as the collection of feedback both between workshops and at the conclusion of each cycle.

Process	Cycle 1	Cycle 2	Cycle 3	Post-cycles interviews
Period	Two weeks Spring 2023	One week Autumn 2023	One week Winter 2024	Two weeks Winter 2024
Workshops	2 workshops (2 half days)	3 workshops (3 half days)	3 workshops (3 half days)	/
People	6 children (workshop 1); 3 children (workshop 2)	5 children (for all workshops)	6 children (for all workshops)	5 NPOs members/ volunteers
Location	Laboratory	Association/Outside	Association	Online
Meetings	1 pre-workshop focus group; 1 post-workshop focus group;	1 pre-workshop focus group; 1 post-workshop focus group;	1 pre-workshop focus group; 1 post-workshop focus group;	2 interviews 1 focus group

Fig. 1. The design process organized into three AR cycles with respectively two, three and four workshops. These three cycles led to the design of three different interfaces. With the exception of Cycle 1, the same children participate in all workshops in a cycle. Each child is always accompanied by a member of the association. Each workshop cycle is preceded and followed by focus groups with the members present during the workshops, in accordance with the Plan and Reflect stages described in Section 3.3.

Eight workshops were conducted across three cycles, comprising planning, action (several workshops), and reflection phases. Each session involved 2 to 6 children aged 8–13 and their accompanying volunteers from NPO-2. In total, nineteen children participated, some across multiple cycles, but never more than two. More details about specificities of each child who participated in the workshops are given in Appendix A, including physical, sensory, and emotional information, as well as preferred modes of communication. These insights are essential to consider when preparing for each workshop. Four accompanying adults took part in the three cycles, three student volunteers or on fixed-term contracts, and the director of J'imagerais. Most workshops took place on the association's premises and in the surrounding outdoor spaces. Figure 1 gives an overview of the three workshop cycles. Cycle 1 took place during the school term, so the workshops were held on two consecutive Saturdays. Cycles 2 and 3 took place outside the school year, i.e. during a holiday period, so the half-day workshops were held over several days.

Each cycle is independent, in the sense that different children and volunteers participate each time. This unpredictability in attendance, due to families not always bringing children consistently, presents a constraint for the NPO that does not always know which children will be present ahead of time, a constraint that we had to deal with. Focus group meetings are held before and after each workshop cycle, involving stakeholders present during the workshops. The three cycles led to the design of three interfaces. We collected records of the software patches, hardware schematics, and Arduino code used to build the interfaces⁵. These materials were documented to support transparency and enable

⁵<https://www.github-of-the-project.com/>

the association, or others to reproduce the workshops. At the end of the three cycles, three semi-structured interviews were conducted, one with the BrutPop member and second author (called B1 in the Section 5 post-cycles interview findings), one with the NPO director of J’imaginerais (called J1 in the Section 5), and one focus-group interview with the three accompanying adults present in all the cycles (called A1, A2 and A3 in the Section 5).

3.5 Data collection

In this project, we adopted a triangulation strategy [21] to strengthen the rigor and trustworthiness of our qualitative inquiry. Rather than relying on a single lens, we combined multiple sources of evidence, perspectives, and methods to capture the diversity of children’s engagement, often expressed through nonverbal cues, embodied gestures, and unconventional forms of participation. We therefore collected four categories of data, each serving a different role in connecting immediate workshop interactions with longer-term reflections and interpretations:

- Documentation (emails, self-reflective notes, meeting reports): These materials played an essential role in reconstructing the ongoing decision-making process. Notes written immediately after sessions captured early impressions and reflexive insights. Shared reports and email exchanges between researchers and NPO members recorded collective reflections across time. This documentation not only preserved an account of events but also revealed how interpretations evolved throughout the 18 months of collaboration.
- Observational data (direct and participant observation): During workshops, we took systematic field notes to document children’s behaviors, interactions, and use of the interfaces. Participant observation [11] was also collected during focus group after each workshops and gave us a perspective on how interactions felt from within the group. These observations were essential to capture fleeting, situated moments of engagement such as spontaneous collaboration.
- Physical artefacts (prototypes, interfaces used): The interfaces created during workshops served as what Scheepmaker et al. [68] call “boundary objects”, tangible mediators between children, volunteers, and researchers, “flexible enough to be interpreted differently”. By analyzing how these artefacts were appropriated, modified, or abandoned, we could trace how design decisions materialized in practice and how children developed ownership of the tools.
- Interviews (one-on-one, focus group): At the end of the project, we conducted semi-structured interviews with NPO members, volunteers, and researchers to capture retrospective reflections on experiences, values, and outcomes. These complemented the immediacy of our observational data. Interviews were recorded, transcribed with Whisper [82], and then manually proofread; the audio files were deleted once final transcripts were produced.

Taken together, these four data sources enabled us to connect the micro-level of interaction (moment-to-moment participation, gestures, sound-making) with the macro-level of reflection (interpretations by volunteers, institutional practices of NPOs, evolving design principles). This multi-layered approach is consistent with the cyclical nature of Action Research, in which each cycle of planning, action, and reflection produces knowledge that informs the next.

3.6 Data analysis

The analysis followed two complementary strands, together producing a layered account of the design process. Combining multiple lenses ensured methodological triangulation [21], positioning our work not as a detached evaluation but as a reflexive, collaborative knowledge-building process consistent with Action Research cycles [40]. First, we

conducted a content analysis [29] of documentation, observational records, audiovisual traces, and artefacts from the three cycles (see Section 4), tracing how design ideas were introduced, modified, or abandoned, and how children and volunteers shaped these trajectories. Second, we carried out a comparative design analysis (see Section 4.4) of interfaces and interactions across cycles to highlight which features persisted or disappeared, thereby capturing both the chronological unfolding of events and the dynamics driving design changes.

The second analysis (see Section 5) is a thematic analysis based on interviews made after the three cycles giving more global insights on the project, the interfaces and design methodologies used, in a longer-term reflective perspectives. First and third author conducted the thematic analysis following the methodology outlined by Braun and Clarke [17]. Each of the two authors independently produced an inductive coding analysis [65] by highlighting relevant portions of the interviews. Inductive analysis involves coding data without adhering to a preexisting framework or imposing preconceived analytical ideas. The codes identified by both authors were then compared and discussed. Codes that were common to both were retained, while those identified by only one author were discussed and included if deemed relevant by consensus. The authors then independently organized the codes into themes, representing their interpretation of the data. Finally, the themes were reviewed and discussed collectively until a consensus was reached.

4 Workshop outcomes and findings

The study was structured around eight workshops organized into three iterative design cycles. Each cycle followed an AR framework composed of a planning phase, an action phase, and a reflection phase. In this section, we describe the three cycles in detail, highlighting the design decisions made during the planning stages, their influence on the unfolding of the workshops, and the insights gained through post-workshop reflection that guided the subsequent iterations. The planning phase involved collaborative scenario development between the research team and members of the partner NPO. The action phase encompassed the implementation of the proposed scenario through workshop activities, including both planned interactions and emergent, unforeseen events that shaped the course of the sessions. The reflection phase gathered participant feedback and consisted of structured discussions with association members to document and analyze individual and collective perceptions of what aspects were effective or required rethinking.

4.1 Cycle 1: Recording and triggering sounds

4.1.1 Scenario. The first workshop aims to have participants record sounds and trigger them using dedicated tangible interfaces. It begins with listening activities of objects and instruments brought to the children, followed by recording activities using microphones and finally playing back the captured material with various sound effects. Children can use dedicated interfaces to trigger modified versions of the recorded material. Several parts of the interface applies a distinct audio effect, allowing children to experiment with how a single input can be altered in multiple ways and to collectively discover the resulting sound variations.

4.1.2 Implementation. The scenario is implemented through four *stations* (see Figure 2 left). Each station is a tangible interface that would be used to record or trigger sounds. These stations are made of plastic or cardboard fixed on tables, and arranged so that participants can easily move around them to move from one station to another. One station is dedicated to the sound recording (called *record station*) thanks to a piezoelectric sensor and a microphone. To start recording, a participant needs to press the red button. The recording stops when the button is released. The three other stations (called *trigger stations*) are made to trigger and play the recording sounds with different sound transformations. Each *trigger station* is characterized by a specific sound effect. Various effects were experimented: reverb, pitch shifter,



Fig. 2. Cycle 1 workshops. Left: A prototype of an interface with four stations Right: Collective jam

echo, spectral resonator. Each *trigger station* is equipped with a piezoelectric sensor placed inside the box in order to trigger the sounds. Participants can interact with the sound by tapping on the box with their hands or with the tools available in the room. If the detected amplitude of the piezo is sufficiently high, a computer triggers the recorded sound with an effect adapted to the intensity of the impact produced by the participant. The software part is divided into two programming elements. One carried by an Arduino board that processes the information coming from the recording button. A second element written in the graphical programming environment Max/MSP and integrated in an Ableton Live session that handles sound recording and storage, the attribution of recording sound to the different stations, and the triggering of sounds when the piezoelectric sensors is activated.

4.1.3 Workshops with the children. We did two half-day workshops spread over two weeks (two Saturdays) with this scenario. The workshops took place in a meeting room in the laboratory associated with the researchers. The venue was chosen because it was interesting for J'imagerais to visit a laboratory and to go out of their venue. The first workshop took place with six children and six volunteers. The second with three children and three volunteers, different from the first workshop. On the recommendations of the members of J'imagerais, we broke the workshop down into steps that allowed us to explore each element of the interface.

The first step was to discover the piezoelectric sensor and how it can be used to record sounds. The researchers brought along a number of objects for the children and members of the NPO to play with and familiarise themselves with the piezoelectric sensors on the recording table. A second step was to let each children record materials and explore each trigger station with their own sound effect to experiment the different sound transformations based on a same recording sound. During the second workshop, the children were much more interested in using the microphone rather than the piezo sensor to record sounds, so that they could record their own voices and observe the effects on them. A third step was to play collectively with the four stations, where one children record different sounds while the others at the *trigger stations* ask to change their sound and effects. To bring the workshop to a conclusion, the group came up with the idea that each child should choose the sound they prefer with the associated effect, then finish the workshop with several sound jams where each child plays with their own box and sound (see Figure 2, right panel). One child preferred to use the microphone to sing and talk along and accompany the group in the jam with his voice.

4.1.4 *Post-workshops feedback.* The fact that the children had the freedom to try out the stations they wanted, without any other instructions, was well received by the members of the NPOs, who felt that the workshop was more like a moment of collective play with the children. This freedom was also appreciated because it allowed the children to take as much or as little part in the workshop as they wanted. Some children were very enthusiastic about using the stations right from the start of the workshop, while others needed more time to get used to them and to take a step back to listen to the others, sometimes because of “*over-stimulation with sound, not easy to get into*” as one volunteer explained. In addition, the stations’ affordance helped “*capture their attention, surprise them*”, as explained by a volunteer, due to the ability to hear many sounds in an amplified way that would not normally be heard. And the simplicity of the device was well received by the group because it allowed very rapid appropriation by the children and volunteers: the “*possibility of seizing what’s there without too many instructions*”, following the volunteers. Interestingly, the action of holding the button down to record and then releasing it to stop recording made participants use the record station in pairs, one that records and another that produces sound, and then led two participants to communicate (often nonspeaking) in order to synchronise and carry out a common action.

We also observed some limitations. Firstly, some volunteers mentioned “*the difficulty of identifying what each trigger station could do in relation to the others*”. Secondly, the environment and spatial organization of the workshop were at first sight perceived as rather ‘studious’ by the volunteers. The interface was set out on tables in a meeting room so that it could be used sitting in front of the tables. The low level of light in the room was also noted as contributing to this atmosphere. At the start of the workshop, this contributed to some children becoming more shy and withdrawn.

4.2 Cycle 2: The Sound map

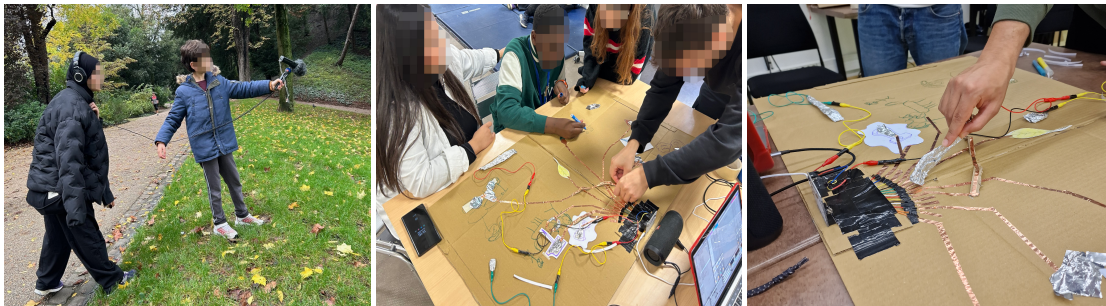


Fig. 3. Cycle 2 workshops. Left: *Sound walk* organized in park well-known by the children. Middle: building of the Sound map with drawings and copper. Right: triggering a sound with an aluminium stick

4.2.1 *Scenario.* We sought to keep the crucial aspect of recording the sounds around us and imagine building an interface, with the children, that could allow these sounds to be expressed in a creative and personal way. The scenario also tried to respond to the limitations identified, in particular by seeking to move away from the studious atmosphere of the previous workshops by rethinking the workshop environment. We chose to focus on the creation of a tangible sound map, developed collaboratively with the children from sounds recorded outdoor. In this scenario, children would capture sounds from their surroundings, with an increased emphasis on the recording process compared to previous workshops. These recordings would then serve as a collection of sounds used to construct the sound map, a visual and tangible representation of the sounds on a two-dimensional cardboard or paper surface. The objective was for the

children to graphically represent the sounds and position them within the spatial constraints of the surface. Finally, each drawing would be made interactive, allowing the sounds placed on the map to be triggered upon engagement.

4.2.2 Implementation. We used cardboard, paper, pencils and copper tape. Copper tape was used to create a circuit between a drawing and an Arduino board. the sound map was only used to trigger sounds. A first program were made for Arduino board that converts a digital input received when one of the thirteen copper circuit is closed in the map, into a midi value. This values are sent by the Arduino board to a Max patch load into an Ableton Live set. This Max patch will map the values received to a sampler with all the sounds loaded. A sound is triggered using aluminium rods connected to this same Arduino board which, once placed on a copper strip, simply closes the electrical circuit and sends a signal to trigger the associated sound (Figure 3, right panel).

4.2.3 Workshops. We realized three half-day workshops during this cycle. The first half-day was in a park familiar to the children and volunteers for the recording session (see Figure 3, left panel). The primary aim of this activity was to immerse the children in the experience of listening to sounds mediated by a microphone and headphones. The second objective was to gather a collection of sounds. The second half-day was dedicated to creating a sound map based on the collection of sounds. This activity occurs within J'imagerais' premises. The children and volunteers drew visual representation of a sound with markers and pencils (Figure 3, middle panel). During the activity, the children had to be helped by volunteers, and two children out of four were contributing to the drawings. Then, we traced copper paths between the drawings representing the sounds and an Arduino board, which was used to send the trigger signals to a computer in order to play each sound. In this cycle, we fostered collective activities, by setting up a workshop that allows us to collectively build the interface. This half-day was organised so that everyone was free to take part in the process as they wish, either by listening to and choosing sounds, or by drawing, or by tracing paths, or all at once. During the third half-day, we finished building the map and then played with it collectively. We were free to use the interface in any way we liked, and a number of different ways emerged spontaneously. First of all, the map was used in an *narrative* way. This was used as a representation of the walk made on the first day. The map was used as a sound support for a story told by volunteers into a microphone, either based on the walk taken, or by imagining a new story with imaginary events that the children tried to illustrate with the sounds available. A second use of the interface that emerged was a *musical* use. A child triggered sounds simultaneously or repeated the same sound without letting the sound sequence finish, thus producing a form of rhythm when the sounds were triggered.

4.2.4 Post-workshops feedback. The volunteers who assisted the children noted a high level of commitment from the children in the various activities, as well as positive forms of non speaking communication (smiles, time spent playing with the various tools). This led to the uses of the created artefact, the sound map, described by a volunteer as “*functional or rather musical interaction*”, illustrate the “*performative*” role of the map. The workshop has also been designed so that children have several ways to participate in the activities and becoming part of the group. If a child is not interested in the sound aspect, they can still participate by drawing, positioning the copper wires, etc. These multiple forms of participation also apply to volunteers accompanying children. The workshops are not just for children, but also for the various people present, as noted by the member of BrutPop: “*This may raise questions about how we ‘calibrate’ our work and our objectives, rather than thinking ‘we’re doing a workshop for such-and-such a sub-group’, how do we think we’re doing a workshop for everyone (including ourselves)?*”.

A key limitation observed with the Sound Map was that the addition of a representational layer through drawing did not resonate with all participants. Some children found this approach overly abstract, which led to limited engagement

with the drawing activity. While a subset of participants actively contributed to creating the sound map, others chose to engage differently by interacting with the completed map, selecting sounds, or simply listening. Given its partial effectiveness as a representational tool, this approach was not pursued further in subsequent iterations of the workshop design.

4.3 Cycle 3: Modular boxes

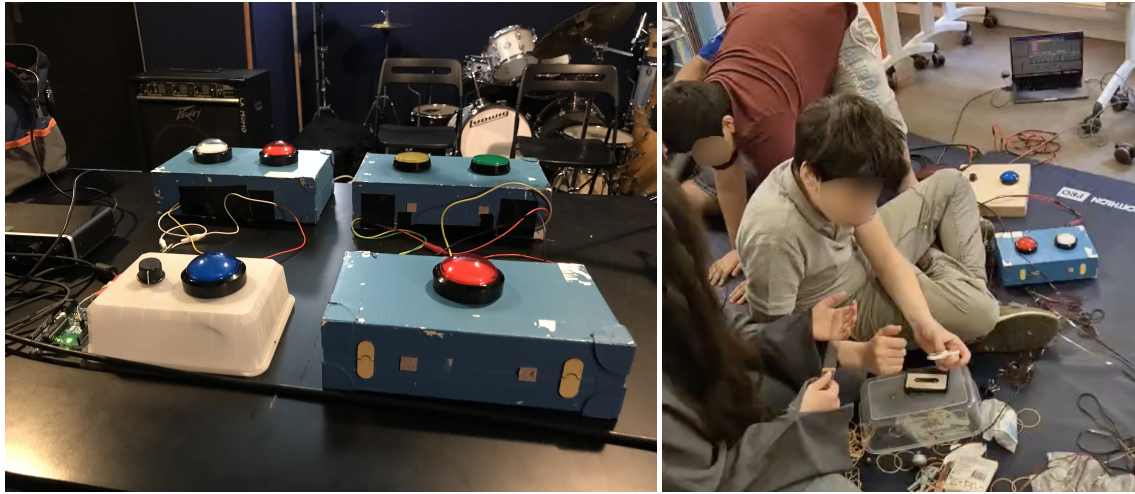


Fig. 4. Cycle 3 workshops. Left: Four types of boxes. Right: Free play session with various objects and boxes

4.3.1 Scenario. During the first two cycles, there were moments of musical improvisation that involved the children in a process of collective expression. The general aim of this last cycle was to encourage these moments. This third cycle takes up the ideas of the musical stations explored in the first cycle at the request of the members of the J'imagerais, who needed our workshops to strengthen the social links between each accompanying volunteer and the child for whom they are responsible, by having an activity that allows them to interact in pairs. Therefore, the scenario for the third cycle builds upon the scenario established in the first cycle, wherein various interfaces were employed to record and trigger sounds (either original or transformed). The primary distinction in this iteration is that each interface operates independently, possessing its own ability to record and trigger sounds. Clear affordances would be integrated into each interface to enhance usability. Each interface would be designed to be used primarily in pairs (child-volunteer). However, they would also function collectively, allowing multiple interfaces to be used simultaneously in a collaborative music-making session.

4.3.2 Implementation. Each station is designed as a modular box for recording sounds using piezoelectric sensors (see Figure 4, left panel). We built four types of boxes:

- (1) A box with a single recording button; once the sound is recorded, it automatically plays back in a loop. To record, press once, and press a second time to stop.
- (2) A box with a recording button that functions the same way as the previous box, along with an additional button to manually trigger the sound.

- (3) A box with two recording buttons that work similarly, enabling the layering of two sound loops through automatic playback.
- (4) A box features a recording button and a knob to apply effects to the recorded sound and adjust the intensity of the effect.

The software is designed to allow boxes to be added or removed without disrupting the overall functionality or requiring recording. The system is configured to support up to thirteen input elements (button or knob) for each Arduino board used. In our case, we used two Arduino boards during the workshops. This modularity allows the interface to be adapted according to the needs of the workshop by adding or removing the desired boxes. To enable easy movement of these boxes within the space, a solution based on adding Bluetooth modules to each box was considered. However, this common approach was not suitable in this context due to two specific constraints. Firstly, it did not allow for the instant addition of boxes, as connecting a new module required someone to spend time managing the connection on a computer. This increased the technological complexity of the system, making it more difficult for members of the NPO J'imaginerais to use, as explained in the Methods section. As a result, we opted to retain a wired connection system using multi-meter cables, which was perfectly suited to the musical play scenarios in which the interface was used. To connect a new box to the system, the user only has to attach two crocodile clips to two screw heads coming out of the box which is directly ready to use.

As in previous cycles, the Arduino board managed digital inputs from buttons and knobs, with a maximum of thirteen connections. These inputs were routed to Ableton Live, where Max patches controlled each box through dedicated tracks. We pre-configured all tracks in advance, enabling new boxes to be added simply by linking their output to the corresponding Arduino input.

4.3.3 Workshops. We realized three half-day workshops during this cycle. The first workshop was organised in pairs, with children and volunteers working together. As in the first cycle, the workshop began with an introduction to piezoelectric sensors from the point of view of recording and listening. Then each pair learned how to operate their own box. The next two workshops were organised collectively. Their ambition was to create, at the beginning of the workshop, a space filled with various objects, including piezoelectric sensors, microphones and different boxes, where the participants could freely explore and play with these materials (see Figure 4, right panel).

4.3.4 Post-workshops feedback. The interfaces were first used to create a relationship between each child-volunteer pair. It enabled the volunteer to gain a better understanding of the child's forms of non-speaking communication, to understand how the child behaves and reacts to situations in the workshop (such as the need to move around a lot or hypersensitivity to certain sounds), and finally to understand the child's tastes and what they like to do in the activities. Once this stage was over, the children spent some time playing with the piezoelectric sensors, microphones and objects available in the workshop space. Some of the volunteers were initially disturbed by this, but saw it as an opportunity to develop new practices: *"I also had the feeling that it was a bit messy and it's true that the whole session didn't have a set objective. However, I was also wondering whether the lack of clear objectives also allowed experimentation that went in lots of different interesting directions, and whether sticking to an objective would prevent that?"* as a volunteer said.

Then boxes with an automatic loop function created a background sound onto which the children could superimpose louder sounds. Placed among various objects, the boxes were moved by the children and volunteers to record new sounds. In this configuration, the interface was no longer the central point, but one element among others in the construction of a sound environment. BrutPop member also noticed the importance of the microphones for some

children whether verbal or not, to record their own voice and play with it, mainly due to the familiarity they have with this sound: *“It was interesting to see how attentive the young people were when they heard their own voices and even reacted or improvised with them. I think it’s striking how even for people who don’t speak, there’s often a very strong connection with the voice/sounds produced with the mouth. And while no one wanted to use the portable recorder the day before, despite our suggestions, it seems to me that all the children used it on Tuesday morning, even though it wasn’t planned at all.”*

4.4 Comparing designs

In this section, we analyze the ADMI designs between cycles. Figure 5 depicts the main design characteristics of the ADMIs from cycle 1 to cycle 3. Design features are divided between sound material, interaction and interface. Colors indicate what has been retained from one cycle to the next, or what is specific to a given workshop.

- **Recording strategy.** We found that what had remained over the three cycles was basing our workshops on recorded sounds, as well as imagining interactions away from the computer. Three sound recording strategies were used: piezoelectric sensors, microphones and sound recorders. While sound recorders were useful for exploring the listening of everyday sounds, piezoelectric sensors and microphones were better suited for integration into manipulative interfaces.
- **Fostering engagement.** We found that direct manipulation brought better engagement. In the first case, the interactions were often direct and associated with familiar elements, the environment or known sound and voices. In the second case, the workshops dedicated to triggering the sounds, such as the construction of the map, or familiarisation with the functionalities of the interfaces, were more difficult for some children to integrate, took longer and required these activities to be broken down into small steps. The barriers to access vary among children; therefore, structuring the activities into small, sequential steps helps reduce these barriers for those who need additional support, while preserving group cohesion and enabling a shared collective experience.
- **Between passive and active interaction.** Introduced in Cycle 3, the interface enabled passive use allowing sound loops to play continuously without requiring sustained input from the children. We found that this functionality supported moments of disengagement and self-regulation without disrupting the overall activity. It offered two key benefits: it respected each child’s individual rhythm by enabling interaction on their own terms, and it served as an attractor, inviting re-engagement when the child was ready.
- **Low-cost material.** The use of low-cost and readily available materials throughout the project facilitated rapid and iterative design of the interfaces. This affordability not only enabled flexible prototyping and modification but also supported the integration of interface construction directly into the workshop activities with the children. For example, in the case of the sound map, children were actively involved in the physical and visual design, fostering opportunities for personalisation, appropriation, and creative ownership.
- **Interface mobility.** Across the three workshop cycles, the interfaces evolved toward increased mobility. While initially fixed to tables in Cycle 1, the modular boxes introduced in Cycle 3 were specifically designed to be more portable and easily repositioned within the activity space. This enhanced mobility enabled the interfaces to adapt to the children’s spontaneous movements and preferences. For instance, allowing them to engage while walking around or to interact more quietly while lying on the floor. By supporting a variety of bodily engagements, the mobile design fostered greater spatial appropriation and autonomy, allowing each child to interact with the technology in ways that were physically and emotionally resonant for them.

	Cycle 1	Cycle 2	Cycle 3
<i>Sonic material</i>	Recording sounds Piezzo and mic to record sounds Objects and instruments as sonic sources	Recording sounds Use sound recorder "Sound walks": Sounds recorded in the wild	Recording sounds Piezzo and mic to record sounds Objects and instruments as sonic sources
<i>Interaction</i>	Triggering sounds Piezzo to trigger sounds	Triggering sounds Conductive tape on a paper	Continuous sonic interaction New controls (knobs)
<i>Interface</i>	No interaction with computers Stations fixed on a table Multi-users interface	No interaction with computers Sound maps	No interaction with computers Mobile sound stations Interfaces to be used by pair Loop function to let the interface in background

Fig. 5. Comparison of the main design characteristics between cycles in terms of sound material, interaction and interface. The colours indicate what has been kept from one cycle to the next.

- **Multi-user interfaces** Throughout the different cycles (particularly in Cycles 1 and 3) we deliberately designed the interfaces to require multi-user interaction. In Cycle 1, for instance, the sound triggering stations were dependent on a separate sound recording station, necessitating collaboration. While this interdependence was set aside in Cycle 2 in favor of more individually usable interfaces, we reintroduced paired usage in Cycle 3. This design decision was based on the observation that shared constraints within the interface promoted the emergence of collaborative scenarios during the workshops. These constraints facilitated the co-construction of meaning and supported deeper engagement from the children by encouraging joint participation and interdependence.

5 Interview findings

This section presents the thematic analysis based on the interviews made after workshops, with the BrutPop member and second author (called B1), the NPO director of J'imagerais and accompanying adult (called J1), and three accompanying adults during the workshops, present in all the cycles (called A1, A2 and A3). We established two themes from our data. The first theme examines the key factors that facilitate adaptation in musical activities and promote children's autonomy. This second theme examines the factors that support an interface design process attuned to social dynamics in the activities framing a relational network-based design.

5.1 Autonomy and Adaptability: Nurturing Self-Directed Engagement

One of the main objectives put forward by the NPO J'imagerais is to encourage children's autonomy, particularly in the social context of the group of children taking part in the activities. J1 understands children's autonomy by

distinguishing between doing and acting: *“Politeness is doing. Acting is something inherent”*. For them this distinction is critical in understanding autonomy as it involves not just the capacity to perform tasks (doing) but the ability to make decisions and take actions that are self-directed and intrinsically motivated (acting). This objective of autonomy structured the way in which the workshops were set up, although there was no guarantee of success. Through the interviews we found four factors that enable adaptation and foster children autonomy.

5.1.1 Fostering autonomy through flexible workshop objectives. We found that a first factor promoting autonomy was not to impose objectives on the workshop. In this way, the children had the space to explore, interpret and create without the pressure of conforming to specific expectations, as A2 explains: *“I don’t think they would say that they had to reach a strict objective, but more that they managed to do this, that they managed to accept wearing the headphones, and even to go and look for sounds. That they smiled at certain things. Finally finding what they like to do, what they want to explore”*. Open instructions invite children to use their imagination and express their individual musical ideas, reappropriating interfaces for their own purposes, as described by B1: *“Some very creative things were emerging, things that were a lot less in line with what we might have expected, that were hijacking our proposals”*.

5.1.2 Open forms of participation. The second factor was to recognize and value the different forms of children’s participation. For example, A3 focused on valuing more passive participation: *“not all the children were equally receptive during the workshops. Even so, I think there are many forms of participation that can sometimes be more passive, and that can be just as valuable for the children”*. Allowing children to engage by listening (or observing others) respects their individual comfort levels and learning preferences, and can be a step towards more active engagement as children gain confidence and understanding.

Valuing diverse forms of participation requires supervisors to question their own bias about what constitutes a legitimate form of participation as illustrates B1: *“what the child was doing was incredibly expressive, aesthetically very surprising and interesting, but it obviously didn’t fit into the “framework” of the workshop as understood by the volunteer, or perhaps not into the “framework” of what they considered as interesting/legitimate/etc. expression”*. The challenge for facilitators and us is to find a balance between guidance through advice and allowing the unexpected and unconventional to emerge.

5.1.3 Valuing the process of appropriation over the outcome. We found that the process of designing and making the interfaces were identified as more important than the final result of the interface at the end, as explain A1: *“For me, the project was not about building a musical instrument; that was not the primary aim of the project. It was also about learning and seeing how such a project unfolds, about the whole process itself.”* The time spent making the interfaces during the workshop, following J1 was more a time to *“create a space in which you allow yourself to explore sound or music in a fairly direct way”*. Here, the term *space* denotes both a physical and psychological environment where exploration is encouraged and facilitated.

B1 pointed out that a diversification in the uses of the same interface has also emerged, suggesting the versatility of these devices: *“With any sound system, the same thing can take many forms depending on the context in which it’s used and who’s using it. (...) Sometimes it’s not necessarily a big deal to guide them towards something because, in fact they don’t give a damn they do what they want”*. By not planning a clear objective as to how the interfaces designed during the workshops will be used, we found that these interfaces become generative tools for developing various autonomous forms of musical play between the participants : *“It’s perhaps almost the idea of appropriation. We thought, this tool is going to be used to create a kind of real-time sound effect for a video. All of a sudden, it becomes more of a sort*

of experimental musical sampler, then a sound support for an oral narration. The idea of narration emerged without me suggesting that it should. So it's interesting to think about how people can take these tools and develop things that make sense to them." (B1)

5.1.4 Tuning the level of abstraction in sonic interaction. We found that children's degree of involvement was influenced by what A3 called a degree of abstraction in interactions: "Either you do something very direct, where the system is very closed, where you do one thing and another thing happens as a result. It's a bit easy to understand and comforting. Or you can do something that's quite open, where the drawings give you the opportunity to get involved and create meaning. But at the same time, it's more open and complex and therefore can be a little more abstract. There's a bit of a balance between the two."

Therefore, the complexity of the interface may stem from its abstraction, i.e. the difficulty of making a direct link between the actions performed and the sounds produced. The difficulties encountered by some children in engaging with interfaces underline the need for personalized approaches that can take into account the complexity of interactions arising from the perceived level of abstraction. J1 asserted that the process of familiarization with complex interfaces involves breaking down activities and repeating them: "You can go through the first stages of recording again. You see, repetition anchors it. But once again, it creates a memory." In that sense, the workshops were organised into activities breaking down the various elements involved in using the interfaces, such as recording sounds, disrupting sounds with selected effects, familiarise with one interaction after another or playing with others.

5.2 Relational network-based design

The workshops bring together people with diverse backgrounds: researchers, NPO members, and children. Each one brought their skills, expectations, and aspirations regarding the outcomes of the workshops and how the workshop will proceed. This section examines the factors that support an interface design process responsive to the social dynamics within a collective context.

5.2.1 Towards a relational network-based design. We found that working to develop an inclusive musicking ecosystem means first and foremost working to create and strengthen relationships between people. As J1 put it, the workshops are the setting up of a "relational network". J1 highlighted the necessity to research of a zone of common interest: "And to use these centres of interest to redefine the space. And not the other way round, forcing ourselves to adapt to the space. Knowing BrutPop's philosophy, it's more or less this idea of how we move forward according to the children. And at the same time, how they stick to what we offer them. To develop this area of interest".

Thus, what constitutes research, in the sense that it allows us to co-construct this space and design musical interfaces, is the development of these relationships to understand and integrate each individual's specificities as J1 explicated: "Now that we all know each other, we're pushing back the boundaries, you see, and I think that's where research becomes interesting again, it's about exploring things we don't know yet". A relational network-based design methodology emphasizes the co-construction of a design space through the development of interpersonal relationships.

5.2.2 Dynamic roles. We found it beneficial that traditional hierarchies were removed: the roles of researcher, assistant, participant and moderator became blurred and interchangeable, encouraging equal participation. Everyone involved is both a contributor and a beneficiary. These roles (participant, assistant, moderator, researcher) were not necessarily assigned to any particular person, which contributed to the evolution of relationships between individuals. Researchers, who usually have an observer role in the workshops, or members of the NPO who may have a role in assisting the

children in the workshops, were also direct participants in order to play collectively with the children, as emphasized B1: “*You mustn’t see these people just as supervisors or support staff but also as beneficiaries*”. This facilitated greater interaction among stakeholders, progressively strengthening interpersonal connections and fostering a deeper mutual understanding within the group.

5.2.3 Nonverbal forms of communication. These relationships were also strengthened by the importance given to non speaking forms of communication. On the one hand, this was particularly important with the children, most of whom were non speaking. How children can take their rightful place within this ecosystem, also understand how children perceive the interfaces present, and in particular how they are engaged with these interfaces requires spending time interacting with children and understanding their non speaking forms of communication as illustrate A1 : “*I saw him more receptive to the sound he heard, rather than looking for it himself. He’s managed to accept this, the headphones, and even go and get some sound. That he smiled at certain things.*”. These expressions may manifest through individualized gestures used to communicate, distinctive bodily movements, unconventional forms of attention, or spatial behaviors, such as moving away from the activity to signal disengagement, or conversely, positioning oneself at the center of the space to indicate active involvement. On the other hand, it was also important for moderators. B1 emphasized this point as follows: “*In a workshop situation, you don’t necessarily want to interrupt the thing to tell someone: you have to do this, so it just requires you to be on the same wavelength a bit and also to communicate a bit non-verbally*”. In this way, similar to moments of collective musicking where non speaking interactions are strong, moments of interface design have also collectively required these forms of communication.

6 Discussion

This research focuses on the participatory design of musical interfaces with and for autistic children. In a first analysis of the evolution of the interface design, we identified insights that promote collective musicking in terms of 1) Sonic material (i.e. recording strategy); 2) Interaction (i.e. fostering engagement, passive and active interaction, multi-user scenarios); 3) Interface (i.e. low-cost material, mobility). Then, through a thematic analysis of the interviews made at the end of the series of workshops, we have identified key factors that allows: 1) to promote the children’s autonomy in the workshops, through open forms of participation, reappropriation, workshop flexibility, abstraction in interactions; 2) to support an interface design process responsive to the relational dynamics within a collective context, through dynamic role assignation and nonverbal forms of communication.

This section first trend

addresses an ongoing tension in the literature on participatory design with autistic people between providing structured, predictable environments and allowing openness to support autonomy. We argue that *designing with ambiguity* offers a way to reconcile these views by situating interpretive interface designed within stable supportive structures. Finally, we examine how power asymmetries in participatory design can be negotiated by addressing the need to establish common ground through the identification and negotiation of differences in stakeholders’ expectations, priorities, and practices, as well as by reflecting on the role of the environments in which participatory activities take place.

6.1 Negotiating participation: between structured and ambiguous design choices

The results presented above contribute to answering our first research question by shedding light on how participation and engagement emerge and evolve over time within collective musicking workshops. They highlight that diverse

forms of participation appeared by fostering children’s autonomy thanks to flexible workshops organization, and the introduction of abstraction within musical interactions, enabling diverse forms of appropriation by the children.

Rather than prescribing fixed modes of use, these design choices supported a range of engagement styles and allowed participants to negotiate their own ways of taking part in collective musicking. However, this approach appears at first glance to be in tension with much of the participatory design literature on working with autistic children, which often emphasizes the importance of providing highly structured, predictable, and clearly framed activities. For instance, within the D4D framework, Benton et al. recommend structuring activities so as to “*set a predictable sequence of activities to make the environment more comprehensible and prevent anxieties related to uncertainty or surprises*” [8]. Similarly, Millen et al. caution that “*when presented with too many open-ended options the child may feel anxious or frustrated and becoming unwilling to participate in the activity*” [61]. Such guidance reflects a concern that excessive openness or ambiguity may increase stress or inhibit engagement. At the same time, recent critical work has raised concerns about how overly constrained design approaches may limit the autonomy and agency of marginalized users, including autistic children. Spiel et al., for example, argue that HCI “*lacks technologies that enable autistic children to engage with them in a self-determined way*”, noting that “*the content is either given by the system or set by teachers around them. Autistic children cannot use these technologies to actively investigate their own interests*” [74]. From this perspective, tightly framed activities risk reinforcing power asymmetries by positioning children primarily as recipients of pre-defined experiences rather than as active agents of exploration.

Our intention is not to challenge the importance of stability, comfort zones, or structure for autistic children, nor to suggest that openness should replace scaffolding in participatory design. Rather, drawing on our empirical experience, we aim to refine this debate by asking what, within participatory contexts, needs to remain fixed and what can productively be left open to appropriation. Our findings suggest that structure and openness are not oppositional, but can be carefully combined within participatory design processes. In our project, we engaged with this approach iteratively, sometimes through trial and error, but always through dialogue with all the stakeholders involved. Certain aspects of the workshops were deliberately structured and ritualized to provide stability: for example, sessions consistently began with a collective introduction round involving children, volunteers, and researchers, allowing each person to present themselves to the others and symbolically marking the transition into the activity. These elements established a stable and reassuring framework, embedding routines that aligned with those already in place within the NPO beyond the scope of the project. Within this frame, however, we deliberately introduced elements of openness into the design of the activities and interfaces. Our findings show that ADMI can benefit from incorporating zones of indeterminacy, where affordances remain open-ended, for instance, when interfaces allow multiple forms of bodily engagement such as pressing, stroking, or moving around an object. This openness enabled children to discover and develop ways of musicking that aligned with their sensory preferences, abilities, and interests. Importantly, this form of ambiguity did not function as a fixed property of the interfaces themselves, but as a principle enacted through practice. Embracing this ambiguity was neither straightforward nor risk-free. Sustaining participation required continuous adjustment, attentiveness to relational dynamics, and sensitivity to diverse expectations and modes of engagement.

To articulate this balance, we argue that ADMI research can usefully draw on HCI work on *designing with ambiguity*, which conceptualizes ambiguity as a property of the interpretative relationship between people and artefacts, and can invite users to construct their own interpretations, negotiate meaning, and engage more reflectively with them [36, 37, 54, 71]. More broadly, ambiguity in interactions between human and non-human agents can support negotiation of lived experience and the establishment of common ground [66]. Despite this substantial body of work, ambiguity has rarely been incorporated into participatory design methodologies involving neurodiverse participants, where

predictability and clarity have generally been prioritized. In contrast, within the non-profit organizations we collaborated with, practices involving a high degree of openness and freedom, such as allowing children to engage musically without explicit instructions or explanations of how interfaces work, were already part of everyday activities, and did not necessarily generate rejection or anxiety. These practices emerged from long-term experimentation and situated expertise developed within the organizations, rather than from formal design guidelines.

In sum, our study suggests that designing with ambiguity can complement existing participatory design frameworks for autistic and neurodiverse children, rather than contradicting them. By situating ambiguity within stable relational and organizational structures, participatory design can support autonomy without abandoning care or predictability. We argue that further investigation of ambiguity within participatory design with neurodiverse communities would advance ongoing CSCW debates on agency and autonomy in inclusive design practices.

6.2 Power relation and asymmetries in participatory design

The findings presented above provide elements of response to our second research question, which asked how participatory design processes could remain responsive to social and relational dynamics within collective contexts. In particular, our results highlight the importance of role assignment during activities and the central place of non-verbal forms of communication in enabling participation. However, these social dynamics evolved significantly over the course of the project and repeatedly raised implicit questions about power asymmetries into these dynamics, especially given that the study involved autistic children, the majority of whom were minimally verbal.

Power relations in HCI and CSCW are not limited to the intentional exercise of coercive control over participants. Rather, they also stem from the positional authority of researchers and designers, which persists even within Participatory Design (PD) contexts [15, 77]. This authority typically grants them responsibility for organizing and planning projects, selecting methods, tools, and techniques, and exercising the power to make design decisions, thereby situating them in a structurally influential position within system design processes. PD has long been envisioned as an approach to democratizing innovation by redistributing power between designers and participants. However, scholars have consistently questioned what participation actually means in practice, prompting reflection on who initiates design activities, who directs them, who benefits from them, and how participation is enacted [13, 79]. This debate has led to broader discussions about values in participatory design [44], how conflicting views are negotiated and articulated, and what constitutes a design outcome [16].

In our experience, power asymmetries between researchers, children, volunteers, and other stakeholders were not fixed, but emerged and shifted throughout the project. They must therefore be continuously negotiated rather than assumed to be resolved through participatory intent alone. Two factors in particular appeared to play a decisive role in shaping these asymmetries and deserve closer examination. We discuss the first factor through one illustrative moment captured by the following citation:

“At one point a child was making really incredible sounds into the microphone. Each time, everyone turned around, wondering where it was coming from, whether it was a sound from outside, or something recorded that he was triggering on the sound map. It might have sounded like sirens or other high-pitched sounds. One of the assistants would encourage him to do other things with the microphone, to either tell a story or sing a song into it. I think she may even have said that the high-pitched sounds weren’t particularly pleasant. Without being critical of the volunteer, it made me wonder about our expectations, about what we want to emerge and what might actually happen, about the unexpected that emerges, and about our ability to

encourage it or, on the contrary, to restrict it and prevent it from blossoming. Here I found, on an individual basis, that what the child was doing was incredibly expressive, aesthetically very surprising and interesting, but it obviously didn't fit into the "framework" of the workshop as understood by the volunteer, or perhaps not into the "framework" of what they considered as interesting/legitimate/etc. expression. Once again, this is not to criticise them, but to question how our own prejudices can sometimes cut off the momentum of possibilities. " (B1)

This account highlights a first source of power imbalance: the absence, at certain moments, of a shared understanding of what constitutes legitimate participation, expression, or contribution within the design process. While the child's sonic exploration was expressive and meaningful, it conflicted with implicit expectations held by the volunteer regarding what the activity should produce. This tension draws attention to the challenge of establishing common ground, understood as achieving mutual understanding through identifying and negotiating differences in expectations, priorities, and practices [50]. In our study, difficulties in attaining common ground emerged not only between children and researchers or volunteers, but also between researchers and volunteers themselves. These difficulties stemmed from uneven recognition of each other's expertise, lived experience, and crucially from divergent understandings of how autistic children express themselves. This misalignment was gradually mitigated throughout the project through sustained attention to how each participant was engaged in the workshops, not only among the children, but also in interactions between researchers and volunteers. These observations were subsequently made explicit and collectively discussed. In addition, the first author took part in the association's volunteer training programs, which aim to establish a shared theoretical and practical foundation regarding disability and appropriate ways of interacting with the children. Notably, these trainings were conducted by autistic individuals with lived experience.

A second dimension of power asymmetry emerged through the choice of environment in which participatory design activities took place. The role of space and setting in participatory design has been widely discussed in prior work. Benton et al. argue in their D4D method that PD must "support a design environment in which individuals feel comfortable and confident generating and sharing creative ideas alongside designers" [8]. Similarly, Harrington et al. emphasize the importance of enabling marginalized people to engage on their own terms, in environments that feel empowering rather than further marginalizing [38]. The volunteers in our first cycle of the project underscores the implicit effects produced by the laboratory as a "studious" space, one that tacitly reproduced teacher-student dynamics between researchers and participants, dynamics that we had sought to avoid. Notably, this effect was not the result of explicit rules or instructions, but emerged from the atmosphere and symbolic authority associated with the space itself. The initial decision to conduct workshops in the laboratory stemmed from the non-profit organization's own practices, which often involve taking children out of familiar environments to visit new places. In response to the unintended power dynamics observed, we later sought to balance this objective with the need to create spaces in which children felt safe and confident. This led us to conduct workshops in environments more familiar to the children, including the organization's premises and outdoor spaces such as parks, where children already had established routines. These choices implicitly redistributed power by situating activities in spaces where children had greater agency and familiarity. We argue that these spatial and organizational dimensions of power deserve further attention in participatory design with neurodiverse populations, where subtle asymmetries can significantly influence who is able to participate, how they participate, and whose expressions are recognized as legitimate.

6.3 Design lessons

In terms of design implications, this paper emphasizes that design must be grounded in a careful attention to the needs, preferences, and rhythms of autistic youth, resisting normative design goals in favor of relational and context-sensitive responsiveness. This stance aligns with prior critiques of deficit-oriented and individual-centric design framings in HCI and CSCW [74]. Within this perspective, our findings do not translate into prescriptive guidelines but instead offer a set of implications for design emerging from situated practice:

- We observed that children engage preferably with sound in an immediate way, while abstract representations, symbolic mappings, or complex intermediary steps were more demanding. The use of low-cost, modular, and mobile interfaces enabled the design of simple workshop scenarios, fostering immediate experiences. Thus, our findings suggest that accessibility was supported by tools that respond to evolving dynamics, and enable rearrangement within the activity space to support spontaneous, non-expert engagement. This suggests that designing ADMIs requires attention not only to interaction techniques, but also to how artefacts circulate, evolve, and become embedded within existing social environments.
- We found that certain design decisions supported engagement at both individual and collective levels. On the one hand, individual engagement was fostered by incorporating familiar elements, such as recognizable sounds (e.g., voice) or by situating interactions within familiar environments, which allowed children to create meaningful anchors and reduced barriers to participation. On the other hand, collective engagement was encouraged by inter-dependencies within the interfaces that required or invited collaboration between participants. For instance, in Cycle 1, separate stations were dedicated to recording and triggering sounds. These findings reinforce the idea that collaboration can emerge not from explicit instruction, but from designed interdependencies within sociomaterial systems.

Rather than prescribing how interfaces should be used, designers are encouraged to create conditions that allow diverse forms of engagement to unfold, shaped by the participants, the setting, and the evolving dynamics of collective activity.

6.4 Limitations

Given as a design intention, relying on the practices and knowledge already existing within the NPOs, was necessary in the design of the interfaces, but can also be seen as a limitation. Indeed, this led to using certain technological tools such as the software Ableton Live or Max/MSP because they are an integral part of the practices of the member of the BrutPop NPO. However, this associative ecosystem has shown us the dynamics of changes that can lead to changes in the tools used. Although the interfaces are totally re-usable and re-appropriable, the software Ableton Live and Max/MSP used in the workshop are considered as non-open source and could become unusable in the case of a continuation of the activities without the BrutPop's members and the researchers. In addition, the time spent in NPO generally represents a very small part of the children's time. To go further, and to have continuous monitoring with children, it would be necessary to continue the workshops in the children's living environment, which are generally medical institutes. This would confront and highlight the friction between the approach according to the social model of disability taken in this research, and a more therapeutic approach generally considered in institutes by medical staff.

7 Conclusion

This contribution presents the results of a year-and-a-half-long research collaboration with two local NPOs aimed at developing and exploring collective musical creation activities with autistic children, with no prior musical training.

We proposed an action research methodology with the NPOs, who are deploying musical and cultural activities for and with audiences with specific needs. This research identified several key elements for understanding the interaction design elements facilitating children's autonomy and engagement in musical activities. We have also shown that design decisions were shaped by careful consideration of social interactions between children, facilitators, and researchers. Although our results were obtained with autistic children, we believe that our findings and discussions on supporting participant autonomy and negotiating power asymmetries align with wider participatory design literature on working with marginalized communities and could provide broader insights for the design of interfaces with people facing barriers to access due to their marginality, whether they are considered disabled or not.

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A Children details

The following list summarizes the specificities of each child who participated in the workshops, including physical, sensory, and emotional specificities, as well as preferred modes of communication. Primarily collected by the NPO volunteers, these insights are essential to consider when preparing for each workshop:

- **Child 1:** Not very verbal, develops language (repetition). Encourage him to talk back and ask for things. Seems to understand the group, but doesn't stay put for long, moves around a lot. Can become attached to facilitators (boy), quickly goes around an activity and needs to run/play, likes to be outdoors. Difficulties with transitions, cries when changing/ending outings. Constantly in play.
- **Child 2:** Non-verbal, except for singing nursery rhymes. Stimulating him to communicate, his language is still developing. Active, he likes to be on the move. He needs to be encouraged to be active. Slightly average motor

skills, but rather agile. You need to guide him in his movements (he may stumble when walking upright). Very attracted to screens, avoid putting the phone next to him.

- **Child 3:** Non-verbal, a lot of no. Tends to stay isolated and behind the group. No structure or school and no support nearby, used to being alone and having things handed to him easily. Uninvolved in activities, he needs to be stimulated and strategies found to get him involved.
- **Child 5:** Non-verbal. Very curious, seeks out windows to observe. Likes to lie down/sit on the floor, likes someone to do things for him when he can do them himself (e.g. his shoes). But will get up when asked. Very tactile, grabs hair without pulling. Lots of cuddling and pinching. Hypersensitive to sound. When frustrated (toooy and frustration) bites hands/arms, but not aggressive.
- **Child 6:** Oral non-verbal, hypersensitive (noise, touch). Can become fixated on something, which causes frustration. Frustration rises sharply when there's a lot of waiting to be done
- **Child 7:** Verbal. Likes to be the first at activities, follows instructions well (which sometimes need to be re-explained if he's not concentrating). Very hyperactive, likes to play and run.
- **Child 8:** Oral non-verbal. Pushes him to do activities. Hypersensitive in general but disturbed by loud noises. Tends to fixate on a leader, needs reassurance. Can rarely point to indicate what he wants.
- **Child 9:** Non-verbal oral, likes to imitate. Very hyperactive. He is aware of danger and holds his hand outdoors. Can scream or break things when frustrated. Difficult to interest him in outings, he prefers to wander.
- **Child 10:** Verbal. He's used to being in a group. Interests: fairy tales (3 little pigs, etc.), can be in a loop. He needs to be brought out of his loop and interested in other things. Likes to be drawn for, encourage him to do it on his own.
- **Child 11:** Oral, non-verbal. He takes a lot on himself and contains his emotions (which he may release at the end of the day in a crying fit). Observe his reactions and reassure him. His stereotypies (repeated hand movements) stimulate him; he likes to move and walk, but doesn't escape. Can focus on an object, which makes him frustrated. Responds to interaction and seeks out animators from time to time.
- **Child 12:** Oral, verbal. He tends to enter a bubble when he starts playing with his drool and ignores those around him. Try to interact with him as much as possible so he doesn't shut himself off. Hyposensitive to touch. At his own pace, but accepts opening up to others and interacting.
- **Child 13:** Verbal, likes to take time to chat with volunteers. Needs attention. Difficulty with noise, may be disturbed by noisy youngsters. Involved in activities that interest him and takes his time.
- **Child 14:** Oral non-verbal. He has a limited attention span, needs to be stimulated and do things in stages. Likes walking and the outdoors. Hyposensitive, sensation-seeking.
- **Child 15:** Verbal, very communicative and autonomous, knows the workings of the association very well. Great interest in cars.
- **Child 16:** Verbal. Poor notion of space, he pushes people around him. Good motor skills, try to get him to move around as much as possible so that he spends his energy. Use echolalia (repetition). Don't hesitate to repeat instructions.
- **Child 17:** Verbal. Dynamic, he can easily become frustrated when locked into something. Needs moments of isolation, taking him out of the group to get him down from frustration.
- **Child 18:** Oral verbal, tends to settle down, lie down and do nothing. May isolate himself in the toilet when not interested in an activity. Outside, he holds the arm of the volunteer + rather slow or focuses on water bottles/

leaves/suit buttons. He needs to be brought into the activity and encouraged to participate. Very involved in arts and crafts. Energy peaks may start running and screaming.

- **Child 19:** Non-verbal oral. Involved in activities, imitates a lot. Needs to be occupied during latency periods. Communication: pointing, takes the leader's hand, eager to communicate, seeks interaction.