# Drawing the User Experience of Young Children

A thesis submitted to the University of Trento
for the degree of Doctor of Philosophy
in the Department of Information Engineering and Computer Science,
International Doctoral School in Information and Communication Technologies

Cristina Core
30th Ph.D. cycle

2018

Advisor
Prof. Antonella De Angeli, University of Trento (Italy)

Thesis examiners
Prof. Netta Iivari, University of Oulu (Finland)
Dr. Elisa Rubegni, University of Lincoln, (United Kingdom)

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# Abstract

The aim of this thesis is to analyse the trustworthiness of drawing as a method for evaluating the User Experience of young children (age 3-6). This method is not new in Child-Computer Interaction, but few studies have investigated it with young children in the kindergarten. This thesis analyses data collected in two case studies. A first longitudinal study, involving 27 participants, was aimed at investigating children's UX when interacting with a system allowing for collective music making by physical movement. The second study, involving 31 participants, investigated children's interaction with a tangible user interface detecting colours and emitting sound according to them. Both studies comprised a drawing activity to be run right after the end of each interactive session. Drawings were thematically analysed and contrasted with opinions gathered by adults attending the interactive sessions with the children (designers, teachers, researchers). According to the analysis, information that can be found in the drawings proves sufficiently trustworthy to capture young children's UX, but it is strongly affected by age, and requires a mediation by teachers to be interpreted.

# Declaration

This disclaimer is to state that the research reported in this thesis is primarily the work of the author and was undertaken as part of his doctoral research. In two out of three of the referenced papers the student was the leading author.

The work reported in Chapters 3,4, 5 and 6 has been published as follows. The content of these papers has been re-interpreted and rewritten in the thesis.

Core, C., Conci, A., De Angeli, A., Masu, R., & Morreale, F. (2017) Designing a Musical Playground in the Kindergarten. In *Proceedings of the International Conference of British HCI* – Sunderland (UK)

Masu, R., Conci, A., Core C., Morreale, F., & De Angeli, (2017) A. Robinflock: a polyphonic algorithmic composer for interactive scenarios with children. *14th Sound and Music Computing Conference* – Espoo, Finland

Conci, A., Core, C., & Morreale, F. (2015). Weighting Play and Learning in Interaction. Play and Learning Experience (PALX) Workshop. *CHItaly* conference – Rome.

# Acknowledgements

I would like to thank Prof. Antonella De Angeli for sustaining me in the ups and downs of the PhD journey, Prof. D'Andrea for the challenging questions, Prof. Netta Iivari for the comprehensive feedback, Dr. Elisa Rubegni for the apt observations, Prof. Janet Read for the inspiring discussions, Dr. Gavin Sim for the thorough assistance, Prof. Panos Markopoulos for the prototyping challenges, and Prof. Liam Bannon for the inspiring talks and encouragements.

I would also take the chance to thank the people with whom I had the pleasure to share thoughts, food, travels, and Povo hill: Aliaksei, Angela, Angela, Francesca, Andrea, Mladjan, Chiara, Zeno, Adriano, Linda, Silvia, Mercedes, Maria, Fabio, Raul, Mela, Eleonora, Gianluca, Francesco, Giacomo, Michela, Maurizio, Stefano, Costanza, Monica, Irene, Andrea, Francesca, AnnaPaola, Nawaz, Antonio, Francesca, Martina, Giada, Lorenzo, Paola, Carla, Massimo, Gaia, MariaPia, and the teachers and the children of Cavedine and Livo kindergartens.

Special thanks to my family and friends for being supportive and patient in the long run.

# Introduction

## Context

This thesis takes inspiration from Inf@nzia DIGItales, a research project funded by the Italian Ministry of Education and aimed at renewing education practices in the kindergarten with Information and Communication Technologies (ICT). This context provided the opportunity to investigate the trustworthiness of drawing as a way to elicit and interpret young children's experiences with technology. The specific socio-technical context investigated in this thesis is a technological multisensorial environment for music education used in a kindergarten.

Reference to the term "young children" in this thesis refers to children aged between 3 and 6 years, the preoperational stage in Jean Piaget theory (Piaget & Cook, 1952), as this specific age group was targeted during the studies reported in the work. According to Piaget, in the preoperational stage, children main characteristics are the articulation of language and the attribution of symbolic meaning to objects. The study of such population is relevant in the context of Human-Computer Interaction and in particular in its subarea, Child-Computer Interaction, because not many research studies target the needs of this particular age group (Plowman & Stephen, 2003; Read & Markopoulos, 2013). Yet, young children are increasingly using technology but often these technological artefacts have not been designed for them (Plowman & Stephen, 2003; Plowman et al. 2012).

The specific educational context that this thesis aims to address is music education as young children are particularly sensitive to music and therefore exposing them to an appropriate range of musical stimuli is essential for the development of their musical taste (Peery & Peery, 1986). Research suggests that music can foster intellectual development and specifically favour language development and the acquisition of reading skills (Weinberger, 1998). The need for music education in Italian kindergartens is often not sufficiently addressed by institutional education program because of the demanding level of music knowledge that the teachers should cover. The need for music education has often been addressed by organizing extra-curricular course and thus resulting in higher costs for the kindergarten or the parents. Technology can come to help in this scenario by offering new opportunities for music education without increasing dramatically the level of work required to the teachers (Masu et al., 2017). In this thesis we refer to two technological solutions – Children's Orchestra and Interactive Pyramids - and explore their use in the kindergarten.

The kindergarten context involve multiple actors with different needs  who bring forwards specific requirements related to time and budget constrained solutions. As discussed in previous research, teachers involved in the design process together with children at school, act as intermediary in the design process (Iivari & Kinnula, 2016). The specific characteristic of the kindergarten context needs to be taken into account in a design project, especially if we agree on a definition of context that reflects a dialogue between users' actions and the environment they modify (Dourish, 2004).

## Technological multisensorial learning

The type of experience this thesis aims to investigate occurs in a technological multisensorial environment. Learning occurring in a multisensorial context has proven to benefit the processing of information as this modality is more similar to the information processing naturally occurring in everyday life (Shams & Seitz, 2008). It is important to note however that information derived from the different perceptual systems must be congruent, meaning stimuli that are consistent with the person's prior experience or that are similar to what can be found in nature (Kim et al., 2008). On the other hand, incongruent stimuli would require more attention and would be counteracted by inhibitory interactions occurring at the sensory level.

The study of young children's experiences in the technological multisensorial context has been addressed by collecting and analysing children's drawings. This method has been frequently used as an evaluation tool in psychological assessments (Machover, 1949; Koppitz, 1968) and as proof in legal trial (Aradau & Hill, 2013). In Child-Computer Interaction, drawing has been used to support both formative and summative evaluations as it was assumed it could facilitate the elicitation of information directly from children, which is relevant especially in the case of young children which are not proficient with language. The interest on drawings constitutes a step towards conducting research that is more attentive towards children's needs, an exigency that has been increasingly noted by researchers (Holt, 2004; Morrow & Richards, 1996). However the modalities through which drawings can be processed by researchers and interpreted into insights able to generate a better understanding of the quality of user experiences need to be further investigated. This issue represents the main focus of the thesis.

## Epistemological Positioning

The complex task to make sense of young children behaviour and to interpret their experiences may lead to multiple constructions of reality, depending on the investigators, the methods, and the data used (Guillemin, 2004). This is especially relevant when addressing the interpretation of young children's drawings which is strongly dependent on the ability, the knowledge and the effort of the researcher.

The epistemological framing of this thesis lies in the qualitative research tradition, as it addressed the study of behaviour in real-word settings favouring understanding, illumination and extrapolation to similar circumstances, rather than prediction, causal relations and generalisation. Therefore this thesis concentrates on the practical implications of collecting and analysing drawings for ascertaining a representation of the elements of an experience which attracted the child attention. The knowledge of these elements is important to understand the child experience and can drive future design.

## Methodology

This thesis analyses a large corpus of drawings (N= 280) collected in different research settings. The first setting consisted of a longitudinal study to evaluate the "Children's Orchestra" (a technologically-augmented space for music education) comparing and contrasting it with the engagement of children following a 12-biweekly class based on the Music Learning Theory pedagogy (Gordon, 2003). Twentyfive children participated in the study which lasted from October 2015 to June 2016. At the end of each class children produced a drawing (N= 197) of their experience and described it to a teacher who annotated it. The conjoint analysis of the drawing and the notes proved useful to identify the **key elements of the child experience**, which following (Di Leo, 1970; Xu et al., 2009) are considered as the focus of the child attention. However, the analysis exposed a strong influence of age on the value of drawings as a tool to evaluate the child experience. Older children (>4) tended to draw the elements of the experience that drew their attention (Di Leo, 1970). Although the teacher's note were often instrumental to understand their meaning, these elements exposed factual differences among the environments and the tasks and subtler information exposed by triangulation. Younger children (3-year-olds) drawing proved more problematic, as they often focused on completely different contexts (e.g., a child drew the mum and another one a tractor) and are almost impossible to understand without references to the teachers' notes.

To further investigate the effect of age and of the teacher notes on the quality of drawings as a tool to evaluate the user experience of young children, we performed two additional studies. A total of 31 children were invited to play with the Interactive Pyramids, a tangible toy to learn music and colour scales, and then draw their experiences. This time the drawing were analysed independently of the teachers' notes and the two sources of information were compared and contrasted.

Results from the conducted studies confirmed the utility of drawings as a way to understand the objects which attracted children attention. However, **the efficacy of the drawing as a communication medium able to detect children's interests was influenced by their age**. The interpretation of the drawings of children aged 3 was often difficult and therefore required mediation of adults such as teachers asking directly to the child the meaning of his drawings. Younger children drawings confirmed a different perception of this age age group of the interactive activities they participated respect to other groups. For example their drawings mainly focused on coloured items instead of the Interactive Pyramids and music. The teachers acting as intermediary of children's drawings were also found useful with children aged 4 while children aged 5 drawings were found satisfactorily self-explanatory.

## Research questions and contributions

This thesis makes a methodological and a practical contribution to the emerging field of Child-Computer Interaction. Firstly, addressing a largely disregarded age, that of young children whose age is comprised between 3 and 4 years. This audience is engaged in research to answer the following questions. The first two questions contributed to the methodological contribution by focussing on the analysis of children's drawings in research evaluations of interactive systems.

**RQ1. Is drawing a *trustworthy* research method to evaluate young children's experience?**

Trustworthiness is the term used in the qualitative research paradigm to provide a description of the quality of the research conducted in naturalistic, real word settings. It encompasses the metrics of validity and reliability used in the quantitative research paradigm (Golafshani, 2003). In these terms trustworthiness can be compared with the internal validity of the quantitative research process where the application of the chosen research method is critical to the production of reliable research data. To answer this question the thesis focussed on two sub-questions dealing with triangulation and age differences.

***- Does knowledge extracted from drawing data sustain findings of other research data?***

In order to evaluate the trustworthiness of drawing, the empirical work used triangulation of methods and data coming from both quantitative and qualitative approaches (Patton, 1990), as both approaches can be used to provide a better insight into the complex target of our thesis: the understanding of young children's experiences.

Study 1 was exploratory and aimed at understanding whether information found in observations was confirmed by the analysis of children's drawings. The study, however, presented the following limitation: it was tested with 4 and 5 years old children. Results informed the second research questions which was the focus of study 2 and 3.

Study 2 aimed at a more in-depth analysis of drawings in three age ranges, age 3, age 4, and age 5, both in a technological and a non-technological condition, separating children's depictions from teachers' notes about the depictions. Results from this study highlighted the difficulty of interpreting 3 year old children's drawings, and, in part, of interpreting those of children aged 4. Therefore the need for relying more on the teacher's notes was higher. Despite the small presence of a musical element in all the drawings of children aged 3, a higher presence of a musical element was found in the teacher's notes.

Study 3 aimed at validating results from study 2 (drawing being ineffective when depicting musical experiences and younger children showing more difficulties) with a task asking children to familiarise themselves with the concept of quantity both as a musical scale (faster and slower music) and a visual scale (darker and lighter colour). In this study, the musical stimuli were the same as study 2, but the visual stimuli varied with respect to study 2 (the rainbow scale was substituted by a single-colour scale varying from a darker to a lighter shade).

**RQ2. What elements of the experience do drawings describe?**

This second research question focuses on the practical implications of using drawings as a child-experience tool. The reflection focuses on the knowledge this method can contribute to design and on the costs required for it. In order to address this question a reflection on the elements that can help the researcher to build the child's personal perspective about the experience they were involved in is needed:

- *What elements of the experience do drawings describe?*

To answer this question, literature about the usage of drawing in psychology has been reviewed. This review analysed the different roles drawing had as a diagnostic tool, in particular as a projective tool, as a memory aid, as a mental impairment indicator and as a developmental indicator (Jolley, 2010). Starting from this theoretical basis drawings have been mainly adopted in this thesis as memory cues which can support children in recalling the interactive experience they participated in. Therefore the usage of drawings for the evaluation of technological multisensory environments has been analysed in three empirical studies. Findings indicate the appropriateness of drawing as a research tool that is respectful of the characteristics of children. Despite this, analysing drawings reveals to be a time-consuming activity and difficulties in the interpretation may arise, especially with children aged 3 years, who are likely to be in the "failed realism" phase of drawing development (Luquet in (Jolley, 2010)). In this phase, children are still in the process to develop their representational skills. Therefore, a meaningful analysis of their drawing requires verbal mediation.

To conclude, the results of the studies performed in this thesis suggest that drawing is a trustworthy method to identify the elements of an experience which attracted children attention. However, their informative value is mediated by the object to be depicted (abstract elements such as music are more difficult to represent) and the development stage of a child who should have reached the intellectual realism phase, where children are capable to represent the item they want to represent, according to the internal model they have built of it through experience.

## Thesis outline

This thesis develops the issues outlined above following this structure (Figure 1):
- the first chapter presents the main characteristics of young children from a developmental perspective with a focus on drawing and outlines the main benefits of multi-sensorial music education;
- the second chapter presents the research problem, relates it to the main gaps in Child-Computer Interaction, the research area this thesis aims to contribute, and outlines the research methods used with children;
- the third chapter presents the user requirements that were identified for the design of a musical interactive system aimed at investigating the research questions;
- the fourth chapter presents the first study aimed at exploring drawing as a research method used to infer aspects of the quality of young children's experience;
- the fifth chapter presents the second study specifically addressing the issue of comparing information that can be deducted from the analysis of depictions and compares it with information derived from other methods;

- the sixth chapter presents the third study aimed to validate results from study 2 by repeating the research procedure in a similar context;
- the seventh chapter discusses findings and their implications for design research and practice.

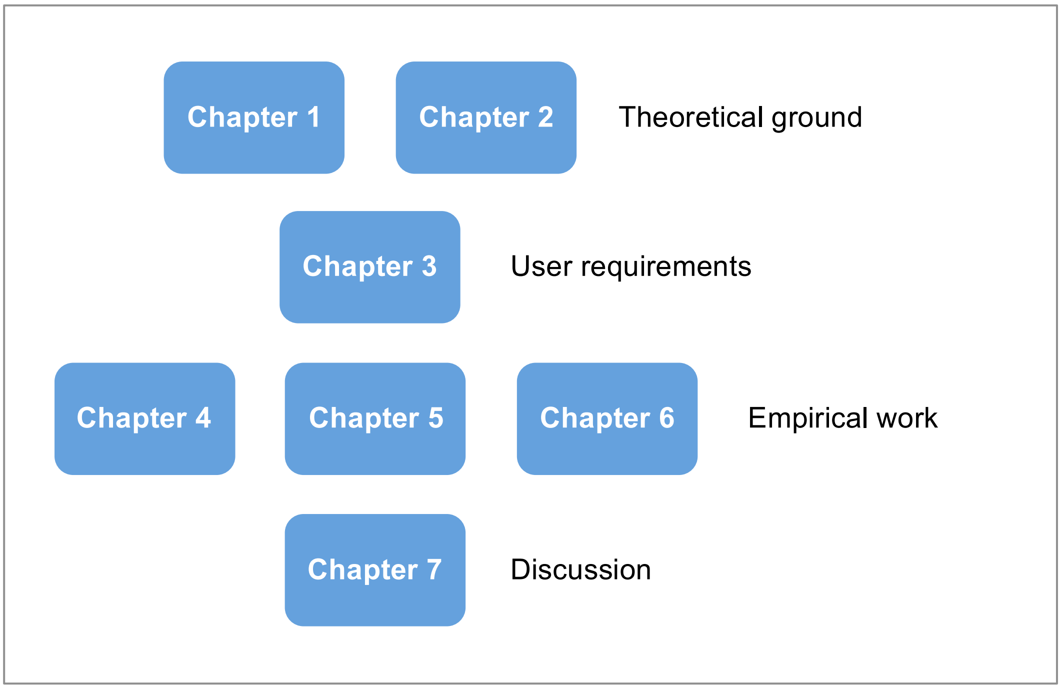



**Figure 1. Structure of the thesis.**

# 1 - Child Development

**Abstract**. This chapter aims to ground the thesis from the perspective of development theories. It introduces the process of child development, succinctly reviewing its main theories and explaining the characteristics of young children (3-6) with an emphasis on multisensorial learning. Then, the chapter provides overviews of music education from a constructivist perspective. Finally, it presents the potential of drawing as a favourite medium used by children to reflect on their experiences.

## 1.1 Introduction

Three main areas can be distinguished when analysing development: physical, cognitive, and emotional and social development. This thesis will predominantly take into account cognitive development theories as a reference. The peculiarity of these theories is that they mainly focus on describing how children's thinking evolves over time and the factors that can influence this process. In particular, this thesis will follow a constructivist approach, an approach to child development that considers the child as able to learn, as opposed to other theories considering the child as coming into the world with no predetermined knowledge.

One of the most influential authors addressing cognitive development was Jean Piaget. His main contribution to development theory was to explain how children's and adults' ways of thinking differ, and to put passive learning into the discussion (Piaget, 1951). Learning is the process during which information is stored and encoded in memory. Piaget theorised that learning in early childhood happens while interacting with objects, with individuals, and through the exchange of ideas and experiences. In particular, Piaget questioned classical education approaches in which the teacher gave lectures to the children, who were supposed to passively acquire knowledge. Those who held these views were theorists such as John Locke in the 18th century (1725) and behaviourists in the 19th century. Piaget, instead, believed that children actively “constructed” their knowledge through experiences.

Piaget described the basis of development from a biological perspective and explained that the human mind, as well as other living organisms, adapts to the environment through experiences which, in their turn, unfold on existing schemata and drive the evolution and consolidation of new ones. According to Piaget, schemata (Piaget & Cook, 1952) are cognitive structures used to make sense of experiences. They represent the basis of reasoning and change with age as the child experiences new events and contexts. For example, a child aiming to transport one or more objects from point A to point B may learn to use a second object, a carpet, to transport it (Piaget & Cook, 1952). This constitutes a schema that can be repeated on other occasions when an object is on a support (Piaget, 1965). Cognitive development is the “equilibrium of assimilation and adaptation” (Piaget & Cook, 1952). *Assimilation* is how pre-existing schemas are used to interpret the environment, for example a young child seeing a camel at the zoo and calling him “horse”. *Accommodation* is when new schemata or adjustments to existing ones are created when pre-existing cognitive structures fail to catch the environment. For example, the child at the zoo calling the camel “lumpy horse” (Berk, 2006).

Building upon theories emphasising the importance of experiences for young children, recent studies stress the crucial importance of play for the development of cognitive and social skills. For example, physical play was linked to the development of brain areas in charge of behavioural and cognitive control, while guided play, adopted to manage the impulsivity of young children, benefited mathematics and reading (Hirsch-Pasek & Golinkoff, 2008). Free play activities, which are unstructured forms of play, presented mutual benefits: they are not only pleasurable but also useful to children as they foster full commitment to completing tasks and provide motivation to face challenges that may occur (Gopnik, 2010). Unstructured forms of play can contribute to children’s wellbeing, making them able to create their own vision of the world and exploring it through the means that they have available, thus reinforcing their abilities, confidence and resiliency (Ginsburg, 2007).

## 1.2 Cognitive perspective

Based on the equilibrium of assimilation and adaptation, Piaget distinguishes four cognitive developmental “stages”:

● *sensorimotor* (from 0 to 2 years): children think with their eyes, ears, hands and other sensorimotor abilities;

● *preoperational* (2 to 7 years): language starts to articulate, together with symbolic play and representative thought;

● *concrete operational* (7 to 11 years): the child starts to use logical reasoning;

● *formal operational* (11 years and older): the development of abstract thought and hypothetical-deductive reasoning.

Piaget’s perspective on development, as occurring in stages, has been considered a limitation of his theory. Other scholars, such as behaviourists and Jerome Bruner, considered that learning occurs as a continuum rather than in stages. According to Bruner, development occurs through the acquisition of new and more powerful forms of mental representations (Bruner, 1964). Enactive, iconic and symbolic representations develop in children throughout the development continuum (Bruner et al., 1976). Enactive representations are related to the human motor system: an example is when some movements, such as the ones involved when riding a bicycle, are learnt. Iconic representations are experiences captured in images. For example, a child who asked to look at a beaker half filled with water that is then poured in a taller and narrower container, is indicating that there is more water in the taller beaker and would use his hands to make a gesture that indicates the height of the column of water (Olson et al., 2014). Symbolic representations are related to language and summarise meaning into symbols: for example, the word “Philadelphia” refers to the city but the symbol conveying its meaning does not resemble the city visually.

Another important difference between Piaget and Bruner is the relative importance given to the social context. Piaget mainly focused on the individual child, whereas Bruner stressed the importance of the socio-cultural environment as a principal factor for understanding child development. In this perspective, Bruner’s view is in line with Vygotsky (1980) who viewed child cognitive development as a socially mediated process. According to Vygotsky (1980) children’s learning occurs when zones of proximal development are created. These zones are defined by the distance between the child’s actual level of development and the level of development he/she can reach by interacting with a more competent peer or an adult.

In the last 10 years, developmental psychology and other sciences have shown an increased interest in grounded cognition (Barsalou, 2010). According to psychologist Lawrence Barsalou, “the environment, situations, the body, and simulations in the brain’s modal systems ground the central representations in cognition”. Young children tend to reason by using tools and manipulating objects and this helps them to translate experiences into abstract concepts. A recent study with five- and seven-year old children found that children’s conceptual processing ability was influenced by objects’ manipulation, and the recalling of motor experiences when processing concepts (Kalénine & Bonthoux, 2008). In particular, manipulable objects were found to facilitate the processing of concepts in a task asking a child to select one out of two visual representations that best match a target figure related to functional situations. For example, when the target figure was a jacket, the child was asked to choose between a balloon and a hanger. It was instead found that manipulability of objects could interfere in a concept processing tasks involving objects which are visually similar, such as a jacket and coat.

## 1.3 Characteristics

Children in the preoperational stage undergo dramatic changes. From a cognitive perspective, they start to articulate language, together with make-believe play and representative thought. According to Piaget, a distinctive deficiency of the preoperational child is egocentrism: the difficulty of understanding other people’s points of view. More recent research findings revised the definition of Piaget and limited it to a tendency rather than a deficiency (Berk, 2006). Accordingly, Vygotsky (1980) viewed egocentric speech, which is typically displayed while children play, as a transposition of the rules of social interaction that the child learns when interacting with adults and peers to the self. As a consequence, Vygotsky called the phenomenon “private speech" rather than egocentric speech.

Besides learning the rules of social interaction while developing language, children’s cognitive development also manifests through the development of their vocabulary. For example, children’s conversations were investigated in later studies with a focus on the use of the adjectives “big” and “little” during conversations with children aged between 2 and 4 years. The study demonstrated that the children, similarly to adults, were able to use contextual information to switch from one adjective to the other (Ebeling & Gelman, 1994). Adults use of the adjectives “big” and “little” varied depending on three contexts: normative context (dimensions of a certain object are compared to an existing mental model), perceptual context (dimensions are compared against another object), and functional context (dimensions are evaluated taking into consideration intended use). However, unlike adults, young children showed difficulties if differences across the contexts were not sufficiently marked.

As a consequence of not having a full understanding of how things function, children’s behaviour has been either associated to egocentrism or to animistic thinking: the tendency to attribute lifelike characteristics to objects. Young children’s play is a manifestation of this condition. An example is *make-believe,* a type of play unique to young children, where they imagine themselves in a fictional situation. For example, children may pretend to be veterinarians to help sick animals. Vygotsky viewed make-believe play as a zone of proximal development where children learn to act according to rules they decide themselves. Similarly, Bergen (Bergen, 1988) and Bruner et al. (Bruner, J. S. et al., 1976) stated the importance of play in children’s early years. More recently, Smidt explained how play helps children in building their identity (Smidt, 2011). This is particularly relevant for children in the *preoperational stage*, because they start developing symbolic thinking; they still think through their senses but, at the same time, start having preliminary mental representations of what they experience.

## 1.4 Multisensorial learning

Given the importance of the senses, multisensory stimuli proved to be more effective than single-sensory stimuli in helping young children improve their performance while executing tasks. As a consequence, this thesis aims to investigate young children’s experience in a multisensorial learning environment. For this purpose this section presents the main learning benefits that multisensorial experiences can bring.

In describing the biological basis of the learning processes, developmental psychologist Alison Gopnik and colleagues (1999) explained how children experience life through their senses (hearing, taste, smell, touch, sight). The information retrieved by the senses is then processed by the left and right hemispheres of the brain. Depending on the kind of activity, one hemisphere is more stimulated than the other. In general, the left hemisphere of the brain fosters analytical thinking: language, logic, mathematics, linearity and sequencing. The right hemisphere is more for holistic thinking and learning of forms and patterns, spatial manipulation, images, imagination, rhythm and music. The assumption that people can be defined as either “left-brained” or “right-brained” has been proved wrong by recent neuroscience research but it is still true that the left and right hemispheres of the brain have different specialisations (Novotney, 2013).

Psychologist Kerry E. Jordan and colleagues, for example, proved that young children execute better numerical tasks when multisensory stimuli occurred (Jordan & Baker, 2011). Moreover, intersensory redundancy promotes children’s economical ability to focus on meaningful events (Bahrick & Lickliter, 2000). Neuroscientist Antonia Thelen and colleagues highlighted that memories of objects known in a multisensorial context are more “robust” than memories encountered in a one-sensory context (Thelen et al. 2014). Moreover, the researchers pointed out that a multisensory context is a situation more likely to happen in real life.

From the pedagogical viewpoint, a major contribution to multisensorial learning was provided by Maria Montessori (Lillard, 2008). Her pedagogy has roots in her assistive work with children with special needs: she was inspired by their need for stimulation. Observing and comparing children with special educational needs with their peers, she found that children with special needs were better at sensory activities. Consequently, she developed a set of materials for helping young children systematise their developing sensory abilities. The Sensorial Materials she developed were inspired by Eduard Seguin (Seguin (in Lillard, 2008)) sensory stimuli for the education of the children with special needs. These materials, which are foundational in Montessori pedagogy, are “sets of objects designed to educate the senses”. Moreover, these materials help children to concentrate, to make judgements, to act purposefully and more. Some of them are used in the studies described in this thesis.

## 1.5 Music Education

Music education can contribute to the development of the child such as the development of fine auditory abilities. In line with the developmental and learning theories presented above, this thesis takes a constructivist perspective on music education for young children and focuses on the active involvement of the body to support music learning. Over the last century, a number of theories of learning and teaching music have been proposed (Delalande, 1993; Gordon, 2003; Odam, 1995; Thresher, 1964). The Music Learning Theory developed by Gordon is one of the most recent and innovative (Gordon, 2003). This theory aims to explain how music is learnt, and stresses the importance of learning music by ear as opposed to teaching methods that concentrate on musical notations. Learning by ear implies a deep development of listening abilities, which Hetland defined as fundamental even for spatio-temporal reasoning (Hetland, 2000).

Building on the importance of promoting physical activities during the early years, Dalcroze states that movement could be helpful for learning rhythms and time related musical aspects (Jaques-Dalcroze, 1921). Dalcroze's strict connection of movement and music reflected a criticism of the cartesian separation of mind and body (Juntunen, 2004) and a conception of musical expressivity as both embodied and relying on physical and social interactions with other people (Seitz, 2005). Moreover, the importance of the body in the construction of knowledge is also in line with theories affirming that people usually know more than they can tell, which Polanyi calls "tacit knowledge" (1966). This is also comparable with the condition of the preliterate child who actually knows more than he/she can express verbally.

Studies assess that listening activities should be structured in activities that stimulate an active participation of the children (Sims, 1986). In these activities, children's attention is high as the focus is on responding to the music they are listening to by moving their body or singing (Sims, 1986). Listening abilities can be enhanced by physical interaction, as those types of activities engage children's attention and memory. In addition, they promote awareness of rhythmic patterns in music, encourage the development of control of body language, and develop the children's perceptual skills (Glover & Young, 2002; Kalénine & Bonthoux, 2008). Furthermore, as Andress suggests (Andress, 1989), musical activities should aim to widen children's musical creativity and curiosity, and not merely seek to instruct them on theoretical notions. Finally, to maximise musical understanding, children should be exposed to a variety of stimuli that have to be musically coherent[1](Gordon, 2003).

From the pedagogical viewpoint, Maria Montessori, the researcher who provided the most comprehensive constructivist curriculum for young children's education (Lillard, 2008), devoted part of her educational curriculum to music. The materials she designed for musical education leveraged on the idea of training the child's perception by educating it to discriminate sound. For example, she proposed exercises that guided the child to discriminate between the presence of sound and its absence, and to distinguish the sounds emitted by different bottles filled with different materials (sand, beans, rice, etc.), and/or different size bells. This approach is similar to that applied in this thesis which evaluate active music making activities aimed at supporting young children's fine auditory system development. The medium used for the evaluation is drawing.

## 1.6 Drawing

Among children's typical activities, drawing has long been regarded as a favourite communication medium to open a window onto their world (Malchiodi, 1998). When young children have not yet mastered abilities such as writing, reading, and speaking, then drawing represents a valid means for communication, making meaning and problem solving (Brooks, 2005). For example, drawing has been used to investigate the effect of stress factors in children undergoing cancer treatments (Rollins, 2005) or to assess children's family attachment (Fury et al.,1997). This thesis emphasises drawing as an evaluation method and, therefore, its meaning and adoption in research contexts is discussed in the following paragraphs.

Scientific interest in children's drawings arose in the late 19th century and was mainly focused on its representational qualities rather than their expressiveness. Representational qualities of drawings are their formal characteristics such as the lines of composition, the spatial organization of elements and the items depicted. Opposed to representational qualities are expressive qualities, which indicate the evaluation of the drawing from an artistic point of view, appreciating their creative aspects. Scientific interest in representational drawing was a consequence of an increased interest in studying origins and change which formed the basis for

[1] Musical coherence refers to the proper use of chords, scales, and rhythms applied in a given set

theories such as Darwin's theory of evolution (Jolley, 2010). A lesser emphasis has been put on children's expressive drawings, which is still in its infancy, and presents ambiguities because of factors such as cultural values, education, and individual skills that can influence research findings.

### 1.6.1 Developmental perspective

From a developmental perspective, Georges-Henri Luquet was one of the most influential authors analysing children's drawings (Luquet in Jolley, 2010). He identified "realism" as the main intention of the child making spontaneous drawings and distinguished the following types of drawings:

- scribbles: in this phase children enjoy the creative act of trace making;
- fortuitous realism: this stage reflects children's tendency to recognise similarities between the world and their scribbles. Luquet's example of a drawing made by a child aged 2 years and 6 months reflects this stage as the child was recognising, in her scribble, a similarity with a bird and stressing this similarity in the drawings by adding legs to the drawn shape;
- failed realism: this term describes children's efforts to represent elements from the real world. This phase is named "failed realism" because the children's drawing abilities are not sufficiently developed to support their effort to make realistic representations. Typical examples of representation of human figures in this stage are "tadpole" figures: representations of the human figure where the human body is missing and a human figure is represented by a head with or without legs and arms;
- intellectual realism: children in this phase make the effort to represent, to the best of their knowledge (with as many elements they know), the item they want to represent, according to the internal model they have built of it through experience. An example is represented by children's depictions of a man on a horse after being shown models with different views of the scene: in this case children use graphic techniques as a transparency to show details of their knowledge about the scene. Thus, we may see the horse depicted from his side because this is the best perspective to showcase the features of the animal;
- visual realism: as a consequence of children's focus on making the most realistic representation of what they want to depict, the child is then reducing details, avoiding representing what cannot be seen from a certain perspective.

The child’s focus in this phase is on the representation of “what they see” rather than on the representation of  “what they know”.

Though Luquet did not favour defining the evolution of children’s drawings as occurring in stages, an indication of the age during which a particular type of drawing is typical is indicated by Krampen (1991): scribbling occurs between 2 and 3 years, fortuitous realism is occurring between 3 and 4 years, failed realism occurrs between 4 and 5 years, intellectual realism between 5 and 8 years, and visual realism between 8 and 12 years.

The developmental perspective on children’s drawings was criticised by John Willats (1977); he agreed with Luquet in stating that children’s drawings’ main aim is realism (Jolley, 2010) but criticised the fact that too much focus was put on the child’s drawing intent (“draw what they see” or “draw what they know”) rather than the drawing itself. Starting from this assumption, Willats developed a graphic analysis of children’s drawings, focusing on the interpretation of lines indicating volumes rather than contours and on the analysis of the drawing system adopted (topology, orthogonal projections, oblique projections, and perspective). Willats merit was to provide a more formal way of analysing children’s drawings and to emphasise the relevance of analysing drawings before providing a psychological interpretation. His approach, nevertheless, is still novel and, therefore needs to be validated as it shows the following limitations: for example it focused on the representation of views of objects, such as tables, that occur only rarely in children’s spontaneous drawings, and the interpretation of children’s drawings presents ambiguities. In this thesis, Willats’ taxonomy is not taken into account because of such limitations and because his studies mainly involved older children aged between 5 and 17 years (Willats, 1977). In Luquet’s taxonomy, these children belong in the intellectual and visual realism stage.

### 1.6.2 Clinical practice

Children’s drawings have been frequently used in clinical practice to facilitate relationship building particularly when a child is reluctant to cooperate, and as diagnostic instruments (Jolley, 2010). Despite this, latter application still misses fundamental validation studies (Bekhit et al., 2005; Cashel, 2002; Camara et al., 2000); drawing is widely adopted to assess children’s intelligence (Goodenough, 1926), personality (Machover, 1949), emotional disturbance (Koppitz, 1966, 1968), and recall memories (Salmon and Pipe, 2000).

The first drawing test aimed at measuring intelligence was the “Draw-A-Man” test (Goodenough, 1926). It consisted of asking the child to draw their best idea of a man: the male figure was thought to be more adequate for the purpose at that time (Harris & Pinder, 1974). The feature of the test was then revised by Harris, in 1963, by asking the child to draw separately a male figure, a female figure, and the child himself/herself. The figure was then scored according to a list of 51 items, including physical dimensions of the human figure and the presence of arms, legs and a head. Naglieri (1988 (in Jolley, 2010)) presented the Draw-A-Person test which proposed the same drawing tasks of the Draw-A-Man test. This test differed from Goodenough’s test as all the drawings were rated while Goodenough excluded the child’s drawing of himself/herself from the scoring. Scores form Draw-A-Person tests proved to be reliable, but their validity as measures of intelligence varied considerably when compared to other IQ tests such as the Stanford-Binet test (Jolley, 2010). The use of drawings as a measure of intelligence has been demonstrated to be useful for measuring levels of intelligence in children who were reluctant to execute other kinds of tests. The main issue with drawing tests for assessing intelligence is the low level of accuracy in respect to other types of intelligence tests, one reason being that this test is mediated by the drawing abilities of the child.

Personality assessments have also been conducted by using drawing as a projective method. An example is Machover’s “Draw-A-Person” test, consisting of drawing two persons of opposite genders (Machover, 1949 in (Jolley, 2010)). The clinician then assesses elements such as which figure was drawn first, the size of the figures, movement, omissions, details, and differences between the figures. In general this test is used to investigate maladjusted personalities. The child’s verbalisations about the persons drawn and stories about them will be noted too, and are part of the analysis. The use of drawings as valid and reliable tools for projective assessments, as in the case of personality assessment, has often been the object of debate in literature (Jolley, 2010) because, often, clinicians’ knowledge of the pre-existing situation influences the interpretation of drawings.

Emotional disturbance has also been investigated through drawing. For this purpose, Koppitz (1966, 1968) developed a test asking the child to draw a person and then analysed it noting the presence or absence of 30 features or indicators of emotional disturbance grouped into three categories (quality of the human figure, special features, and omissions). The validity of such a kind of test in identifying children's emotional disorders has been questioned by Catte and Cox in 2000 (in Jolley, 2010) who compared and statistically analysed scores obtained from the clinical group with two emotionally well-adjusted control groups (one with children whose age matched the clinical group and the other one with children whose mental age matched the clinical group).

Children's representational drawings were also analysed and compared with drawings from children with specific disorders. For example, Cox and Cotgreave (1996) reported that drawings from children with mild and severe learning difficulties show a delay in their development, as their drawings were similar to that of younger children. Clements and Barrett (1994) investigated and compared drawings from children with Down syndrome, showing a different pattern of drawing strategy. In their study, 29 children with the syndrome, whose age was between 5 and 12 years old, were asked to draw a specific scene with an object partially occluded and their drawing was compared with the drawings of children whose development was in line with the average. It was observed that drawings of children with Down syndrome showed poor planning and poor attention. Correlations between the syndrome and the quality of the drawings is still not clear although poor visual abilities, attention, motor abilities, and little understanding of spatial relationships are thought to play a role. Autistic children's drawings presented a great variability, reflecting the variability of the autistic spectrum but, in general, autistic children's drawings reflected developmental delays too. Developmental delays were evident even with drawings from children with William syndrome, and blindness.

### 1.6.3 Memory cues

Drawing also showed potential for recalling past events from memory during interviews (Jolley et al., 2002; Salmon, 2001; Butler et al., 1995). The main advantage of having children draw what they remember of a past event is its facilitatory effect in retrieving memories because it helps the child to structure them. In particular, this facilitatory effect is noticeable when children are asked to recall an interesting event (Salmon & Pipe ,2000 (in Jolley, 2010)). Further evidence of such a facilitatory effect has been shown with children aged 5 and 6 years for recalling items related to past events up to a year ago. Despite the benefits of using drawing to support event recall, it must be noted that, apart from in ideal conditions, there is an increased probability of getting inaccurate information during a interview comprising drawing activity; inaccurate information carried by the interviewer may be reported by the child.

In line with drawing being a tool to support event recall and following a socio-constructivist perspective, Dyson (1992), recognised that the drawings made by children aged 5-9 during an ethnographic study at school could be interpreted as attempts to reflect on their experiences. Despite agreement on the age range during which children show a particular drawing behaviour being controversial, it is recognised that children learn that different hand movements result in different marks on the paper (Matthews, 2003). In this sense, it is recognised that drawing helps children to translate actions they make with their bodies, and upon objects and media, into representations, symbols, and signs that help them make sense of, and organise, the experiences they have lived – a mechanism that is at the basis of thinking (Matthews, 2003). In defining the characteristics that are common in young children's drawings, Di Leo (1973) supported the idea that children's drawings reflect their effort to depict the real world. He identified what kind of relevant information can be found in children's drawings by analysing related work and empirical data:

- children draw what is important to them, especially people, animals, houses, and trees;
- they draw, to a greater or lesser degree, something of what they know about the object they are drawing;
- they draw what they remember about the object;
- they depict their idea of the object plus their feelings.

These items will be useful as a guideline for the analytical work carried out in the experimental chapters of this thesis (chapters 3, 4 and 5) aimed at assessing young children's experiences. The following sections will briefly outline the main characteristics of what the type of stimuli that the interactive systems used in the experimental setting aim to promote and of their educational goals.

## 1.7 Conclusion

This chapter provides the main theoretical references for understanding the main characteristics of the target user of this thesis, young children, and the specific context of this research, which is multisensory music education, and drawing as a research method.

The following chapter will focus on the gaps of research in Child-Computer Interaction which this thesis aims to cover. In addition, it reviews methods that have been adopted in this field to evaluate interactive systems with young children, with a specific focus on drawing.

# 2- Child-Computer Interaction

**Abstract.** This chapter provides a methodological framework for the thesis. It reviews Child-Computer Interaction, the practicalities of CCI research, current approaches to CCI research, and suggests an approach to address the issues and increase the quality of research findings. The approach builds on triangulating multiple sources of research data and was validated in three studies which are described in Chapters 3, 4, 5 and 6.

## 2.1 Introduction

In the inaugural article of the first issue of the International Journal of Child-Computer Interaction, the editors define CCI as “an area of scientific investigation that concerns the phenomena surrounding the interaction between children and computational and communication technologies.” (Read & Markopoulos, 2013). By analysing related work, the authors highlight that one of the current major challenges for the CCI community is to reconcile child development theories with the design of interactive systems.

Jean Piaget’s child development theory (1952) has long been the main source of reference in the CCI community. More recently, grounded cognition has attracted the attention of CCI researchers (Antle, 2013). In particular, potential for future investigation has been found in the following theories and concepts: embodied developmental cognition, stating that “the development of intelligence depends on the specifics of the genetic, physical, social, emotional, and contextual environment in which a child is situated” (Antle, 2013 p. 32); complementary strategies, stating that physical actions can contribute to reducing the load on cognition (Kirsh, 1995); and mental simulation, which stresses the importance of movement for thinking (Barsalou, 2010).

The concept of complementary strategies argues that the cognitive processes involved in problem solving tasks can be improved by adapting to the environment (Kirsh, 1995). Using external elements to offload cognition is defined as “a complementary strategy”. Complementary strategies involve pragmatic and epistemic actions. Pragmatic actions are goal-directed actions, while epistemic actions are actions changing the world with the aim of making the task easier to solve. A typical example of epistemic action is the Tetris game: pieces are rotated “not to solve the task at hand but to better understand how rotated pieces look” (Kirsh & Maglio, 1994). Such theories and concepts put an emphasis on the role of the body in elaborating experiences; this is particularly relevant for young children as making experiences with their senses constitutes a major determinant of their learning process. A better understanding of children’s development would support the development of evaluation methods that are more reliable in assessing their experience, a concern that still needs to be addressed by the CCI community and whih this thesis discusses.

### 2.1.1. User experience

The first studies of young children’s experience with technology focused on usability problems. For example, Hourcade and colleagues investigated children aged 4 and 5 years executing pointing tasks with a mouse and compared their performance with older children’s and adults’ performance (Hourcade et al., 2004). The study observed young children’s need to have larger visual targets on the screen because of their motor abilities not being fully developed. This finding was confirmed when children failed to perform “drag-and-drop” actions using a DiamondTouch tabletop interface (Mansor, De Angeli, & De Bruijn, 2008, 2009). However, children still deeply enjoyed the interaction and were capable of finding creative solutions to their difficulties.

Beside addressing usability problems, more recent research has investigated young children’s experiences by looking at them holistically. When looking at children’s experiences, an adult definition of user experience is generally adopted. The concept of “User Experience” (UX) shifts HCI attention from the focus on the pragmatic element of the interaction to the focus on experiences that have a positive impact. An agreed definition of *User Experience* in HCI research is missing; and this thesis builds on the proposal by Hassenzahl & Tractinsky, 2006. These authors define UX as “a consequence of a user’s internal state (predispositions, expectations, needs, motivation, mood, etc.), the characteristics of the designed system (e.g. complexity, purpose, usability, functionality, etc.) and the context (or the environment) within which the interaction occurs (e.g. organisational/social setting, meaningfulness of the activity, voluntariness of use, etc.)". In this sense, three main directions have been found to contribute to the definition of *User Experience*: aesthetics, emotion and affect, and experiential. These dimensions are based on the assumption that a positive UX is a prerequisite for engagement.

The equation "positive experience = engagement" has been broadly adopted in CCI research, and fun has been considered a key element when defining children's UX and one of the main motivations for children to interact with technology (Inkpen, 1997). Carroll (2004) defined fun as: "Things are fun when they attract, capture, and hold our attention by provoking new or unusual perceptions, arousing emotions in contexts that typically arouse none, or arousing emotions not typically aroused in a given context." Another major contribution to the definition of UX for children comes from the work of Zaman and Abeele (2007, p. 200). Taking inspiration from Communication Sciences, specifically the Uses and Gratification framework, the authors elaborated the likeability framework for describing young children's experiences with technology at home. The framework assumes that interactive toys and games are media, and views fun as being composed of the seven dimensions: (1) challenge, (2) control, (3) social experiences, (4) fantasy, (5) diversion, (6) arousal, (7) creative & constructive expressions. These dimensions aim to identify the gratifications young children seek when interacting with technology. Though this framework is not definitive, it provides elements with which to picture a child's experience, and it is relevant to this thesis as it was developed to address young children's experiences (age 4-6).

This thesis expands previous definitions of user experience in the CCI community, expanding them with concepts and theories of child development. As discussed in Chapter 1, experiences are a fundamental part of the child's development: they are the bases of learning (Piaget 1951). The thesis suggests that the evaluation of the child's experience does not only have to address the hedonic qualities of an interactive artefact, but also strongly involve other pragmatic qualities, such as its educational value.

Reviewing the concept of experience with respect to children, Green and Hogan (2005) defined it as “the fact of being consciously the subject of a state or condition or of being consciously affected by an event”. Such a definition stresses the centrality of children’s consciousness, thus reflecting an increased attention towards the child as a sentient being. Understanding children’s experience is a highly inferential process and recalling significant events is essential to this process. For this reason, verbal and drawn information, reported by the child and significant adults involved in the experience, can contribute to generating understanding of the quality of children’s experiences.

### 2.1.2. Evaluation studies

Evaluating the children’s experience presents several difficulties. The specific characteristics of young children render most of the conventional UX-research methods difficult to use. For example, asking young children to rate their experiences tends to lead to a positivity bias (Zaman et al., 2013). Asking children to describe experiences requires well-developed vocabulary and good understanding of the intended function of a system, which young children rarely have. They have, rather, a limited attention span and limited vocabulary, easily become tired and bored - if an activity is not easy to understand and fun it may be difficult to convince them to participate in it. Children do not easily differentiate an interaction activity from the system itself, they do not want to upset experimenters, and they dislike choosing unhappy faces to describe their experience. Finally, asking children to perform tasks may require them to follow precise instructions, which may be impossible to enforce. Conducting research in CCI requires accounting for such challenges, embedding an evaluation task in a fun activity within a meaningful context, to be done in a safe and familiar environment. In addition, it requires reviewing and defining approaches to ensuring the rigour of the research.

Performing UX evaluation with children requires richness of details to tease apart the impact of context and the fun of the activity from the actual system of quality. Qualitative methods suffer from the challenges of working with children and produce open-ended, narrative, and holistic information (Green & Hill, 2005). In accordance with Garbarino and Scott (1992 (in Green & Hill, 2005)) who state that “the more sources of information an adult has about a child, the more likely that the adult is to receive the child's message properly", this thesis suggests that triangulation can increase rigour in CCI research. CCI research with young children should be cautious in adopting evaluation methods that could provide non-informative or misleading information such as directly asking children if they liked a system (this typically resulting in "yes" and "no" answers). Instead, CCI research interested in generating better understanding of children's experiences should rely on the collection of indirect markers of system quality, such as children depicting or not depicting a specific system feature in a drawing, thus indicating items that were relevant to the child (reference in chapter 1.4). Indirect markers of system quality are often noisy, and trustworthy conclusions cannot be drawn based on a single method.

### 2.1.3. Research rigour

Discussions of research rigour in quantitative research mostly focused on the concepts of validity and reliability. Valid means "true and capable of being supported" (Ray, 1997). L. E. Berk further states that "the concept of validity can be applied to the overall accuracy of research findings and conclusions" (Berk, 2006). Validity can be both internal and external. Internal validity means that the conditions internal to the design of the study allow an accurate investigation of the researchers' hypothesis. In CCI studies, internal validity is often challenged. It is critical to differentiate between the effect of the system and the effect of the evaluation activity (which is often fun), alongside the effect of the context and the evaluators on the children's behaviour. External validity refers to the extent to which findings generalise to settings and participants outside the original study (Berk, 2006). This is an important concept in CCI, as young children are particularly susceptible to context variations.

The concept of reliability refers instead "to the consistency, or repeatability, of measures of behaviour" (Berk, 2006). To be reliable, observations and evaluations of people's actions should be agreed upon by more than one researcher. Researchers determine the reliability of data in different ways. For example, in observational research, researchers are asked to evaluate the same behaviours, and the degree of agreement between them is what makes the measurement reliable (Berk, 2006). A high level of reliability may be difficult to achieve in evaluation studies with young children, as they require expertise and sensibilities for understanding child behaviour, which is often unavailable in design projects.

The two terms, validity and reliability, originated in the positivist tradition, a philosophical line of thought that emphasises the detection of regularities in observable events. For this reason, these terms are more widely recognised when dealing with quantitative research. Some authors (such as Stenbacka (2001)) also discuss the use of these terms for qualitative studies, which are often conducted in CCI. Qualitative HCI research aims to “describe and explain phenomena in a rich, often exploratory way” and is “a situated activity that locates the observer in the world” (Denzin & Lincoln, 2000). Qualitative research consists of a set of interpretive, material practices that make the world visible. These practices transform the world. They turn the world into a series of representations, including field notes, interviews, conversations, photographs, recordings, and memos to the self. At this level, qualitative research involves an interpretive, naturalistic approach to the world. This means that qualitative researchers study phenomena in their naturalistic setting, attempting to make sense of, or interpret, phenomena in terms of the meanings people assign to them (Blandford et al 2016).

Patton (2001) points out that, in qualitative research, the phenomena are studied in context-specific settings with a naturalistic approach aiming at generating understanding, while in quantitative studies phenomena are manipulated through variables in order to decode their functioning. Stenback (2001) then argues that the concept of reliability is not relevant in qualitative studies as the concept itself is bonded to that of measurement, while qualitative research is concerned with generating understanding and interpretation. The term “validity” in qualitative research is, instead, substituted by terms such as rigour and trustworthiness, terms that denote a specific attention to the research process. Such attention towards the research process is in line with ensuring the internal validity of the research, as external validity is directly linked to the extent to which research results are generalisable to other contexts and circumstances, and qualitative research is more concerned with rigour in the process (Golafshani, 2003).

Research rigour in qualitative research can be achieved by adopting the following strategies: triangulation, disconfirming evidence, researcher reflexivity, member checking, prolonged engagement in the field, collaboration, audit, providing thick and rich descriptions and peer debriefing can all contribute to ensure research rigour (Creswell & Miller, 2000). Triangulation of data, a strategy seeking convergence of information derived from different methods to determine research findings, puts more emphasis on the researchers' lens and the systematic analysis of data (Creswell & Miller, 2000). Such an attentive processing of research data fits with the purposes of this thesis which aims to emphasise the researcher's role in the analytical process.

The approach to the analysis of triangulated research data in this thesis is mixed; the analytical process proposes different degrees of transformation of the qualitative data which can be extracted from each method (Table 1). After having identified the first set of codes, counts of the items that were recognised in the original source (for example drawings) were performed in order to estimate, quantitatively, the presence of the codes in the sample under analysis. The aim of this approach is to explicate the interpretive process that relies on research findings and thus promote the rigour of the analysis.

**Table 1. Example of the levels of analysis performed with children's drawings.**

| **Method** | **1st hand data** | **2nd hand data** |
|---|---|---|
| drawing | codes | Frequencies of codes |

## 2.2 Methods in CCI

Studying children's experience with CCI mandates an active involvement of different users, such as children and teachers, with a running system in a realistic context of use, such as kindergartens. This thesis identified four main categories of methods which were successfully used with young children: observational methods, verbal methods, survey methods, and visual methods (Table 2). In this chapter, methods used in CCI research with young children are reviewed and a specific focus is put on the review of drawing as an evaluation method.

**Table 2. Summary of methods used in previous research.**

| | |
|---|---|
| Observational Methods | - Naturalistic observations (Mansor et al, 2008- 2009)<br>- Participant observations/ethnography (Wyeth, 2006)<br>- Direct and indirect observations (Antle et al., 2008, Sylla et al., 2011; Addessi & Pachet, 2005) |
| Verbal Methods | - Interviews (Sylla et al 2011)<br>- This or That (Zaman et al., 2013)<br>- Laddering interviews (Zaman, 2011)<br>- Think-Aloud (Donker et al., 2004) |
| Survey Methods | - Multiple choice question boxes (Golsteijn et al., 2015)<br>- Fun toolkit (Read & Macfarlane, 2002) |
| Visual Methods | - Problem Identification Picture Cards (Barendregt & Bekker, 2006; Barendregt, Bekker, & Baauw, 2008)<br>- Drawings (Sylla et al. 2011) |

### 2.2.1 Observational Methods

Observational method, as reported in Markopoulos et al. (2008), refer to “an examination of a phenomenon that results in a description suitable for the purposes of a research or evaluation study.” Observations can be direct, meaning that they are collected through the senses of the observer, and indirect, where records are made. They can be carried out in the field and in the lab. Both choices present advantages and disadvantages. Conducting observations in controlled settings, such as research laboratories, can affect the realism of the findings; some aspects, such as social dynamics and motivations, might not emerge. In the case in which the observers engage with participants, a participant observation is being performed, a method that has similarities with ethnography. Ethnographic work aimed at exploring young children’s play experiences in the kindergarten has been carried out by Wyeth (2006).

Participant observation results are more useful when evaluating the role of a product, usage patterns, conventions, and any social aspect emerging. “Participant observation is less applicable for analyzing user experience at a more cognitive and sensorial level or for evaluating user performance”

(Markopoulos et al., 2008). An example of a context where participant observation is relevant is the school context. Opposite to participant observation there is passive observation. This method limits the interaction with participants to the minimum. Passive observation carried out in the lab and passive observation conducted in the field are different. During passive observation in the lab the observers and the observee are often separated physically in two different rooms in order to minimise interactions. When passive observation is carried out in the field, such observation is also called "naturalistic observation" and the observer minimises their interactions with the observees but both subjects share the same physical space. An example of naturalistic observation of young children can be found in (Farver & Branstetter, 1994 (in Berk, 2006)) where 3 and 4 year olds were observed in childcare centres and behaviours such as crying were noted down.

Observations are further differentiated in structured and unstructured observations. Unstructured observations do not have pre-determined goals when performing them, thus resulting in more open-ended findings. These types of observations may be more difficult to analyse, as each researcher may add their own perspective. A rich set of information can be captured but this method may lack focus with respect to the purposes of the evaluation. Structured observations are, instead, more focused and are usually run in phases: at first a focus of the observation is determined, then guides and forms to perform the observation are developed, observers are recruited (and trained if necessary), observations are performed, and the analysis and the interpretation of findings is carried out.

### 2.2.2 Verbal methods

Verbal methods mainly rely on the linguistic skills of both interviewer and interviewee. In the case of young children this may be particularly challenging as their language skills are still in development so they may need more explanations and more careful wording from the researcher. Verbal methods can be broadly differentiated in interviews and surveys.

### 2.2.2.a Interviews

Among verbal methods, interviews aim to investigate participants' perceptions, thoughts, abilities, feelings, attitudes, beliefs, and past experiences (Berk, 2006). In the context of interviewing children, clinical and structured interviews are distinguished. Clinical interviews are flexible and a conversational style is maintained. An example of a clinical interview is Jean Piaget's interview of a 3 year old child about his understanding of dreams:

"Adult: Where does the dream come from?
Child: I think you sleep so well that you dream.
Adult: Does it come from us or from outside?
Child: From outside.
Adult: When you are in bed and you dream, where is the dream?
Child: In my bed, under the blanket. I don't really know. If it was in my stomach, the bones would be in the way and I shouldn't see it.
Adult: Is the dream there when you sleep?
Child: yes, it is in the bed beside me" (Piaget, 1926/1930, pp. 97-98 in Berk 2006).

The main advantage of clinical interviews is to let the participants express their thoughts in a manner as close as possible to the manner they usually express themselves in everyday life. Clinical interviews also allow the collection of a large amount of information in a short time. A disadvantage of the method resides in the accuracy of the information retrieved as several factors may interfere: the interviewee may desire to give answers that please the interviewer, questions may be misunderstood, and the interviewee may have difficulties when expressing thoughts in words. This limitation is reduced by the adoption of structured interviews where each interviewee is asked the same set of questions in the same way (Berk, 2006).

A special type of interview, the laddering interview, has been evaluated with young children in the context of Child-Computer Interaction (Zaman, 2011, 2013). This method, which has roots in the field of communication science, investigates children's product preferences. The interview is structured in two phases: in the first phase the interviewer asks the interviewee to compare products and explain preferences, in the second phase the interviewees are asked to reflect on their choice criteria and to explain why this criteria is meaningful to them. The interviewer typically asks questions like “Why is that (attribute) important to you?”. The aim is to identify the links between the identified attributes. Young children were able to express their product preferences but only children aged 5 and above were proficient in producing ladders. Another issue with the method is that children are not keen on providing an explanation about the values that are meaningful to them when expressing their product preferences (Zaman 2011).

Among the verbal methods, think-aloud protocols have been used to assess usability problems with children (Bruckman et al. 2002). These protocols are often used with observations. Donker et al. (2004) used this method with children aged 6 and 7 years old and noted that they tended to remain silent. In the study, only 28 out of 70 child participants made notes.

#### 2.2.2.b Surveys

Common survey methods are questionnaires and rating scales (Markopoulos et al 2008). Among survey methods specifically developed for children, the Fun Toolkit is a set of tools used to measure fun after the use of technology. The kit is made up of four tools. The funometer is a vertical scale mimicking a thermometer whose inner line indicates the perceived amount of fun. The Smileyometer is a 5-point Likert scale with smiley faces. The fun sorter is a table ranking different activities comparatively, from the most to the least enjoyable. Finally, the “again again” table aims to assess whether the child is keen on repeating the activity by selecting three possible choices:  “yes” “maybe” “no”.

The Fun Toolkit tools have been generally used with children aged between 6 and 10 years old (Read et al 2002). Among the tools in the kit, correlation between the Smileyometer and the Funometer was found but not with the other tools. Zaman et al (2013) evaluated Smileyometer and “This or That” methods with children aged from 2 to 4 years old. They noticed an overrepresentation of positive extreme scores in the case of the smileyometer and the appropriateness of preference testing, such as the This or That method, with young children. In Zaman’s evaluation of the Smileyometer (2013) children tended to rate things with the highest positive grade available on the scale (5- brilliant). According to the author (Zaman, 2013), the This or That preference test proved to be internally reliable and uni-dimensional for children aged 4 and older. In other areas of research, such as health, children aged 6 and 7 years were found to give more extreme answers on the Likert scale (Rebok et al. 2001 in Zaman et al. 2013).

To conclude, four main issues have been identified when conducting surveys with children: satisficing and optimising, suggestibility, tendency to positive evaluation with specific question formats (such as the Smileyometer, a 5-point Likert scale with smiley faces representing the following ratings: awful, not very good, good, really good, brilliant), and language effects.

### 2.2.3 Visual methods

Visual material can be helpful to make the child feel more comfortable during CCI evaluations. An example is Problem Identification Picture Cards (Barendregt et al. 2008). The cards were sets of 8 pictures developed to depict usability (perception, cognition, and action) and fun (challenge, fantasy, curiosity, and control) problems. Each set was composed of 8 pictures to avoid overwhelming the children. The method was found useful in helping 5 and 6 year old children to express more problems when performing Think Aloud and to act as memory aids for the child. Moreover, the method proved to be useful for retaining children's attention during the study.

A distinction must be made when asking children to produce images themselves in order to express an evaluation of the interactive experiences they make. Several studies in the field of CCI have employed drawing at different stages of their design intervention. Three main stages of this involvement were identified: ideation, formative evaluation and summative evaluation. Guha and colleagues focused on the ideation stage (Guha et al., 2004) and used drawing as a way to engage children aged 4-6 in field observations and for ideas brainstorming. More recently, Rubegni and Landoni (2018) adopted drawing for facilitating young children's ideation process aimed at the creation of stories with the iPad in the kindergarten. The study reported the importance of drawing for allowing young children to express their ideas and promote creativity. In using drawing for brainstorming, Guha and colleagues stress the importance of proposing different approaches to drawings to avoid the children becoming bored while doing a repetitive task. Nicole and Hornecker (2012) employed drawing to perform formative evaluations with children aged between 5 and 12 instead. They evaluated a set of early prototypes of touch screen and table-top interfaces for a museum application by collecting drawings from children and adults. The approach proved particularly useful for prompting discussion during interviews with children.

Unlike formative evaluations, summative evaluations with children’s drawings mostly involved older children. For example, Xu and colleagues invited a class of children aged 8-9 years old to play with four different interfaces and then to draw their experiences (Xu et al., 2009). The children could talk while drawing and the observers could ask for clarifications. After the drawings were completed, the researchers performed a thematic analysis. Four themes were identified: “fun” as an expression of satisfaction and engagement, “goal fit” as the appropriateness of the interface for the activities proposed, and “tangible magic” as the dimension measuring how the tangible qualities of the technology affect interaction and user experience. Each drawing was coded noting the presence or absence of the themes and inter-coder reliability was assessed. The coding activity lasted 2 hours, until all the coders had analysed all the drawings. The themes were present in more than 65% of the drawings. The drawings helped to identify children’s values, for example the elements of the interactive system that were more important for them, and to determine what children knew (Xu et al., 2009).

Sylla and colleagues analysed a corpus of drawings to support the comparative evaluation of a graphical and tangible interface promoting oral hygiene awareness (Sylla et al., 2011) with a sample of 4 and 5 year old children. The authors differentiated between "central elements", depicting items that were used in the interaction activity, and "other elements", depicting external items, such as the child, the computer, or other persons. Results highlighted that the drawings mainly captured the central elements of the experience. This finding is consistent with research on children's artistic expressions which demonstrated how they tend not to draw unnecessary elements or elements that are not of interest to them (Matthews, 2003 - see section 1.4). Drawing also proved useful to discriminate between the graphical and tangible interfaces, highlighting different attractors of the child’s attention. Statistically significant differences occurred when comparing the “other elements”: children using the TUI reported more of these items in the drawings.

To summarise, past CCI studies highlighted the potential of drawing as an elicitation technique in interaction design with young children. However, the main emphasis was not on its usage as an evaluation technique, an issue that this thesis can help to address. This thesis will discuss further the usage of drawing in CCI to capture young children's experiences.

## 2.3 Interactive musical systems

Several studies have recently presented interactive systems supporting children's musical experiences. This section gives an overview of the methods that have been adopted for evaluating children's interactive musical experiences. To provide a broader overview, the reported studies comprise evaluations of both young children and older children. Such systems can be clustered around two main themes: systems for *acting as a musician* and systems for *listening as a musician*. The first theme comprises systems that are concerned with body movements as triggers to make the child impersonate the role of musician. The second theme is, instead, concerned with training the child to listen to, and distinguish, musical variations.

### 2.3.1 Acting as a musician

"You're the Conductor" falls into the first category – acting as a musician. In this system, children (aged 4-11) took the role of an orchestra conductor: they could control music volume and tempo by interacting with an augmented baton (Lee, Nakra, & Borchers, 2004). This system was evaluated through observation in a museum setting and it was mainly aimed at evaluating technology robustness. Other systems were designed to support young children to learn to play traditional instruments. An example is the "Music Paint Machine", a system which targeted children aged 5-7 (Nijs & Leman, 2014). This system was evaluated with specific tests assessing musical learning, while a 4-point Smiley-based questionnaire with an extra "I don't know" option allowed the child to rate their experience with the system.

Andantino is an interactive system for teaching piano. It was evaluated in observation sessions with two children aged 12 and 13 years and 6 children aged 7-11 years (Xiao et al., 2016). The system consists of a projective system able to transpose line silhouettes on a traditional piano, in front of the learner, while he was playing the instrument. The learning style of the system was inspired by

Dalcroze Eurhythmics and was aimed at promoting an intuitive understanding of music. The observations from video recordings of the interactive sessions and their transcripts reported positive feedback for the system's offering an enjoyable musical experience to the children. This could be possibly because less emphasis was placed on musical notation, which has been reported as a factor of stress during children's approaches to learning music.

### 2.3.2 Listening as a musician

Other systems focussed on the child's capability to *listen* to music, particularly to recognise musical variations. A strong focus on musical variations can be found in the system developed by Antle and colleagues for children aged between 7 and 10 years (Antle, Droumeva, & Corness, 2008). This system proposed a metaphor based on body movements, which was designed with four music experts. Children's movements were captured by a tracking system and mapped onto a percussive sound output, which varied according to the child's movements. Specifically, *tempo* was mapped with reference to the speed of the children's movements, *volume* with reference to the intensity of the activity, and *pitch* reflected the proximity among children. Contrary to the system described in this thesis (chapter 4), the system did not control harmonic and melodic features, and consequently did not require a complex algorithmic system to deal with such elements. The evaluation of the system comprised of the assessment of children's performance by annotating the time the child took to complete the task, a questionnaire evaluating their motivation and interest, ease of learning, intuitiveness, and concentration required. The researchers annotated children's verbal explanations of how they performed with the system, and their likes and dislikes. Video-recordings were also collected too for subsequent observational analysis.

Similarly, the "Continuator" facilitates piano learning by automatically engaging in musical dialogues with a child performing on a keyboard. The system, which was designed for children aged 3-5, takes the music performed on the keyboard as an input and plays back coherent excerpts that mirrors children's play (Pachet, 2003). The design of the interaction proved successful in capturing and holding children's attention during the musical activities (Addessi & Pachet, 2005). Indeed, concealing the technological apparatus of the system can enhance the user experience and promote increased engagement (Bolter & Gromala, 2006).

To evaluate their experience with the Continuator, children were asked to draw their experience one week later, and video observations were analysed.

Smartphones and tablets also offer opportunities to improve children's music listening and music making abilities (Rajan, 2014). Musical applications and console games involving music have flourished in recent years. Hein distinguished between games with an educational purpose, (those teaching the player to read and write notes); rhythm-oriented games (such as "Guitar Hero" where the player follows visual cues to play back a song in time); and "music toys" (which allow children to improvise music) (Hein, 2014).

Despite the relevant contributions of the studies outlined above, literature on interactive systems aimed at providing meaningful musical experiences to young children is still quite exploratory. Many learning concerns are still not addressed, especially in the case of systems supporting multiple users' interactions. One such example, in the case of non-expert musicians, such as children, is guaranteeing musical coherence during a group exhibition is important to give them valid musical stimuli. At the same time, making sure that each child can distinguish his/her unique contribution during group performances can help the child to learn and improve on his/her errors.

## 2.4 Conclusion

This chapter presented a general methodological framework wherein the contribution of this dissertation should be positioned, emphasising an interpretivistic approach supported by triangulation. In addition, this chapter suggests that drawing describes the experiences of young children well. This is supported by the reflection of children's everyday life and therefore by their recurrent practice of drawing at school and at home. These practices offer to the child the opportunity to re-elaborate the experiences they participated in and to organise them. The child's artwork becomes an expression of what the child took away during these experiences and, thus, a manifestation of his/her thoughts. However, little studies have evaluated the trustworthiness of drawing as an evaluation method for young children, leading the way to the research questions addressed by this thesis.

# 3 — Spaces for Music Exploration

**Abstract.** The research described in this thesis is framed in the music learning domain. In particular, this chapter aims to be technology-focused and define desirable characteristics for an interactive music learning space for the kindergarten. The acceptability of a music playground and the practical constraints to using it in a kindergarten were evaluated. The following section illustrates the activities run for requirements elicitation and for requirements testing.

## 3.1 Requirements elicitation

In this section the activities leading to the definition of the user requirements of the interactive music learning space are presented.

The user requirements were collected by analysing related work on music education of young children (see 2.3) and by conducting focus groups and workshops with users and domain experts, as reported in Table 3.

**Table 3. User requirements elicitation activities.**

| | **Activity** | **Users** |
|---|---|---|
| 1 | Literature review | - |
| 2 | Focus group | 10 kindergarten teachers |
| 3 | Focus group | 12 parents |
| 4 | Workshop | 5 Music teachers |

### 3.1.1 Activity 1: literature review

Goal: ascertaining the best music learning objectives for young children

Method: literature review of music education for young children

Outcome: This phase was informed by the review on music education reported in chapter 1.5 and on previous research in CCI (chapter 2.3). Based on this work, the Music Learning Theory (Gordon, 2003) was selected as the ideal framework to ground the design of the artefacts presented in this thesis because it provides simple and actionable information to drive system design.

According to Edwin E. Gordon (2003) children are born with an intrinsic level of musical attitude and “movement activities and the chanting of rhythm patterns will improve a child’s ability to learn to sing tonal patterns, because movement helps the child bring subjective unconsciousness into subjective consciousness” (Gordon, 2003). According to the Music Learning Theory, the development of musical skills is parallel with the development of other cognitive abilities, such as visual and linguistic skills. This work was expanded taking into consideration the importance of multisensorial learning (chapter 1.4) and particularly the work by Maria Montessori which has directly inspired the artefacts evaluated in study 2 and study 3 reported in this thesis (chapter 5 and chapter 6).

In addition, research on CCI identified two main functionalities of the systems designed to facilitate music learning in a children population. These systems may help the child to “act as a musicial” and to “listen as a musician”. The Children’s Orchestra (presented in chapter 4) aims to integrate these two functioanal and experiential goals into a coherent and rich musical experience, based on the assumption that active listening is a fundamental component of music literacy (Gordon, 2003).

### 3.1.2 Activity 2: focus group with kindergarten teachers

Goal: understanding major contextual issues connected to the introduction of technology in the kindergarten. A focus was put on adopting technological solutions for music education.

Method: focus group with teachers of the kindergarten. The focus group was setup in a local Italian kindergarten, was led by 2 psychologists and involved 2 observers. The conversations were transcribed and analysed by the author of this thesis.

Outcome: the focus group conducted with the school teachers revealed the potential constraints that could emerge in the school context. Their opinion was that technology in school requires passive activities such as having children merely as observers rather than as active participants. They suggested using the activities which engage children's senses to increase their self perception and sense of involvement. The results of the focus group also suggested to take into account the limited resources available in the kindergarden. These resources refer to the limited digital literacy of the teachers, economical possibilities available in the context of states school, and time constraint to integrate new activities in a busy school curriculum.

These results further support the requirements emerged from activity 1 suggesting to emphasise children active behaviour (which includes both active listening and direct music making) and stress the importance of multisensorial learning. In addition, the workshop clearly identified contextual requirements calling for simple and flexible low cost technology.

### 3.1.3 Activity 3: focus group with parents of young children

Goal: understanding parents' perception of their children using technology. A focus was put on adopting technological solutions for music education.

Method: focus group with the parents of the children attending a local Italian kindergarten. The focus group was organised in the same state kindergarten as Activity 3. It was led by 2 psychologists and involved 2 observers and 12 participants. The conversations were transcribed and analysed by the author of this thesis.

Outcome: Parents reported that children frequently used technology, and that its role was mainly to entertain them. In general, it emerged that parents were not against technology but they preferred their children to play outdoors thus emphasing the importance of physical activity over sedentary behaviour. In addition, the importance of adult supervision was stressed.

### 3.1.4 Activity 4: workshop with music teachers

Goal: identify the major issues in teaching music to children. Specifically, it aimed to define the learning objectives of the system, to understand which kind of musical stimuli were suitable for young children (music style), and to envision possible metaphors to facilitate the understanding of music notions in a young children population (interaction style).

Method: workshop with 5 music teachers. The workshop involved an interaction designer, a composer, five music teachers and an artist in residence. It lasted 1.5 hours and included brainstorming and structured activities facilitated by different probes (images and videos, paper-based scenarios). Notes were taken during the workshops and results were analysed and discussed by a team of experts covering different disciplines, such as music, interaction design, the Art and Computer Science. The author of the thesis contributed to the analysis bring her own expertise in CCI.

Outcome: The most interesting finding was the importance of teaching children to discriminate between musical parameters variations. In particular, the teachers suggested narrowing the focus to three musical parameters: volume, articulation, and speed. "Speed" refers to the speed of the downbeats in a time unit[2], "articulation" refers to the transition or continuity of a note, and "volume" refers to the loudness of the sound. According to the music teachers, to achieve the understanding of such structural elements, children should be able to access them independently from other parameters.

In addition, the focus group engaged in a discussion about the most appropriate sound palette for the interactive system. It was suggested that to avoid forming an incorrect imprinting on the child, synthetic sounds were preferable to approximations of existing music instruments. Virtual simulations of musical instruments indeed flatten the variety of the original melodies, resulting in unrealistic tones (Di Carlo et al., 2013). Interestingly, the personal relationship of a child with an instrument had to be taken into consideration. For instance, a child whose parents play the piano is likely to have a particular relationship with the timbre of that instrument, which could constitute a bias towards the timbre of other instruments and thus reduce the impact of the activity. Based on these considerations, it was suggested that synthesising the music with a timbre that does not recall any specific instrument helps the children to avoid this bias and stay focused on the music.

[2] References to speed are to the rhythmic density of the melodies rather than the general tempo (BPM).

The teachers also emphasised the importance of playful social interactions as a major motivational driver. According to them, systems to teach music to young children should emphasis social connections and fun. Storytelling was also proposed as a major factor to enact these ludic group interactions in practice. Storytelling was presented as a way to translate musical variations into enacted experiences.

### 3.1.5 Conclusion

The activities described above informed the definition of the initial requirements for the design of musical interactive systems for kindergartens. The following table sums up the activities run and derived information which have been used (Table 4).

**Table 4. Initial system requirements.**

| Activity | User requirements | Requirements for the design |
|---|---|---|
| Literature review | - | Promote occasions of active listening and music making |
| Focus group with teachers in the kindergarten | Accessible technology that can be used to support teaching | Design interfaces that are as easy to use as possible<br>Miminise economical costs |
| | Involve children in activities which involve the senses | Plan activities which involve a range of sensorial stimulation |
| Focus group with parents | Supervision during the activities which involve the use of technology | Have an adult as intermediary between the children and the technology |
| | Avoid situations where the child is a passive recipient of technology | Propose interaction models which involve the body |
| Workshop with music teachers | Facilitate the capabilities to recognise the variations of musical parameters in an instrument neutral music | Control musical parameters independently<br><br>Play a synthetic music timber |

## 3.2 Requirements testing

The user requirements described above were used to inform the conceptual design of musical interactive systems to be adopted in the kindergarten. This knowledge were used to define a conceptual design which was refined iteratively with users and gave rise to the artefact presented in chapter X. In particular, the following activities were run:

2 Workshops with music teachers supported by low fidelity prototypes;

A Wizard of Oz session with young children allowing them to experience the system.

A reflection-in-action approach was followed (Schon & De Sanctis, 1986). This approach emphasises the dialogical nature of the design process. In this sense, during the design process, changes suggested by the design team were applied to a specific context which, in turn, contributed to the initial design ideas thus establishing a mutual exchange of knowledge. This allowed to evaluate and refine Children's Orchestra iteratively and in context, and provided some general indications which were integrated in the design of the Interactive Piramid tested in studies 2 and 3.

### 3.2.1 First workshop with users

A workshop with 3 music teachers with experience with young children education was run. The music teachers involved in this workshop differed from the music teachers involved in the previous activity. The workshop lasted 1 hour approximately. During the workshop the research team showed visual material to the teachers to support discussion on children's interaction.

Low cost, robustness and ease of use were confirmed as being the main constraints of system design. The teachers elaborated on different ideas of how the interactive system could be used in their teaching practices. The most innovative aspect was the possibility of augmenting active listening with the direct manipulation of polyphonic music. They envisioned an environment which could help children to recognise variations in different structural music parameters controlled by individual children, and to independently agree on adopting a classical style music genre.

The insights gathered during the workshops informed the design of two storyboards representing possible scenarios of use. They were drawn in cartoon style (Figure 2) by Adriano Siesser, an artist in residence and discussed with two music teachers who were experienced in preschool education.

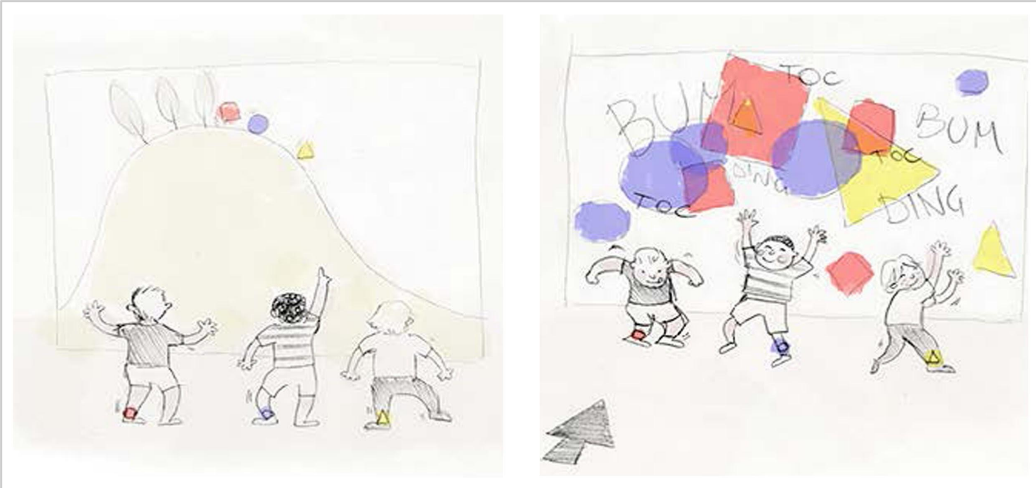


**Figure 2. Initial storyboards.**

This feedback informed the development of a first prototype[3] describing two scenarios with a coherent musical track which informed the system presented in chapter 4 of this thesis. The first scenario recreated a scene of the Nabucco by Giuseppe Verdi. For example, children could control the *speed* by moving to a specific area of the stage or the *volume* of their instrument by moving their arms. Each child played the role of a character wearing costumes and masks and using objects related to it. The stage was covered by a large carpet of different colours associated with a prerecorded music clip. Children had to listen carefully to the opera: when their turn came they moved to the correct area of the carpet and triggered the voice of their character by moving their arms. The second scenario described a situation in which children selected their favourite costume, mask, and other objects and built their own Musical Tale accordingly. This scenario used automatic music composition to give children control of low level parameters of the composition.

### 3.2.2 Second workshop with teachers

The scenarios were discussed in a subsequent workshop with the same group of teachers. Overall, they preferred the first scenario as it allowed a more direct control of the music, although they felt the need for more precise instructions to introduce the children to the activity.

The main outcome of this design activity was a three-staged educational format for the interactive system including a phase of acculturation, manipulation and narration. The first phase (acculturation) was meant to help the children

[3] **https://youtu.be/m-UIKx9F90E**

distinguish different musical parameters, specifically speed[4], articulation and volume. They had to make movements according to the variations of the music, which was controlled by the teacher. In the second phase (sound manipulation) children controlled the musical parameters by moving around the room. In particular, music speed was controlled by the speed of movements, and articulation by proximity. A child with a conductor role was given the control of the volume. In the third phase (narration) storytelling and fantasy play were introduced. Children dressed up and invented their own stories as part of the process of making music.

### 3.2.3 Wizard of Oz

The three-staged educational format derived from the workshop described before was pilot-tested as a video using a Wizard-of-Oz method with the help of a tutor. Three children (5 to 6 years old, two females and one male) were invited to act for the video (Figure 3).


**Figure 3. A frame of the Wizard of Oz session.**

The children were accompanied by one parent each who signed a consent form allowing us to use the recordings for research purposes. Involving the children in this phase was fundamental as a preliminary evaluation of their experience. It allowed us to identify specific behavioural challenges related to children from a young age group.

[4] References to speed are to the rhythmic density of the melodies rather than the general tempo (BPM).

For example, a child was reluctant to follow the instructions of the tutor and remained at the margins of the interaction space for most of the time, paying little attention to the tasks. However, during the narration phase he was excited to play the part of the king and showed a keen interest in the activity. In general, costumes were perceived positively even if they were sometimes intrusive. In particular, masks were discarded, as the holes for the eyes did not perfectly fit the child's face. The pilot helped in assessing that less intrusive objects (e.g. magic wands, crowns, swords, and capes) were preferable, as they did not hinder children's movements.

The videos were particularly effective in communicating the idea of the musical playground. Ultimately, a music teacher decided to apply the educational format in her teaching practice in a kindergarten and participated with us in the actual development of the Children's Orchestra.

### 3.2.4 Results

The requirements emerged from the elicitation activities (section 3.1) were thus refined during the testing activities and can be summarised as (i) learning outcomes (ii) music style and (ii) interaction requirements (Table 5).

**Table 5. Requirements which emerged during the activities with users.**

| | |
|---|---|
| (i) Learning Outcomes | Promote active listening.<br>Distinguish variations in speed, volume, and articulation.<br>Recognise the voices of a polyphony.<br>Encourage music making over active listening. |
| (ii) Music Style | Classical music style.<br>Coherence of the polyphony.<br>The timbre should not resemble that of any existing instruments.<br>Present a wide range of varied music. |
| (iii) Interaction requirements | Children have to control low-level parameters.<br>Each child autonomously controlled a voice.<br>Promote social interaction.<br>Technology should be transparent.<br>Provide tangible objects<br>Give a small set of clear rules to avoid distractions. |

## 3.3 Conclusion

In this chapter we reviewed the steps and the iterations which led to the definition of a musical learning space for kindergartens, implemented in Children's Orchestra which is described in chapter 4. The first activities were useful to provide the initial guidelines to define the best frame that would have allowed for optimal musical interactive spaces for young children and teachers.

The iterative process of defining and revising requirements by involving users allowed the research team to not only create a space for the mutual negotiation of the best interactive system but also informed the best practices to adopt which finally inspired different elaboration in the form of the systems tested in studies 2 and 3. In the following chapters the technology thus informed was adopted for exploratory evaluations of the triangulation approach in CCI to explore the trustworthiness of drawings as a medium to illuminate the child experience.

# 4 - Study 1: Music-Movement Association

**Abstract.** This chapter explored the analysis of drawings in triangulation with other data sources which would contribute to answering the following research question:

- RQ1: Is drawing a *trustworthy* research method to evaluate young children's experience?

To this end, we explored the drawings collected in a longitudinal study which explored the experiences of young children with a technology-enhanced movement-based interactive system for music education. The adoption of movement for music education is not new in music pedagogy and is the basis of recognized pedagogical approaches, such as Dalcroze Eurhythmics (presented in Chapter 1).

## 4.1 Introduction

As discussed in chapter 2, several methodological concerns surrounding the reliability and validity of clinical assessments based on drawings have been raised because of the interpretive nature of drawing analysis (Thomas & Jolley, 1998). Triangulation can help overcome the issue of having multiple interpretations by filtering the information derived from multiple data. A methodological validation of drawings as a means of eliciting children's multisensorial experience in HCI is therefore presented. For this purpose, a large sample of drawings collected in a longitudinal study aimed at evaluating a technology-enhanced classroom for music education, using traditional education setting as a baseline, have been analysed. The analysis triangulated several sources of information including ethnographic observations of designers engaging with the field (42 hours overall), pedagogical reflections elaborated with the diary approach, a post-study interview (1 and a half hour) and in-depth interviews with two kindergarten teachers who participated in the project (1 hour overall). This rich set of data was compared and contrasted with the analysis of the drawings the children made after each music class. Results of the study are reported highlighting potentials and challenges of drawings in longitudinal HCI research with young children.

## 4.2 Method

This study was conceived as a longitudinal case study and collected a large corpus of drawings in two different educational setting. In the first setting (hereafter referred to as the "Children’s Chorus"), students were engaged in music education by an expert teacher following the Music Learning Theory approach (Gordon, 2003). This approach prescribes a set of embodied exercises children have to engage with while following the music created by an expert teacher singing or playing music. For example, children were guided by the teacher to learn some musical chants repeating rhythmically onomatopoeic sounds such as “pam” with the help of movement and a coloured foulard: children went round and round holding the foulard, following the teacher’s vocalisations and singing themselves at a regular pace until the teacher changed rhythm.  The second setting (thereafter referred to as the "Children’s Orchestra") was a technological extension of the approach whereby the control of the music was delegated to an algorithmic composer. Delegating this part of the music knowledge to the algorithmic composer would overcome the practical limitations of music education in Italian kindergartens, whose education system suffers from being underfinanced. Children’s Orchestra was iteratively developed while testing it with children between the age of 4 and 5 years (Core et al., 2017). As part of the evaluation children were invited to draw their experience after each class. These drawings were compared with researchers’ observations and teacher’s interviews collected both during the Children’s Orchestra and Children’s Chorus. The rationale for performing the analysis both in Children’s Orchestra and Children’s Chorus was to observe major changes in the drawings related to the presence or absence of the interactive system.

### 4.2.1 Participants

Two different groups of 4-year-old and 5-year-old children participated in the Children's Chorus and Children's Orchestra sessions; the children took regular classes every 15 days. A sample of 25 children (18 males, 7 females) aged 4 and 5 years old attended 11 lessons. They were divided into two groups: 12 children of 4 years old (9 males, 3 females); and 13 children of 5 years old (9 males, 4 females).

The activities of the groups were facilitated by a music teacher specialised in music pedagogy, following the Gordon theory (see chapter 1), and singing for the young children in the Children's Chorus setting. In addition, a kindergarten teacher supervised each lesson.

Ethical approval for conducting the study was obtained from the Human Research Ethics Committee of the University of Trento. A consent form was distributed to the parents. The form asked for their consent to: 1) use a series of safe sensors in the music laboratory; 2) use recordings of the activities for research purposes. A total of 25 parents consented to the first point. Only 12 parents gave consent for us to use the video recordings. As a consequence, videos could not be used for performing the analysis of the activities. The participation in the study was free of charge, all the costs were covered by the University of Trento.

### 4.2.2 Location and materials

The Children's Chorus and Children's Orchestra were tested over a period of seven months, from November 2015 to May 2016, in a kindergarten located in the North of Italy, in the Trentino region. The activities took place during the school's working hours as part of the timetable. Children's Orchestra was set up in a dedicated room containing a rug, two loudspeakers, and a control desk (Figure 4).

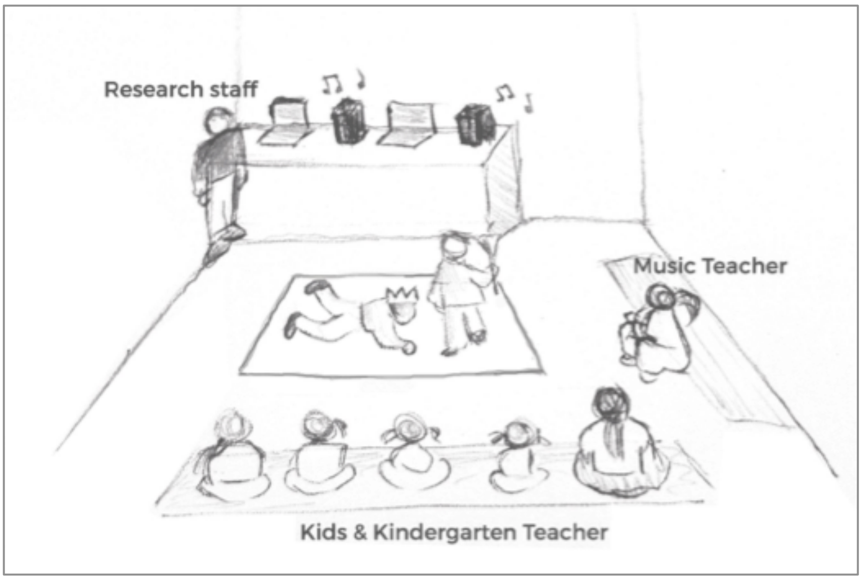



**Figure 4. Set-up of the Children's Orchestra space.**

### 4.2.3. Musical Interactive System

Children's Orchestra was a musical interactive system aimed at supporting young children in active music education group sessions in the kindergarten. The term "interactive system" in this context is in line with Benyon et al.'s (2005) definition, referring to all the "components, devices, products and software systems that are primarily concerned with processing information". Differently from this definition, the definition of "interactive media", as defined by Mclever Lopes (2001), stresses the importance of the user being in control of "the sequence in which they access content". In this thesis we refer to interactive systems rather than interactive media because the definition of interactive system does not put a strong emphasis on the control of the sequence through which the user can access the content. The system described in this thesis was derived from the Music Room (Morreale et al. 2014; Morreale, 2015). Children's Orchestra consisted of a tracking system able to detect movement patterns of two to four children in a room and in the translation of such a pattern in inputs for algorithmically generated music (Masu et al., 2017). Children could compose a western classical-style musical score (based on piano, violins and trombone) by moving within a room. Children's Orchestra consisted of an automatic music composer, two controllers, and a tracking system.

The architecture of the music composer was based on an extension of Morreale et al., (2013) which followed a rule-based approach to control a number of musical parameters in real-time, allowing the generation of multiple melodic lines

(Masu et al., (2017). As a consequence, each child could control their own melody, thus modifying the music without reciprocal interference. Furthermore, the algorithmic composition granted continuous access and control to low-level structural parameters, such as speed, volume, and articulation. Finally, the algorithmic solution guaranteed a number of different compositions but, at the same time, restrained the musical outputs to correct melodic and harmonic rules.

The process of generating music from user movements involved two steps. First, a tracking system detected the child movement to extract cues from their behaviour (e.g., their relative position and speed). Second, the movement data were passed to the algorithmic composer which translated them into combinations of musical factors, which determined the change produced in the generated music (Morreale & Masu, 2013). The design approach aimed to make the technology invisible to the visitors in order to foster their engagement with the creative act rather than with the technological infrastructure.

Following this approach, two types of artefacts were developed to control the music generated by the algorithm. This distinction reflected the different requirements of the proposed learning process: during the first phase the music was controlled by the music teacher with a *remote controller*. This was necessary to help the student familiarize with basic knowledge on music parameters. During the subsequent stages, each child controlled a melodic line using body gestures. Each child's movement had to be detected independently by the tracking system, as each movement corresponded to a single melodic line which was contributing to the whole melody.

When designing the remote controller, the limited familiarity of laypersons with technology and cost limitations needed to be taken into consideration. The remote controller was, therefore, implemented as a smartphone web-application, ensuring it was accessible, portable, and cost-effective (Figure 5). The mobile controller allowed to make adjustment of the global music volume and each child's voice speed (slow (L) and fast (V) ) and articulation (staccato (S) and egato (L).

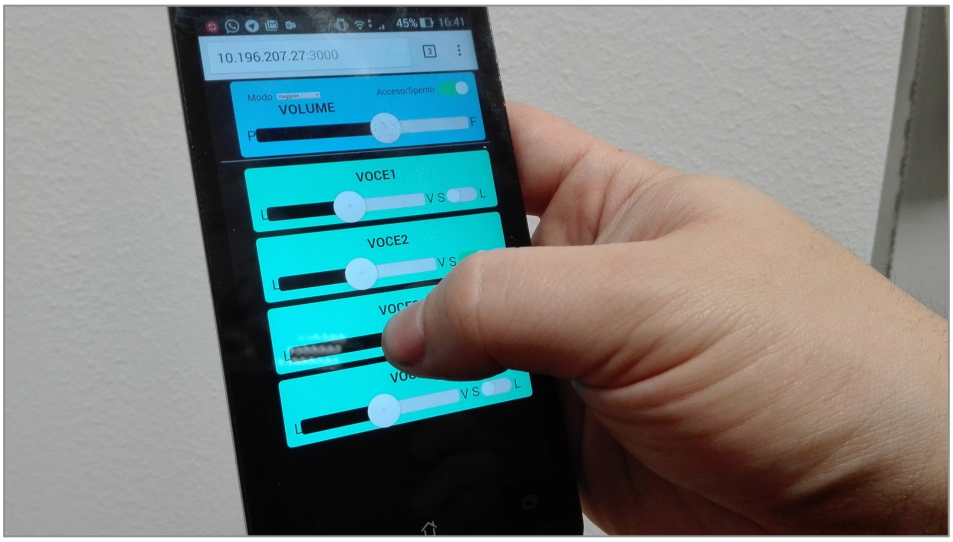



**Figure 5. Children's Orchestra mobile app controller.**

The tracking system underwent a number of iterations. The first prototype was developed adopting an infrared-based (IR) solution and LED lights (Figure 6). In this solution, an IR camera mounted on the ceiling tracked and followed a number of objects augmented with IR LEDs using computer vision techniques (Figure 6). The IR-based system was represented by a small-sized (32x32 mm) IR videocamera set on the ceiling of a room. LEDs were hidden inside paper-based crowns that were to be worn by children. Two laptops were used to, respectively, administer the music algorithm and check signals registered from LEDs. A set of speakers was also provided in order to have a satisfying audio performance inside the room (Figure 4).

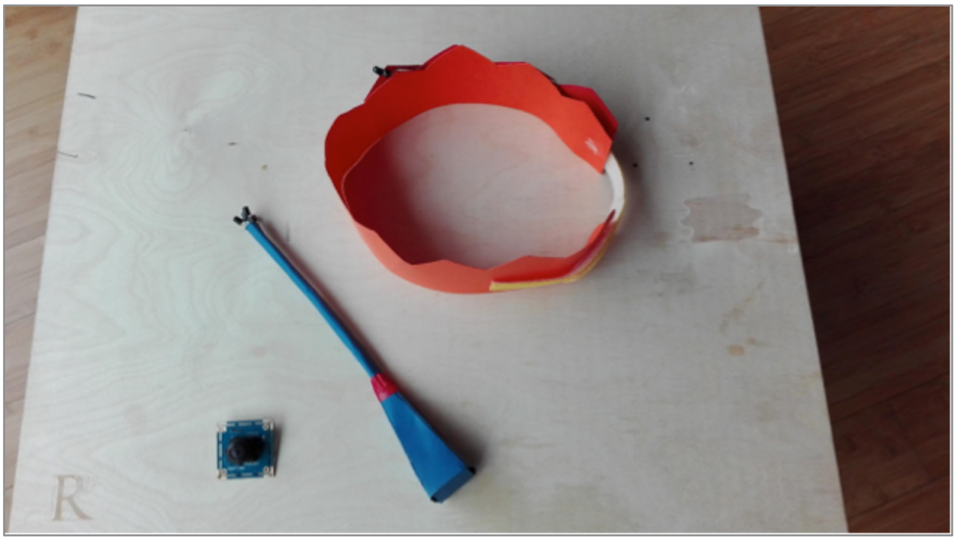


**Figure 6. First interactive system configuration: the IR videocamera (on the left) and the paper-based objects augmented with LEDs whose signal could be detected by the videocamera.**

However, the first prototype suffered from visual occlusion limitations, and another tracking system was developed to overcome them (Figure 7). The new system used objects with embedded motion sensors, such as accelerometers. Relying on accelerometers allowed us to avoid signal losses and provided a finer control. The accelerometer was hidden inside a box and mounted respectively on the crown and the wand. The technological change the first to the second prototype was not noticed by children and in general the system performed well.

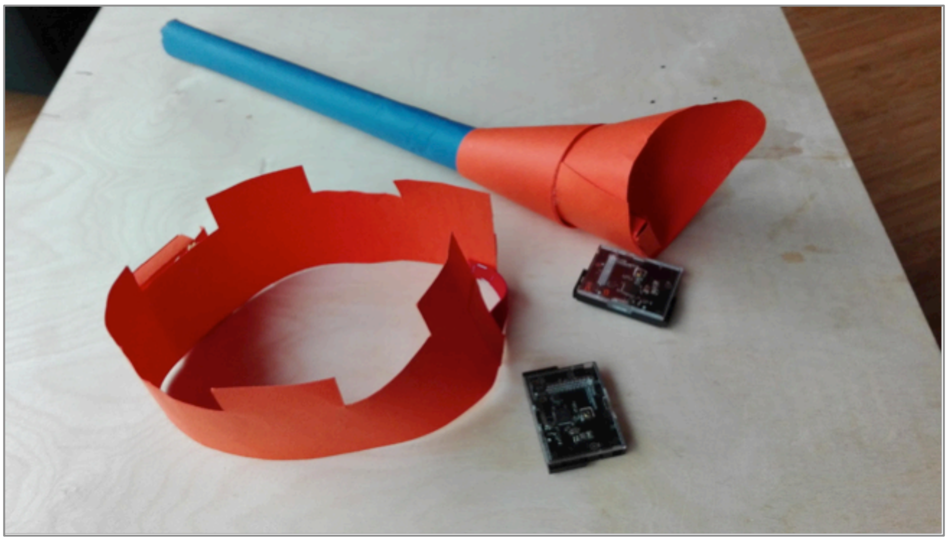


**Figure 7. Second interactive system configuration: accelerometers and the paper-based objects in which they were hidden.**

## 4.3 Procedure

Both groups (Children's Orchestra and Children's Chorus) followed a cycle of music lessons. They occurred approximately every 15 days and were administered by a music teacher in the same room. Each lesson lasted 30 minutes (involving around 10 children per group) and were structured in three phases: acculturation, manipulation and narration. The acculturation phase (lesson 1-7) aimed at sensitising children to different musical parameters: articulation (legato-staccato), speed (slow-fast) and volume (loud-soft). The manipulation phase (lesson 8-10) let the children explore the musical parameters by moving their bodies. The narration phase (lesson 11-15) had children controlling the music while acting in the role of an animal (for example, they had to move slowly to play slow and soft music and thus avoiding waking the sleeping wolf).

**Figure 8. Children's drawings after Children’s Orchestra and Children’s Chorus lessons. Teacher's notes provide complementary information.**

At the end of each session, the children were asked to draw what they experienced (Figure 8). Drawing took place in a different classroom equipped with desks and chairs and was supervised by the school teachers. Each drawing was accompanied by short teachers' notes reporting children's explanations of what had been drawn. For example, in Figure 6, the note at the top of the panel reports the following explanation: *“It is me dancing with the magic wand. I am remote controlling the music. When I was going fast, the music was going fast. When I was going slow, the music was going slow”*.

During the study, the music teacher was asked to fill in a diary on a regular basis. The diary provided the teacher's point of view on the activities, with a focus on learning and a comparison between the different approaches. A large set of field observations were also collected in-situ by the three researchers, focusing on children’s experiences, technological setup and technology limitations. Two interviews, investigating the perception of the interactive system and its educational value, were also conducted with the three teachers who assisted with the activities. The interview questions can be found in Appendix 1. Each interview lasted approximately 30 minutes.

In the following paragraphs we describe the educational setting followed in Children's Orchestra in details.

### 4.3.1. Phase 1

The first phase, acculturation, was meant to teach the children to distinguish a number of musical parameters: speed, articulation, and volume. This phase was divided into three groups of seven lessons:

- during lessons 1 and 2 the children familiarised themselves with the environment and music. They were exposed to the combined variations of volume, speed, and articulation. The music was controlled by the teacher with a remote control, and the children were invited to move freely on the carpet in sync with the music. A piece of polyphonic music with four melodies was played and the variations occurred on all the melodies at the same time. Initially, the teacher played with the children, but, as time passed, she instructed children to carry out specific movements to stay engaged with the music. The movements were based on the observation of children's spontaneous behaviour. To help children recognise the changes in the music articulation, the teacher used the carpet: when the music was staccato, the children were to jump off the carpet, as opposed to jumping on the carpet for legato. To keep older children focused on the music, the teachers divided them into smaller groups (2-4 children each) who were invited to play on the carpet in turns.

- Lessons 3, 4, and 5 focused on assessing the degree of understanding of each musical parameter focusing respectively on speed, articulation, and volume variations were conducted. In order to better focus on a single parameter, the other parameters were kept constant during the exercises. The changes occurred consistently to all the four melodies. A summary of the exercises and a description of the music played in each of them is reported in Tables 6 and 7.

**Table 6. Fixed and varying parameters in the structured laboratories.**

| Parameter variation/Lab | Lesson 3 | Lesson 4 | Lesson 5 |
| --- | --- | --- | --- |
| Fixed parameter | articulation | Speed | volume |
| Varying parameter | speed | articulation | articulation |

**Table 7. Details of the parameters which varied in each exercise in the structured sessions.**

| | Speed in lab 3 | Articulation in lab 4 | Articulation in lab 5 |
| --- | --- | --- | --- |
| Exercise 1 | low | legato[5] | legato |
| Exercise 2 | medium | staccato[6] | legatissimo |
| Exercise 3 | high | legatissimo[7] | staccatissimo[8] |

- In Lessons 6 and 7, polyphonic music was introduced. The aim was to help the children recognise a polyphonic composition of two or three melodies. The teacher manipulated the speed and the articulation of the different melodies separately, using the remote control and would guide the children to actively manipulate a polyphony of two or three lines. In these two lessons the teacher started to manipulate the different melodies separately and asked the children to react to the changes to each different melody independently (each child followed a different melodic line). Children were exposed to a specific melody and asked to react to its changes independently of the other melodic lines. In this phase, children were divided into sub-groups (2-4 people) to experience the system.

### 4.3.2. Phase 2

The second phase, manipulation, gave children's active control of the music. In particular, the speed parameter was controlled by the speed of children's movements, and the articulation parameter by children's proximal distance. In lessons 8, 9, and 10 children were given two magical objects they could use to

[5] Notes are played smoothly and connectedly.
[6] Notes are played separately and distinctly.
[7] Notes are played smoothly and extremely connectedly.
[8] Notes are played extremely separately and distinctly.

control the music: a crown and a sceptre. Each child controlled their respective musical line, the lowest line with the crown and the highest with the sceptre. In particular, in lesson 8, children were told for the first time that they could influence the music with their movement. To make it clear, the teacher physically followed the children, using the remote control according to their movements (Fig. x). This session was crucial to introduce the concept of active control over the music allowing the shift from active listening to music making.

In lesson 9, the children, in solo sessions and in groups of four, were given two magical objects (two crowns) which they could use to control the music. In lesson 10 children in couples were given a magic crown and a magic sceptre each and were asked to explore the magic properties of their objects by making different movements. The activities performed in lesson 10 were designed for pairs of children: one child had the crown, the other one the sceptre. The lesson began with a demonstration of the crown and the sceptre, then the children were asked to try the objects. The children entered the active area one at a time and the gradual activation of the individual voices was useful to help them to recognise different musical lines in a polyphonic melody.

### 4.3.3. Phase 3

In the third phase, narration, children engaged with stories. In lessons 11 and 12, narrative elements such as animal characters and magical tools were introduced to support make-believe play. Partially inspired by existing tales for children, four stories that allowed the four combinations of music speed between the two children were designed: fast-fast, fast-slow, slow-fast, slow-slow. In turns, each pair of children was asked to impersonate the characters narrated by the teacher, and also were asked to move around the room in order to create a melody that would help their characters to overcome a critical situation. The dynamics of the stories helped the children to familiarise themselves with the independent speed changes between two musical lines.

The children gradually reinterpreted and appropriated the plot of the stories. The accuracy of their movements played a critical role in the narrative. For example, in turn, each child played the role of the witch or wizard while the other played the role of the princess or the prince. They performed actions to help the puppies avoid the dangers of the forest. For instance, they had to move slowly to avoid waking up the bear, or to hurry when followed by the bear. Social interactions between the children were fostered by the stories. All the stories had the same aim: to help the children to get out of the imaginary forest. An example of the stories used for this phase is given below:

*“A few puppies were lost in the forest.*

- *The groundhog was sleeping, the music has to be very slow, otherwise, the animal will get up.*
- *Happy butterflies need to be vitalised so they will show the way out of the forest, the music is to be very fast.*
- *The chatty bear appears in the distance, the witch/wizard uses his power to talk to the bear and the princess/prince must not disturb him/her. The low voice is thereby active and the high one is very slow.*
- *It is night, the sceptre lights up the surface of a lake, the royal swan appears floating on the water. The princess/prince has to run to summon the attention of the animal. The low voice is very slow and the high one is very fast.”*

The social aspect which emerged as a major requirement in Chapter 3 was fostered by building narratives that favoured interaction among children. For example, in one story a child was playing the part of an eagle that was brooding but needed to fly away to catch some food. Not to leave the egg unattended, she asked her friend, the ant, to look after her egg.

## 4.4 Analysis

The analysis largely focused on the drawings, as these were an elaboration of the children’s experience obtained directly from the children. A total of 197 drawings were collected (93 in the Children’s Orchestra and 104 in the Child Chorus setting). Interviews, observations, and the diary were an indirect source of data as they were mediated by adults. The entire sample of drawings was iteratively analysed by the researchers. The results were triangulated with a rich set of data sources (Table 8).

**Table 8. Data sources.**

| |
|---|
| **Children's data** |
| 197 drawings (children aged 4 and 5 years) |
| **Adult's data** |
| 2 interviews with the school teachers (2 sessions of 30 minutes each)<br><br>42 hours of ethnographic observation (29 hours observed by 2 music experts, 13 hours followed by 2 PhD students in Child-Computer Interaction)<br><br>A 1 hour and a half hour post-study interview with the music educator plus her diary of the experience |

Drawing analysis followed three sequential phases: identification, annotation, and discussion of the codes. It involved a group of three researchers with expertise in Human-Computer Interaction (including the author of this thesis). In the first phase, drawings were grouped and analysed by lesson, learning phase, and interaction condition. The researchers repeatedly went through the sample of drawings looking for notable or shared features, which led to themes emerging from the data, together with group discussion and individual reflection.

In the second phase, the researchers analysed the 197 drawings collected during the study by performing a thematic analysis. They independently examined all the drawings by noting the presence or absence of the coding elements identified before. Inter-coder reliability was assessed at the end. Five themes were identified (Table 9).

**Table 9. Themes and definitions.**

| Themes | Definitions |
|---|---|
| Human Figures | The presence of human figures in the drawing and/or a clear statement of the presence of people in the teacher’s note was identified. People who were not related to the experimental setting (e.g. ‘my uncle’) were omitted. |
| Happiness | The presence of elements referring to children’s experience in the drawing or in the teacher’s note (e.g. representation of him/herself with a happy face was coded as positive) was identified. |
| Music | The presence of music related elements in the drawing or in the teacher’s note (e.g. the drawing of musical notes or a written description of the music in the note) was identified |
| Movements | The representation of movement and/or the description of physical movements in the teacher’s note. The coding distinguished between the movement correlated with music and unrelated movements. |
| Objects | The representation or description of tools used in the experimental setting. The coding distinguished between the active objects (e.g. sceptre), passive objects (e.g. carpet) and other objects (e.g. technical equipment) |

In the third phase the three researchers discussed the identified themes and sub-themes. Data were annotated only in the case of a clear consensus amongst the researchers. When a consensus was not reached, the encoding of that particular characteristic was omitted. If the discussion highlighted an interesting point that did not meet the predefined characteristics, the researchers added a new code. Table 10 shows an example of a researcher’s coding related to Figures 9 and 10.

Table 10. Example of one coding of one researcher.

| Themes | Scores of Fig. 7 | Scores of Fig. 8 |
|---|---|---|
| **Human Figures** | 3 + author | author |
| **Happiness** | present/happy | present/happy |
| **Music** | Depicted and described | Depicted and described |
| **Movement** | present and related to music | absent |
| **Tools** | carpet and other tools | not present |

**Figure 9. Example drawing of a 4 year-old child from (lesson 4). The teacher's note reports: "I drew myself and my friends. We play with Children's Orchestra. With the striped music we had to stay inside. With the toc toc toc music we had to stay outside."**


**Figure 10. Example drawing of a 5 year- old child (lesson 4). The teacher's note reports: "Me and the notes."**

## 4.5 Results

The data derived from the drawing analysis, the teacher's interviews and observations were triangulated. The approach to triangulation followed in this study applied one layer of transformation to data extracted from children's drawings. A comprehensive evaluation of each theme, identified in the drawings throughout all the 12 lessons, was compared with findings derived from the other research methods. Subsequently, findings from data illustrating children's experiences related to each lesson were reported in order to evaluate the agreement of information derived from the drawings with other research data. The results are structured in two sections based on an overall comparison between the two educational settings (Children Chorus vs. Children Orchestra) and the longitudinal evaluation.

### 4.5.1 Overall evaluation

Due to the large amount of drawings, it was initially difficult to spot differences between Children's Orchestra and Children's Chorus, which became clearer only when comparing the frequency of occurrence of different themes. However, a difference that was immediately evident was related to the depiction of music. In Children's Chorus children drew musical notes mainly, while in Children's they represented the music more abstractly (scribbles, waves, multiple segments etc.).

In general, drawings reflected the experiences of the activities that were run as the central elements ( Appendix 2). For example, the *objects* in the artworks matched with the objects that were used in class. Objects were present more frequently depicted in the Children's Orchestra drawings (84%) than in the Children's Chorus drawings ( 36%), $\chi^2$ (1,N=197) = 47.70, p<.001. This result matched with findings from the interviews where the teachers reported that children were more attracted by the remote controller and the other tools used in the Children's Orchestra than by those used in the Children's Chorus (e.g., foulard).

Differences were also noted when looking at the presence of *movement*. It was present in 44% of Children's Orchestra drawings and in 23% of Children's Chorus drawings ($\chi^2$ (1,N=197) = 9.80, p<.001). This matched the difference between the two systems, in particular Children's Orchestra's focused on children's movements as direct controllers of the musical output.

*People* were present in 91% of Children's Orchestra drawings. By comparison in Children's Chorus, it was 61%, which was significantly lower ($\chi^2$ (1,N=197) = 23.75, p<.0005). This difference reflected the fact that the Children's Orchestra was designed to foster social interaction between children. Teachers' interviews supported this aspect, reporting higher interaction in the technological enhanced setting. Moreover, the music educator, in her interview, reported that children learnt to use the system also due to the relationship between them and her.

During the interviews, the teachers were asked to highlight peculiar aspects in the drawings. One teacher reported that, in all the drawings, the children depicted themselves with a smiling face. The same teacher reported that the children were happy to draw their experience after the activity with the system ended. This is important information, as the teacher reported that children were generally reluctant to draw on other occasions during the normal course of the academic year.

#### 4.5.1.a Longitudinal analysis

To investigate time variations, a longitudinal analysis of the drawing was carried on. The presence of a musical theme in Children's Orchestra showed a uniform trend from lesson 2 up to lesson 7, followed by a big decrease in lesson 8 (Figure 11). The gap in lesson 8 coincided with the moment in which there was a major change of the technological setup. This lesson was the first one in which the music was actively "following" children's movement. In previous lessons, where acculturation exercises took place, the interaction paradigm was the opposite: the children were following the music. The music educator's interview reported children's difficulty in adapting to the new interaction paradigm, which may have decreased the attention they put on the musical output.

The presence of a musical theme in the drawings of the Children's Chorus condition showed a significant decrease in lesson 5 (Figure 11). This Lesson was focused on the "articulation" dimension which was explored using the educator's voice. This was a limitation because the activity could only be performed by one child at the time, generating a loss of attention of the children who were not engaged in the exercise. The music educator's diary also highlighted that children had difficulties recognising “legato” and “staccato” in her voice., and soon became disengaged.

From lesson 8 up to 11 an increasing trend of the presence of music in the drawings can be identified. This can suggest a "learning effect" At the same time the educator's notes confirm that throughout these lessons children got accustomed to the tool. Conversely, in lesson 12, the music was absent in Children's Orchestra, differently from Children's Chorus. Considering researchers' notes and teachers' interviews this gap reflected the fact that, from lesson 12 onwards, the activities were dominated by the narrative elements. When the children started to interpret the stories, their focus was mainly on the characters of the story rather than on the musical outcome. From lesson 12 onwards, drawings were mainly dominated by the narrative elements, such as the animals children interpreted.

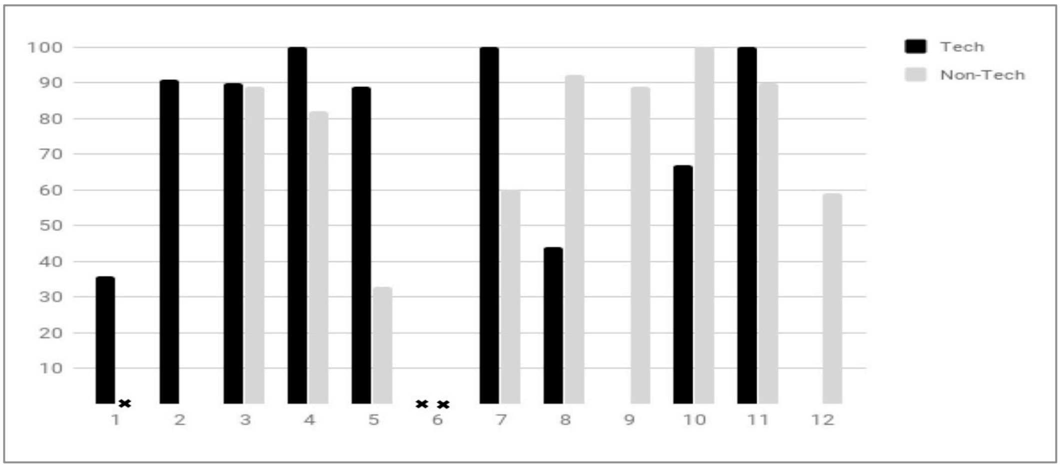



**Figure 11. Presence of the music in Children's Orchestra (black bars) and Children's Chorus (grey bars).**

Some data are missing (x) due to lack of time. In Lesson 2 (condition Children's Chorus), and lesson 12 (condition Children's Orchestra) no music elements were represented.

In Lessons 1 of the Children's Orchestra, regardless of their age, children drawings mainly focused on other children and the teacher, as well as their movements, rather than on the music whose presence was limited (Figure 11). Nevertheless behavioural observations reported that the children reacted correctly to the musical changes and had movement reactions, such as jumping, following the music beat. Interestingly, most of the drawings of children aged 4 displayed smiling faces, which were interpreted as instances of engagement. These data were consistent with the diary, the observations and the interviews. The teachers described an engaging experience for the children, but with little focus on the music.

In lesson 2 the number of times the music was reported in the drawings increased (Figure 11). Despite the need for more precise instructions, it was evident that children spontaneously reacted to the musical variations. Their reaction, however, was modulated by the different parameters and their combination. All of the children instinctively performed fast movements (such as running, or spinning) when the music was fast, but their reaction to slow music was more delayed and less evident. In particular, children were more reactive to changes in speed when the articulation was staccato and the volume was low. The parameter that appeared to be easy to perceive was articulation, particularly while changing from legato to staccato. In general, children tended to react to staccato by walking in synchronisation with the music displaying robotic movements. As a general observation, the music was too repetitive to fully engage children and the algorithmic composer was modified consequently.

Behavioural observations in lesson 3 confirmed a mediation effect between speed and articulation. Children reacted more easily to extreme variations. In particular, when the music was fast or staccato, they had difficulties noticing the changes. After a few trials, however, all the children reacted as expected. Children's drawings were not particularly useful in highlighting the difficulties children encountered when reacting with movement to musical variations.

All exercises of lesson 4 (Figures 9 and 10) proved to be successful, specifically the legato condition with medium volume levels (between piano and forte). Children moved in circles while changing the speed of their movements. The central element of this lesson was the music, which was present in all the drawings; movements were rarely depicted. Children were able to discriminate variations in the music. In their drawings, they described the music as slow or fast, or as "toc toc" (staccato) or "like a wave" (legato) (Figure 9).

In lesson 5, the drawings reflected the children's difficulty understanding changes in volume, as variations of this parameter were not reported either graphically or in written form. In particular, lesson 5 highlighted that variations of volume were often disregarded and children tended to move by following speed and articulation parameters. The variations of volume, especially for extreme articulation values such as staccatissimo and legatissimo, were less clear and the assistance of the teacher was necessary to make the children notice the changes. On the other hand the combination of low volume together with staccatissimo and high volume together with staccato seemed to be more effective. Drawings reflected this trend and showed no connection with the volume. At the end of the structured exercises, the children reacted slowly to each parameter when changed independently. When more than one parameter was changed at the same time, the children struggled to understand what was happening.

In lessons 6 and 7, the children appeared to be capable of recognising their voice correctly, particularly in regard to the highest and the lowest voices. Drawings of lesson 6 are missing both in the technological and non-technological conditions because of lack of time to run the activity. However, in the drawings of lesson 7 it was clear that music and movement were the central elements. Furthermore, it was evident that manipulating more than one parameter was difficult for the teacher and confusing for the children. Consequently, it was decided to use a two-voice polyphony manipulating only speed for the following sessions.

In lesson 8, each child controlled an independent line. Initially, they acted alone, then in a group of four. However, as they showed some shyness when alone, and groups of four were too large to create a meaningful piece of music, the session was organised so that pairs of children could take turns. The children tended to move their arms a lot, thus we planned to introduce a second object: a sceptre. Looking at the drawings, half of the 4-year-old children clearly described the relationship between the music and their movements, thus showing that they were aware of controlling it. This relationship was less clear for the younger children as only one third mentioned it in the drawings.

In lesson 9's drawings, half of the 4-year-old children clearly described the relationship between the music and their movements, thus showing that they were aware of controlling it. This relationship was less clear for the younger children as only one third mentioned it in the drawings.

In lesson 10, the introduction of the sceptre was generally well accepted, and it was depicted together with the crown in most of the drawings. Moreover, they induced a couple of spontaneous fantasy play episodes during the session. At the end of each session, the music teacher asked the children to describe the music, their movement and the resulting musical changes. The children were able to remember and describe the music correctly.

In lessons 11 and 12, the children liked the animal character and it was easy for them to engage in fantasy play. Also, the choice of the forest was appropriate because children could easily imagine this environment. In the drawings, both groups depicted the animals, the trees, and the rivers as central elements; the sceptre and the crown were less evident in respect to the previous session. Both groups depicted the animals, the trees, and the rivers as central elements; the sceptre and the crown were less present with respect to the previous session.

## 4.6 Discussion

In this study the children were asked to represent visually a specific event they took part in. This is particularly challenging in the case of elements such as music that do not have tangible qualities, and required the children to make a creative effort to give form to what is not perceivable by sight.

Drawing is a method commonly used both in psychology and education to make children reflect on their thoughts. A reflection can be made by asking the children to produce a drawing of an event they took part in. In this sense, the children were stimulated to take inspiration from experiences and generate a screenshot of their experiences. Children's effort to synthesise their experience might not give exhaustive results for research purposes because drawings can be cryptic, especially in the case of young children who have not yet fully mastered their drawing abilities. However, as shown in literature (Jolley, 2010), drawing is useful to identify the most important element of children's experiences. In this sense this method allows the children to express their voice in the design project.

Children's drawings in this study reflected some of the information gathered through other means, such as behavioural observations and teachers' interviews. The subjectiveness of the analysis of the drawings was limited by having a precise description of the codes to identify in the drawings, by having multiple coders, and by triangulating the data.

With reference to the following research question "*Do analysed drawing data confirm the findings derived from other research data?",* in general, drawing data confirmed data derived from observations and interviews. It must be noted that the analysis of the drawings was influenced by teachers' notes on the drawing themselves, an issue that was addressed in the subsequent studies. Triangulation, too, was weakly performed in some cases as it was very difficult to balance the punctual information derived from the observations and the interviews with the analysis of the drawings.

The analysis of the drawings was useful to weigh the relevance of the elements constituting children's experience throughout the longitudinal study. This was useful to monitor the relevance of the musical aspect overall and evaluate the impact of new exercises or new interactive modalities. Despite this being useful to provide an general picture of the musical experience overall, triangulating drawing data with other data suffered from a lack of detailed information that could, instead, be found in observations and interviews. For example, in picture 7, a child depicted the main elements of the exercise about articulation ( such as "toc toc" music) but no further information, such as the perceived difficulty of the exercise, can be derived.

Analysing the design process, children constantly influenced the design, which unfolded and evolved around their behaviour and drawings, while the teachers acted as mediators in the design process. They modified their teaching style spontaneously, responding to children's behaviour and requesting several adjustments to the technology to suit their evolving needs. Teachers and designers worked in a team despite having different specific priorities and interests. A considerable effort was put into engaging children in the activities.

## 4.7 Conclusion

The content of the drawings mirrored information found in observations, interviews and diaries. In some cases, the drawings highlighted differences between the conditions that could not be clearly inferred from the other data sources. A limitation of comparing children's drawings with adults' observations, interviews and diaries is that children's drawing is highly variable while the other data sources are more certain. On the other hand, having a large collection of drawings can counteract this effect and provide a more reliable analysis.

# 5 - Study 2: Music-Colour Association

**Abstract.** This chapter further investigates the use of drawings in triangulation with other data sources, aiming to refine results answering the two research questions considered in Chapter 4:

- *Is drawings a trustworthy research method to evaluate young children's experience?*
- *What elements of the experience do drawings describe?*

From a methodological perspective, the study emphasised the analysis of young children's drawings (respectively 3-year-olds, 4-year-olds, and 5-year-olds) and compared the main elements depicted by the children with information derived from teachers' annotations and questionnaires, and researchers' observations.

## 5.1 Introduction

In the previous study, drawings were analysed thematically, by relying on both the elements drawn by children in each drawing and teachers' annotations on the drawings reporting their explanation of what children drew. This did not allow for a precise identification of the contribution of the information derived from children's depictions and their contribution in triangulation with other data. Moreover, a more accurate identification of the influence of children's different ages on the drawing analysis has been taken forward. This study takes into account the limitation of weak triangulation performed in the previous study by conducting a separate analysis of children's depictions and teacher's notes related to the drawing itself. The musical activities proposed were also adjusted as it was observed that children tended to react more easily to extreme musical variations and that "speed" was the parameter most easily understood by the children (see also Core et al. 2016). For this reason, musical variations focusing on the speed parameter of a given melody were proposed in the current study, where children's reactions to musical variations that offered a range of intermediate tones was investigated. This was explored in both a non-technological (baseline) and technological condition: evaluating the colour sorting exercise with and without the use of the music, respectively.

This study assessed to what extent information derived from young children's depictions was in agreement with information derived from teacher's data and evaluated differences among different age ranges.

The main finding from this study was that the analysis of drawings would partially support findings in triangulation with other methods and that younger children had lower levels of attention when compared to older children.

## 5.2 Method

### 5.2.1 Participants

A total of 31 children attending a local Italian kindergarten participated in the study (Table 11). The children were divided into small groups by the teachers (3-5 children per group). Each group included children of the same age range : 11 children aged from 3 to 4 ½ years old (age range A), 13 children aged from 4 ½ to 5 ½ years (age range B) and 7 children aged from 5 ½ to 6 ½ years (age range C). A kindergarten teacher was present at each session, together with two researchers. Overall, 5 teachers were involved in the study. They had worked on colour with children throughout the year. The teachers who habitually follows a specific age group were involved in the study in order to make the children more at ease.

**Table 11. Participants in study 2.**

| Condition | Technological | | | Non-Technological | | |
|---|---|---|---|---|---|---|
| Age | A | B | C | A | B | C |
| Number of participants | 7 children divided into 2 groups (4 and 3 children respectively) | 9 children divided into 2 groups (4 and 5 children respectively) | A group of 4 children | A group of 4 children | A group of 4 children | A group of 3 children |

## 5.2.2 Location

The studies took place in a kindergarten located in the North of Italy. Each group took part in the study in the room where they habitually had activities so that they were at ease with a room they already knew. There was only one exception, when children of age range A were located in a room usually devoted to activities with children of age range C.

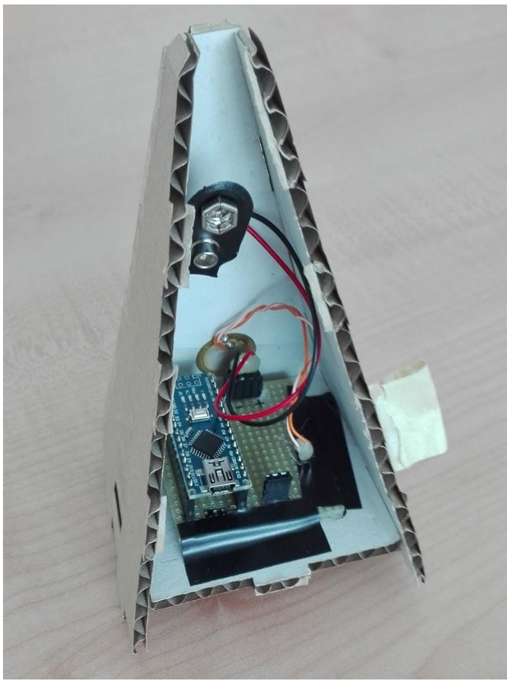
## 5.2.3 Interactive Pyramids (IP)

The Interactive Pyramids (IP) are multimedia Tangible User Interfaces (TUIs) which were developed at the interAction lab of the University of Trento by Andrea Conci. Prior to the study reported in this thesis it had been used for playful navigation of museum exhibits with groups of children aged 9 years. In this section the main characteristics of the device are presented. More details about the device can be found in Andrea Conci's doctoral dissertation (to be published in 2018).

The IP was a device with the shaped as a square-based pyramid hosting a colour sensor located in its base which was able to detect different colour ranges (Figure 12).

**Figure 12. Two IPs with coloured objects to detect.**

The IP had the following dimensions: 7x7x14 cm. Its shell was realised in cardboard because this was a lightweight and cheap material. The detector was programmed using a nano-Arduino board (Figure 13). The base of the IP had a little indent that hosted the colour sensor (Figure 14). This was realised in order to prevent occlusions when detecting colours. The indent was realised by putting an intermediate layer at a distance of 1.5 cm from the base. The layer presented a hole at its centre through which the sensor could detect the colour of objects.



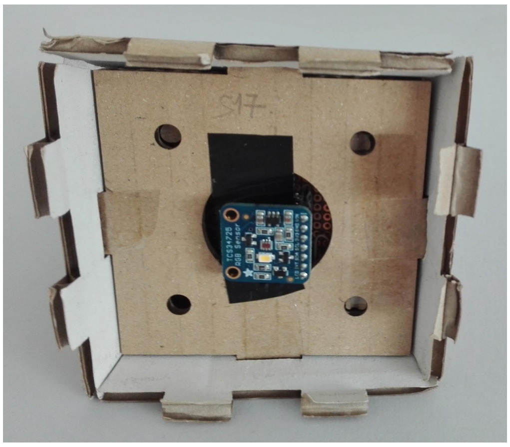


**Figure 13 and Figure 14. View of the components inside the device and the colour sensor at the bottom of the device.**

Each time the sensor detected a colour that fell among the colour ranges that it was programmed to detect, the device emitted a melody in MIDI that was stored in its memory (the refrain of “Stage 1” melody from the Castlevania videogame: https://freemidi.org/videogame-1122-castlevania-i ). The melody was always the same one, but varied in its speed. The melody looped until it detected a new colour and stopped if the IP detected white colour. When passing from one colour to another, the delay of the colour sensor detecting the colour of each object was less than 100 msec (software robustness).

The pedagogical aim at the basis of the study described in this chapter is to leverage on the child’s knowledge of colour to guide the learning of musical variations. The study took inspiration from the work of notable pedagogists such as Maria Montessori and Bruno Munari, and from the observation that education in the kindergarten heavily relies on visual material. The study explored the link between visual cues and musical stimuli with the aim of creating meaningful connections. The colour cues chosen for the study belong to the rainbow spectrum, an organised set of colours conveying the concept of scale. The same concept of scale was transposed to audio stimuli. The concept of scale is important in young children’s development as it is an early mathematics concept relying on the knowledge that children acquire when exploring everyday situations, such as comparing object dimensions (the item on the left is bigger than the item on the right, etc.). The concept of scale is commonly used in Montessori pedagogy, as her exercises devote considerable attention to ordering and systematising perceptual information derived from the senses.

The IP was able to recognise seven different colours. For this purpose, seven coloured objects were hidden in the kindergarten classroom where the study took place (Figure 15). The objects were: a dark green cardboard based cylindric box (measuring cm 9x5), a light green desktop plastic bin (approximately cm 5x5x10), a yellow cylindrical tin tea box (cm 10.5 x 15.5), an orange travel document case (cm 2 x 12.5 x 23.7), 5 red mounted Lego Duplo bricks, 6 blue mounted Lego Duplo bricks, and a pink plastic mug (cm 7.8 x 10). These objects were chosen as they were simple and almost plain coloured so the IP could identify them easily.

**Figure 15. Coloured objects brought into the kindergarten.**

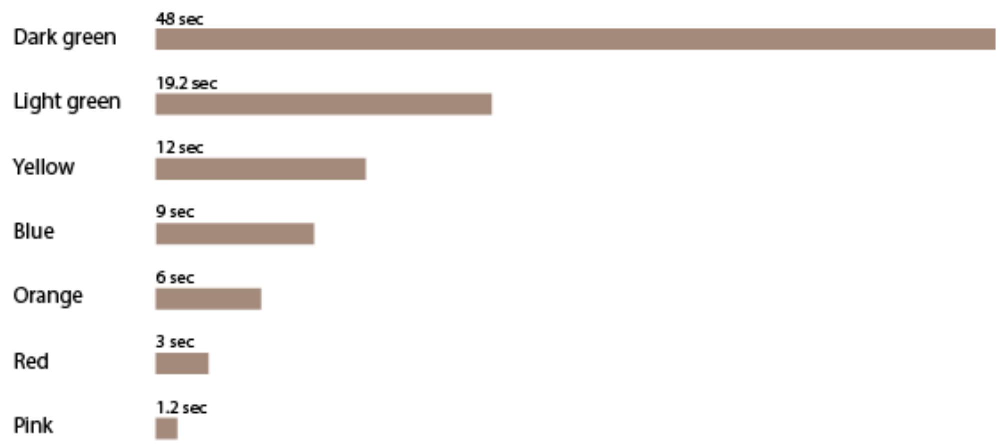
The decision to bring selected objects to the kindergarten classroom was made to be sure that the IP would work with the associated colours. The fact that having other objects in the classroom would be decoded by the detector was considered as a stimulus because the child had an extended range of objects he/she could try on the IP, not only the ones provided.

The colours chosen for the mapping were “green”(dark green and light green), “yellow”, “blue”, “orange”, “red”, and “pink”. When the IP detected each colour, the triggered melody was reproduced at speeds that varied from slow ("dark green" triggered the slowest melody) to fast ("pink" triggered the fastest melody).

More specifically, the colour-music mapping, for this configuration of the detector, associated the following colours to each speed at which the melody was reproduced :

- *Dark green* was associated with the slowest speed at which the music was reproduced (slow2: normal speed * 4 );
- *Light green* was associated with a slow speed (slow1: normal speed *1.6);
- *Yellow* was associated with the normal speed at which the music was reproduced - normal speed;
- *Blue* was associated with a fast speed at which the music was reproduced (fast1: normal speed * 0.75);
- *Orange* was associated with a faster speed at which the music was reproduced (fast2: normal speed * 0.5);
- *Red* was associated with a faster speed at which the music was reproduced (fast3: normal speed * 0.25);
- *Pink/Violet* was associated with the fastest speed at which the music was reproduced (fast4: normal speed * 0.1).

The following scheme summarises the timing of each sequence (composed by a refrain and a variation of the refrain) played at different speeds according to the detected colour:




The speed variations of the music were defined based on the findings of the previous study (chapter 4, see also Core et al. 2016) and adjusted by trial and error by two  researchers. At first, the speed of the music track was accelerated and decelerated linearly, but successive adjustments were made during the process because the differences between the samples were not considered clear enough. Only two slow tracks were provided, because adjusting the sample to slower ones that were easily distinguishable from one another was very difficult. On the other hand, accelerating the sample made more evident the differences more evident between the samples, so four accelerated samples were identified and adopted for the study. This also constitutes a limitation that might have influenced children's understanding of music variations. No further investigations on the aspects concerning the consistency of the music samples were performed, however, as this was not the scope of the research studies.

### 5.2.4 Materials

Each room where the study took place had at least one table with chairs; and toys such as Lego bricks and boxed games: objects such as textiles, mini-kitchen utilities and furniture; and children's drawings. The room was also equipped with materials for drawing, such as paper sheets and markers.

## 5.3 Procedure

The study took place within 3 workdays (Table 12). Each session lasted approximately 40-60 minutes.

**Table 12. Distribution of the sessions in study 2.**

| | Day 1 | Day 2 | Day 3 |
|---|---|---|---|
| Technological | 4 children in age range C (Session 1)<br><br>4 children in age range B - Session 2 | 4 children in age range A - Session 5<br><br>5 children in age range B - Session 7 | 3 children in age range A - Session 8 |
| Non-technological | 4 children in age range B - Session 3 | 4 children in age range C - Session 4<br><br>4 children in age range A - Session 6 | |

As an ice-breaking activity, all the children were asked to draw themselves while they were doing something that made them happy. This activity lasted approximately 30 minutes and involved all the children. Then, the 31 participants were split between the technological and the non-technological conditions. Participants undergoing the study in the technological condition used a working version of the IP which would react to the colour objects. Participants in the non-technological condition used a non-working version of the IP.

The children were then divided into groups of 3-4 children of the same age range and were invited to enter the room where the study took place. A total of 20 children engaged in the technological condition while 11 children engaged in the non-technological condition. Table 1 provides a summary of the sample in the two conditions as a function of age.

After giving a brief explanation of how the IP worked, the children in both technological and non-technological conditions were asked to give a name to the device. Specifically, children in the technological condition were told that the device was able to recognise some colours of objects in the room while children in the non technological condition were told that the device could make magic things and to express their preference on the functions the device was supposed to have.

For the technological condition, the children were invited to explore the room with a device each and discover what made the device emit a melody. The children were then asked to bring the objects that made the IP emit sounds to a table that was in the classroom. The room was already filled with toys the children habitually used, but 7 items were added (one per rainbow colour) to ensure that the children would find something that would make the device play a melody (a pink plastic cup, an orange documents holder, blue lego bricks, red lego bricks, a yellow cylinder, a green box and a green plastic table bin - see Figure 15).

The children were then asked to group the objects they found by colour and to listen carefully to the different melodies that the device emitted as a response to to the different colours detected. The objects that were detected and emitted sound ranged throughout the rainbow spectrum: yellow, orange, red, green, blue, and purple. This colour scheme was not revealed at the beginning. When enough objects were on the table, the children were asked to group them by colour, try again the colour on them, and then asked to explain if they noticed some difference in the melody emitted by the IP. At the end of the session the children were asked to verbalise the colours on the table. A rainbow was then assembled with the coloured semi-circles (Figure 16) to show them that rainbow colours were used and that the device emitted different sounds as a response to different colours.

**Figure 16. Cardboard-based rainbow model.**

At the end of the session the children in the technological condition were asked what they would like as a desired new function of the IP. Though the participants sample is small, this question aimed to get an insight on children's age-related preferences.

Children in the non-technological condition, instead, were asked to look for coloured objects in the room whose colour matched the colours of the rainbow (for this purpose, cardboard semi-circles that could be piled up as a rainbow were provided - Figure 16) and to group them by colour on the table. The activity lasted 15 minutes approximately and no sound was used. The children were then given an empty IP and asked to imagine a function for the IP which they were told was magic. This activity lasted approximately 5 minutes.

This question aimed to capture children's expectations and to make them feel involved in the design process. The study lasted approximately 20 minutes overall.

Children were finally asked what they would like as a desired function of the IP. This question was meant to capture the differences between expectations of the IP with previous usage of the technology (technological condition) and with no knowledge of the IP's behaviour.

Afterwards, each child both in the technological and non-technological condition, was asked to rate the activity by inserting  a red coin in one of three boxes (Figure 17). Each box had a face displaying a different emotion : happy - :) -, indefinite - :| -, and sad - :( .

**Figure 17. Rating boxes used for children's appreciation of the activity.**

After rating the activities, the children in both conditions were then asked to draw, in groups, what they had done. The teacher asked the child what they drew and annotated the answer near the drawn elements. This activity took approximately 10 minutes.

The teacher present during the session was asked to fill in a 5-point based questionnaire rating the children's attention throughout the session from "5 - very attentive" to "1 - distracted". Each teacher filled in the questionnaire after the end of each group's study session. Semi-structured interviews, aimed at gathering the teachers' opinion of the proposed activities and the IP, were conducted at the end of the study. Each interview was individual and lasted approximately 30 minutes. Questions are reported in Appendix 1.

## 5.4 Analysis

This section reports the procedure used to analyse the data collected by each evaluation method used in this study. The analysis is reported following the temporal order in which the evaluation method was used during the study. This sequence is relevant because the methods may have influenced the experience of the child.

### 5.4.1 Rating with smiley boxes

The number of children's votes for each session, both in the technological and non-technological conditions, were collected and the overall counts compared from the two conditions.

### 5.4.2 Analysis of drawings

The drawings were analysed separately from the teacher's annotations. Similarly to Study 1, each drawing was analysed by a researcher noting down the recognisable elements that were known to be present in the study settings. The elements found in the drawings were grouped into the following categories:

- "human figures" when a child depicted human figures (as a whole or in parts) as themselves alone and/or with peers and/or other human beings were reported;
- "Coloured items" when the child depicted the coloured items that were part of the activity (rainbow, coloured cards);
- "IP" when the children depicted the technological device they had used;
- "music" when the drawing represented the music played by the IP;
- "rating" when elements related to the rating activity were depicted (items such as the rating boxes and the coins were depicted).

The depicted elements were annotated without consulting teacher's notes on the drawings. For each drawing the presence (coded as 1) or absence (coded as 0) of each element was coded. Music was considered only in the technological condition. An example of a drawing performed by a child in age range A is represented in Figure 18 and its related coding (Table 13).


**Figure 18. Drawing of a children in age A in technological session 8 where the child depicted the toys he brought to the researchers, himself playing and an IP he is playing with.**

**Table 13 for Figure 18. Example of analysis (1= item present; 0 = item absent).**

| **Session** | **Child ID** | **Human figures** | **IP** | **music** | **Coloured items** | **rating** |
|---|---|---|---|---|---|---|
| 8 | AH | 1 (himself) | 1 | 0 | 1 | 0 |

Analysing the drawing in Figure 19, without looking at the teacher's notes, the following elements can be identified: the child and his friend holding an IP each (Table 14). The teacher's additional note specifies that the child on the left is asking "why does the IP emit signals on the ground too?", and the child on the right will try that, too, later.


**Figure 19. Drawing of a child in age C in technological session 1.**

**Table 14 for Figure 19. Example of analysis (1= item present; 0 = item absent).**

| Session | Child ID | Human figures | IP | music | Coloured items | rating |
|---|---|---|---|---|---|---|
| 1 | CD | 1 (Himself and a friend) | 1 (One per child) | 0 | 0 | 0 |

To check the reliability of labeling, 45% of the whole sample (31 drawings and 31 annotations) was analysed by another researcher (at least one group in each age range both in the technological and the non-technological condition): 7 drawings from the technological condition (4 drawings from children in age range B, 3 drawings from children in age range A), 7 drawings from the non-technological condition (3 drawings from children in age range C, 4 drawings from children in age range A), and 7 teacher's annotations from the technological condition (4 notes related to 4 drawings of children in age range B, 3 notes related to 3 drawings of children in age range A) and 7 teacher's annotations from the non-technological condition (3 notes related to 3 drawings of children in age range A, 4 notes related to 4 drawings of children in age range B).

### 5.4.3 Analysis of teacher's notes

The teachers' notes associated with each drawing were analysed. The notes were translated from Italian and are reported in Appendix 3 (technological condition) and Appendix 4 (non-technological condition). Following the same procedure applied to the drawing analysis, the presence / absence of key elements was coded (example in Table 15):

- "Human figures" was acknowledged when an explicit reference to human actors was made (e.g., my friends) or the words "I", "we" were used. In the case of mentions of human beings that were not related to the study, such as "mum" the reference was disregarded.
- "IP" was noted down when written reference to the IP was made. Examples are "volcanoes", "pyramid", "mountain" (names that children sometimes gave to the IP) and non specific reference to the device ("it", "this").
- "Music" was written down when explicit written reference to music was made and when implicit written reference was made to it, such as in the case of "emit a signal" and "sounds".
- "coloured items" was considered as present when reference to physical objects which could trigger the device was made. They included the coloured objects, parts of the room, and the generic term "colour". Items such as "rainbow", "table" and "cup" were all noted as "coloured objects".
- "Rating" was annotated when written reference to elements belonging to the rating activity was made. For example items such as "the boxes", and "the coin" were annotated as "rating".

Sometimes, especially in the case of children in age range A, items that were not related to the study setting were found in the teacher's notes. For example, the notes included items such as "the grass", "the mum" and "the house". These items were not considered in the analysis as they were not central to the evaluation of the children's experience in the study.

**Table 15. Technological condition. Example of analysis of the teacher's notes related to child CD in the technological session. 1= item present; 0 = item absents.**

| Session | Child | Teacher's notes | | | | |
|---|---|---|---|---|---|---|
| 1 (tech) | CD | "I say: why does it emit signal when on the floor?" "After also CC tries" | | | | |
| | | **Human Figures** | **IP** | **Music** | **Coloured items** | **Rating** |
| | | 1 | 1 | 1 | 1 | 0 |

### 5.4.4 Children's ideas

Children's names for the device, and children's suggestions for change and children's ideas for the redesign of the IP were collected. Children's ideas were categorised into two macro-categories: "animate" and "inanimate". The animate macro-category was split into "human" and "animal". The "inanimate" category was split into "natural elements" and "other objects" in order to better identify the nature of the attributes or functions the children gave to the IP and the empty IP.

In particular, the following coding scheme was adopted:

Animate:

- Human:
  - Attribute (HA): a child suggested making the IP look like a human being.
  - Function (HF): a child suggested making the IP act as a human being.
- Animal:
  - Attribute (AA): a child suggested making the IP look like an animal.
  - Function (AF): a child suggested making the IP act as an animal.

Inanimate:

- Natural elements:
  - Attribute (NA): a child suggested making the IP look like a natural element such as a mountain and/or a volcano.
  - Function (NF): a child suggested making the IP act like a natural element such as a mountain and/or a volcano.
- Other objects (house parts, buildings, shapes, toys, tools, objects):
  - Attribute (EA): a child suggested making the IP look like an object and/or add items to it.
  - Function (EF): a child suggested making the IP have a function inspired by an existing object.

### 5.4.5 Teachers' evaluation

After each session, the teacher supervising the activities was asked to evaluate children's attention using a 5-point semantic differential scale (5 = very attentive, 1= very distracted). The question was proposed to the teacher at the beginning of the session so that she could observe the children focusing on their attention. Most of the teachers filled in the questionnaire at the end of the session, and some of them filled in the questionnaire during the session. Scores in both the technological and non-technological condition were collected and compared.

The teacher's interviews were analysed by identifying the main concerns and/or positive points related to the experience with the device overall. The interviews were recorded and transcribed. Emerging themes from them are reported in the results section.

### 5.4.6 Researchers' observations

Naturalistic observations were annotated during the sessions by the researchers.

## 5.5 Results

This section reports the findings from the methods discussed previously, following the same temporal order. Initially, rating with the Smileyometer, children's drawings and teachers' notes are analysed. Next, a comparative analysis was done on the information derived from different methods to understand whether there is agreement between them and to assess the amount of information that can be assessed by each different method.

### 5.5.1. Rating with smiley boxes

Overall, the rating exercise appealed to the children but proved harder than expected (Table 16). The teachers had to verify that the child had understood the meaning of each smiley face, by asking them to describe it. This situation was more common in the case of children in age range A, who often put the coin in the box which did not match their intention. For example, a young child had put the coin in the box with the unhappy face but when the teacher asked what the face meant he said that it was a happy face. In addition, the boxes had to be emptied after each session because the children tended to be curious and look inside them to spot if there were coins. This would distract the children from the task and potentially influence their votes.

**Table 16. Children's rating scores.**

| Age | Technological condition | | | Non-technological condition | | |
|---|---|---|---|---|---|---|
| | :) | :\| | :( | :) | :\| | :( |
| A | 4/7 | 3/7 | 0/7 | 3/4 | 0/4 | 1/4 |
| B | 7/9* | * | * | 3/4 | 0/4 | 1/4 |
| Total | 11 | 3 | 0 | 6 | 0 | 2 |

*missing data

In general, results from this method are consistent with previous research (Zaman et al., 2013), reporting a tendency to have an over-representation of positive rates. This is possibly due to the fact that children are asked to rate playful experiences and no discomfort was present. This would have been different in the case of rating painful experiences, as in the case of evaluating medical experiences. Results from the rating activity are reported in Table 16. Overall, the children in both conditions rated the activity as positive 17 times, neutral 3 times, and negative twice. In particular, 11/14 positive ratings were collected in the technological condition and 6/8 positive ratings were found in the non-technological condition. Data about children in age range C, in both the technological and non-technological conditions, was missing due to time constraints.

### 5.5.2. Drawing analysis

Of the elements identified through thematic analysis, the “music” theme was the least common in the drawings. This may have been due to a lack of interest of children in the music but also the difficulty of drawing something as abstract as music. The presence of such elements in the drawings of children in the technological condition, as analysed by a coder expert in Child-Computer Interaction, is reported: 11 depictions of human figures, 16 depictions of Tangible User Interfaces, 2 depictions of music, 10 depictions of coloured items, and 7 depictions of rating. In the non-technological condition the following frequencies of depicted items are reported: 3 depictions of human figures, 7 depictions of the non-working Tangible User Interface, 2 depictions of music, 11 depictions of coloured items, and 8 depictions of rating (a summary of the results can be found in table 17).

**Table 17. Comparative table of the items found in the technological condition.**

| Age | Drawings, notes | Human figures | IP | music | Coloured items | rating |
|---|---|---|---|---|---|---|
| **A** | **drawings** | **2 /7** | **3 /7** | **0 /7** | **5 /7** | **1 /7** |
| | **notes** | **4 /7** | **3 /7** | **0 /7** | **5 /7** | **1 /7** |
| **B** | **drawings** | 5 /9 | 9 /9 | 2 /9 | 5 /9 | **5 /9** |
| | **notes** | 1 /9 | 9 /9 | 5 /9 | 2 /9 | **5 /9** |
| **C** | **drawings** | 4 /4 | 4 /4 | 0 /4 | 0 /4 | **1 /4** |
| | **notes** | 4 /4 | 0 /4 | 1 /4 | 0 /4 | **1 /4** |
| | **Total drawings** | **11 /20** | **16 /20** | **2 /20** | **10 /20** | **7 /20** |
| | **Total notes** | **14 /20** | **9 /20** | **5 /20** | **7 /20** | **7 /20** |

The degree of agreement between two coders, who independently analysed the whole sample and 45% of the sample respectively (at least one group per age-range in both conditions), has been evaluated (Appendix 5). Agreement between coders evaluating the presence or absence of depicted elements in the technological condition is 80%. Agreement between coders evaluating the presence or absence of depicted elements in the non-technological condition is 93%. Overall agreement between coders evaluating the presence or absence of depicted elements is more than 85%.

The elements identified in the drawings and the elements identified in the teachers' notes in the technological condition have been compared. Counts of the items found both in the drawings and in the teachers' notes of the whole sample are reported in Table 17.

Complete agreement between the items found in the drawings and the items reported in the teacher's notes were found in all the items related to children in age range A except for "Human Figures" item.

It also emerged that there was complete agreement between the number of "rating" items found in both drawings and notes of children in age ranges A, B, and C.

Complete agreement was also found between the "human figures" items found in the drawings and in the teacher's notes of children in age range C.

Disagreement between the presence of "human figures", "music", and "coloured items" was found in age range B:
- "Human figures" were depicted (5/9 times) more than reported in notes (1/9 times);
- "Music" was depicted less (2/9 times) in respect to the times it was reported in the notes (5/9 times);
- "Coloured items" were depicted more (5/9 times) than they were reported in the notes (2/9 times).

Disagreement between the presence of "IP", "music" was found in age range C:
- "IP" was depicted every time (4/4) while it was never reported in the notes;
- "Music" was not depicted, while it was reported in one of the notes (1/4 times).

Results of a comparison of elements in the drawings with elements in the teachers' notes in the non-technological condition is summarised in Table 18.

**Table 18. Comparative table (non-technological condition).**

| Age | Drawings, notes | Human figures | IP | Coloured items | rating |
|---|---|---|---|---|---|
| A | **drawings** | 0 /4 | 1 /4 | 4 /4 | **2 /4** |
| | **notes** | 0 /4 | 1 /4 | 3 /4 | **2 /4** |
| B | **drawings** | 0 /4 | 4 /4 | 4 /4 | **3 /4** |
| | **notes** | 3 /4 | 4 /4 | 4 /4 | **3 /4** |
| C | **drawings** | **3 /3** | **2 /3** | **3 /3** | **3 /3** |
| | **notes** | **3 /3** | **2 /3** | **3 /3** | **3 /3** |
| | **Total drawings** | **3 /11** | **7 /11** | **11 /11** | **8 /11** |
| | **Total notes** | **6 /11** | **7 /11** | **10 /11** | **8 /11** |

Overall, both methods reported the same information. Only in the case of "coloured items" related to children in age A sample, and in the case of "human figures" related to children in age B sample did the information differ:

- in the case of the non-technological condition only coloured items slightly differed in the case of children in age range A: it was found more (4/4 times) in depictions rather than in the teacher's notes (3/4 times) (Table 18);
- different information was found when inspecting "human figures" in the drawings and in the teacher's notes of children in age range B: no depictions of human figures were found, while human figures were reported 3 out of 4 times.

Limitations of these results must be taken into account in this case as the sample is very small.

### 5.5.3 Children's design ideas

In this section, the ideas expressed by the children when asked what they would like the IP to do are reported (Table 19). Children in the technological condition expressed their wishes for something that could be different in the IP and children in the non-technological condition expressed what they would like the empty IP to be and/or to do.

The data presented below expresses children's preferences for characteristics the IP should have, in their opinion (Table 19).

**Table 19. Children's ideas in the technological and non-technological conditions.**

| | **Age A** | | **Age B** | | **Age C** | |
|---|---|---|---|---|---|---|
| | Tech condition | Non-tech condition | Tech condition | Non-tech condition | Tech condition | Non-tech condition |
| | "Look at a book"<br>"Put hands and eyes"<br>"Markers"<br>"Sheet of paper"<br>"Fingers, hands"<br>"Make it sit"<br>"Needs a chair"<br>"Hands to climb" | "Tent"<br>"Volcano"<br>"Castle"<br>"Pyramid"<br>"Sand"<br>"Lights"<br>"Magic window" | "Rectangle"<br>"Point of.."<br>"A solid shape by putting 2 devices together"<br>"Volcano"<br>"Sun" (red and yellow are colours of the sun)<br>"Decorate the device"<br>"Notebook attached for writing"<br>"Make it a alarm clock"<br>"A blanket"<br>"Put a lego brick on it"<br>"Attach a fish to it" | "Pyramid"<br>"Mountain"<br>"Roof"<br>"Small house"<br>"Button"<br>"Makes lunch"<br>"Tower"<br>"Sink to wash things"<br>"A bird's beak"<br>"A table to put flowers on" | "Make stories"<br>"Find money"(money is yellow as the yellow Lego bricks)<br>"Writing wishes to parents"<br>"Speedboat"<br>"Tower" (by piling the devices)<br>"Telescope"<br>"rocket" | "Jump"<br>"Play"<br>"Fly"<br>"Clean the house"<br>"Clean the roof"<br>"Be happy"<br>"colour/paint the wall"<br>"tent" |
| Animate | 6 /8 | 0 /7 | 1 /11 | 3 /10 | 3 /7 | 7 /8 |
| Inanimate | 2 /8 | 7/7 | 10 /11 | 7/ 10 | 4 /7 | 1 /8 |

Children's ideas were categorised according to the following coding scheme:

**Animate**:

- Human (H)
  - Attribute (HA): the child expresses a desire to make the IP look like a human being.
  - Function (HF): the child expresses a desire to make the IP act as a human being.

- Animal (A)
  - Attribute (AA): the child expresses a desire to make the IP look like an animal.
  - Function (AF): the child expresses a desire to make the IP act as an animal.

**Inanimate**:

- Natural elements (N)
  - Attribute (NA): the child expresses a desire to make the IP look like a natural element such as a mountain and/or a volcano.
  - Function (NF): the child expresses a desire to make the IP function like a natural element such as a mountain and/or a volcano.
- other - house parts, buildings, shapes, toys, tools, objects - (O)
  - Attribute (OA): the child expresses a desire to make the IP look like an object and/or add items to it.
  - Function (OF): the child expresses a will to make the IP have a function inspired by an existing object.

Findings show that children in age range A engaging in the technological condition prefer to attribute “animate” characteristics (6/8 instances) while in the non-technological condition all the children, who had experience with a non-working version of the IP, had shown a preference for inanimate characteristics (7/7 instances). This may reflect the difficulty for children in this age range to attribute characteristics or features that were not present, as interacting with the IP may be considered as “animate” (technological condition) and interacting with the non-working version of the IP as “inanimate” (non-technological condition).[9]

The children in age range B, involved in the technological condition, seemed to prefer to attribute inanimate characteristics to the IP in the technological condition (10/11 instances) and to the empty IP in the non-technological condition (7/10 instances). This may reflect a preference in this age group for aspects related to the personalisation of the IP[10].

[9] Children in age range A, participating in the technological condition, total 7 so it is probable that one child expressed two ideas, not just one. Children in age range A, participating in the non-technological condition, total 4, so probably almost every child expressed two ideas, not just one.

[10] Children in age range B, participating in the technological condition, total 9 so it is probable that some children expressed two ideas, not just one. Children in age range B, participating in the non-technological condition, total 4 so it is probable that almost every child expressed more than two ideas, not just one.

In age range C, a slight preference for inanimate attributes was shown in the technological condition (4/7 instances), while a more evident preference for animate attributes has been shown in the non-technological condition (7/8 instances). This particular age group may be more interested in adding attributes to the empty IP that make it "animate", in contrary to its present condition, the empty IP being a static toy[11].

Additional analysis was run on the data in order to see if other patterns could be identified but no clear additional information emerged (Table 20).

**Table 20. Children's ideas coded.**

| | **Age A** | | **Age B** | | **Age C** | | **Total** |
|---|---|---|---|---|---|---|---|
| | **Tech** | **Non-tech** | **Tech** | **Non-tech** | **Tech** | **Non-tech** | |
| Human Attributes | 2 | / | / | / | / | / | 2 |
| Human Functions | 4 | / | / | 2 | 3 | 6 | 15 |
| Animal Attribute | / | / | 1 | 1 | / | / | / |
| Animal Functions | / | / | / | / | / | 3 | 3 |
| Natural Attributes and Functions * | / | 2 | 2 | 1 | / | / | 5 |
| Other Attributes | 2 | 3 | 6 | 4 | 4 | 1 | 20 |
| Other Functions | / | 2 | 2 | 2 | 3 | / | 9 |

* items falling into the natural attributes and natural functions categories were merged as it was very difficult to detect children's motivations sustaining their choices and there was no time to ask the child to elaborate more on their ideas.

[11] Children in age range C, participating in the technological condition, total 4 so it is probable that almost every child expressed two ideas, not just one. Children in age range C, participating in the non-technological condition, total 3 so it is probable that almost each child expressed more than two ideas, not just one.

In the following section, the presence of children's ideas in other data is reported:

- there was no presence of children's design ideas in other data in both the technological and non-technological conditions for age range A;
- teachers' notes reported the IP as a "volcano" in all the 4 drawings of children in age range B engaging in the technological condition. In the non-technological condition, the teacher's notes explained that the child wished to transform the device into something else ("a bird's beak"). Another child, according to the notes of the teacher, mentioned that the device was meant to "do things … make a table .. a bird". Another child too, in the teacher's notes referred to the fact that the IP could be transformed into something else;
- the drawings of children in age range C, engaging in the technological condition, were not relevant for highlighting new design ideas for the IP, they only reported what happened during the session. In the non-technological condition, reference was made to magic characteristics of the device in 2 of the drawings.

### 5.5.4. Teachers' questionnaire on children's attention

Children in age ranges B and C, in the technological conditions, were more attentive than children in age range A (Figures 20, 21, and 22). The teacher's mean rate for children in age range A was 3.28 with 0.88 StDev. The teacher's mean rate for children in age range B was 4.77 with 0.62 StDeV. Teacher's mean rate for children in age range C was 4.75 with 0.43 StDeV.

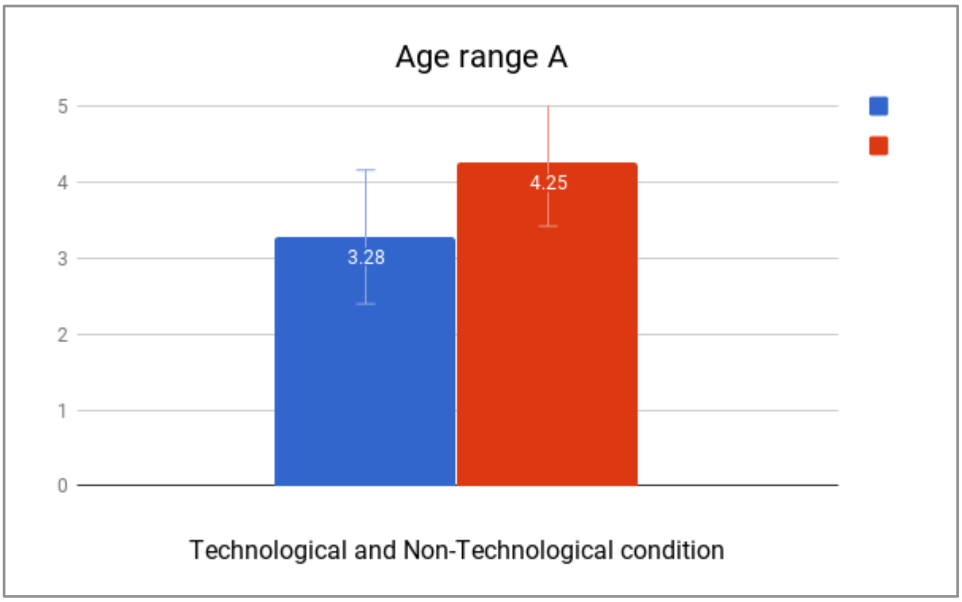



**Figure 20. Attention levels of age range A children in technological (blue bars) and non-technological conditions (red bars).**

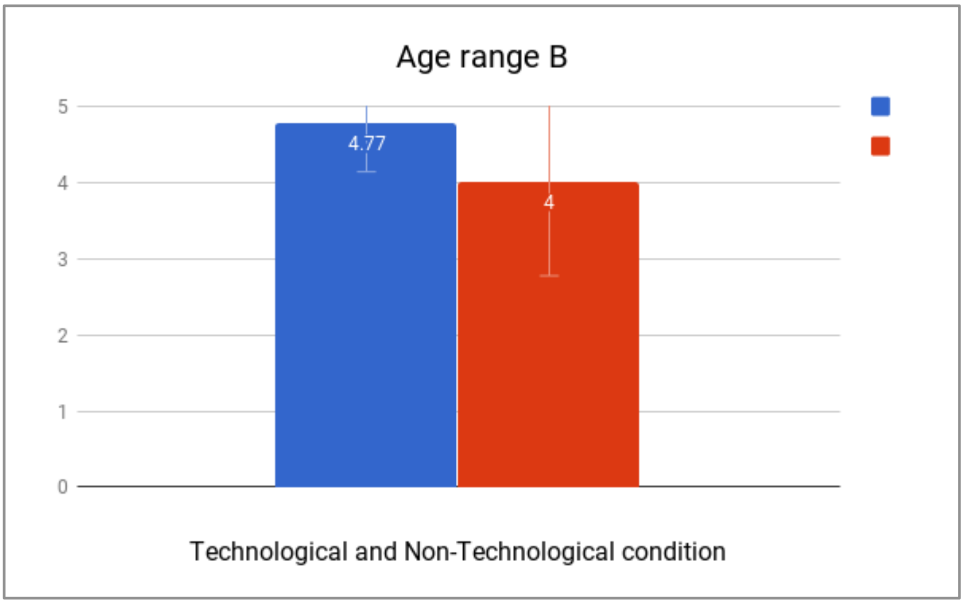



**Figure 21. Attention levels of age range B children in technological (blue bars) and non-technological conditions (red bars).**

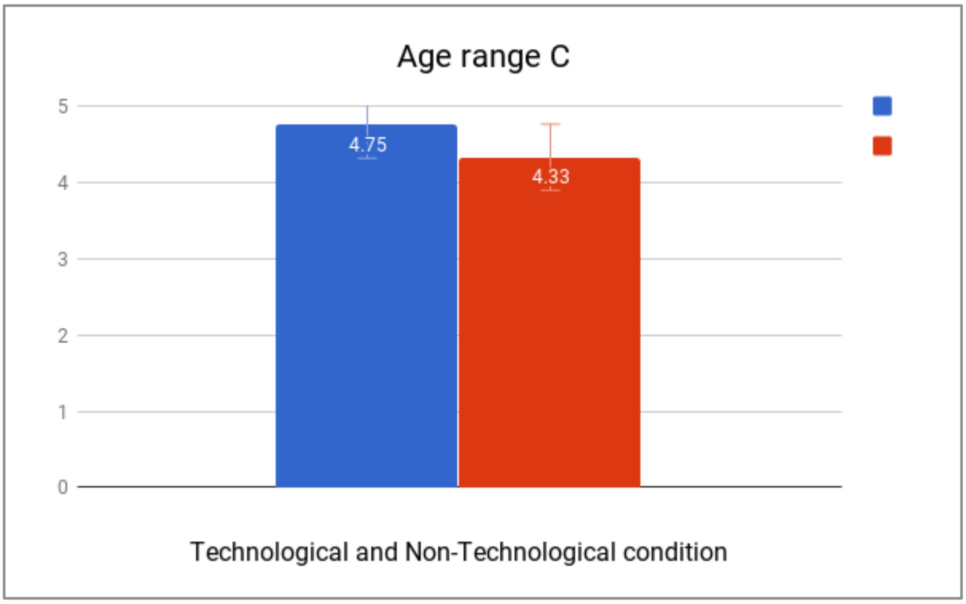



**Figure 22. Attention levels of age range C children in technological (blue bars) and non-technological conditions (red bars).**

A Kruskall-Wallis test showed a statistically significant difference in the technological condition between the three age groups ($H(2)=11.73$, $p<.05$) with a mean rank of 4.93 for age range A, 13,72 for age range B, 13 for age range C (Tables in Appendix 6 and Appendix 7).

## 5.5.5. Teacher’s questionnaire data and drawing data

Teacher’s questionnaires regarding children’s attention were compared with information about the child’s interaction with the IP in the children’s drawings (Figure 23 and Figure 24). The aim of this analysis was to assess the relevance of the information derived from adult data when compared to information that can be found in children’s drawings. To compare the teacher’s questionnaire (based on a 5-point Likert scale) with the children’s drawings, each drawing was assigned a score. The score assigned to each drawing reflected an overall judgement of the child’s interest in the interactive behaviour of the IP:

- Y(yes)= the child depicted the device and the teacher’s notes report that he/she was trying the device on coloured items. The teacher’s notes were included in the analysis for more trustworthy results in the case of ambiguous drawings, such as children’s drawings in age range A, and for gathering children’s eventual elaborations on the activity.
- M(maybe)= the child depicted the device but the teacher’s notes do not report more information about the child interacting with the device
- N(no)= the child did not depict the device

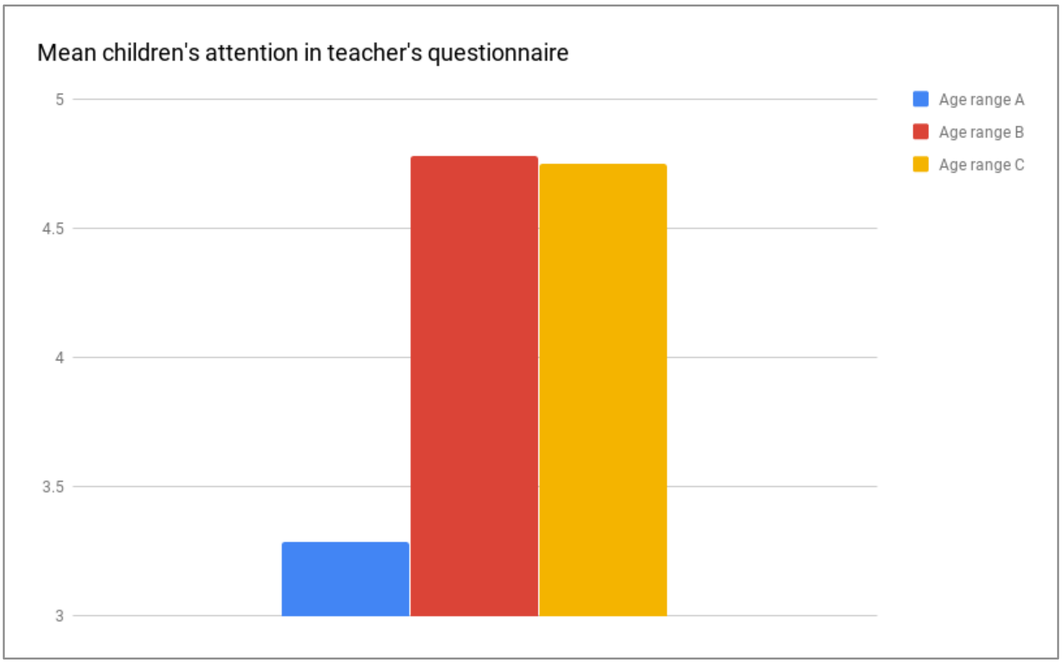



**Figure 23. Mean rates of children’s attention rated by the teachers on a 5-point Likert scale.**

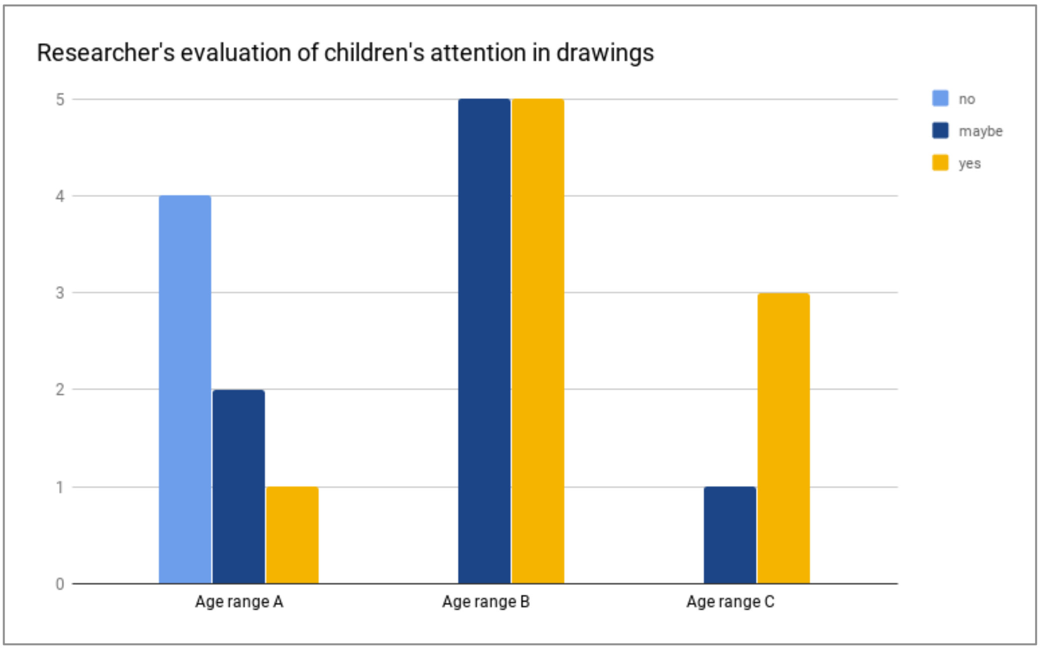



**Figure 24. Frequencies of the researcher's evaluations of children's attention in children's drawings.**

Rating 5 occurred 11/20 times (3/4 in age C, 8/9 in age range B, 0/7 in age range A); 4 occurred 5/20 times (1/4 in age C, 0/9 in age range B, 4/7 in age A); 3 occurred 2/20 (0/4 in age range C, 1/9 in age range B, 1/7 in age range A); 2 occurred 2/20 times (0/4 in age range C, 0/9 in age range B, 2/7 in age range A).

**Y** occurred 9/20 times (3/4 in age range C, 5/9 in age range B, 1/7 in age range A); M occurred 7/20 (1/4 in age range C, 4/9 in age range B, 2/7 in age A); N occurred 4/20 times ( 0/4 in age C, 0/9 in age B, 4/7 in age range A).

**Comparison.** In almost all the cases during which **Y** occurred, the teacher's rating was 5 (only in one case was it 4). When **M** was reported, teachers' scores ranged from 3 to 5 (3 was reported once in age range B, 4 was reported 3 times: once in age range C, and twice in age range A). When **N** was reported, teachers' scores ranged from 2 to 4 (2 was reported twice in age range A, 3 was reported once in age range A, 4 was reported once in age range A).

### 5.5.6. Teachers' interviews

The two teachers who supervised children in age range A reported that they had to intervene frequently to support the children interacting with the IP because the tasks proved to be difficult for this age range. In particular, the small variation in the music was difficult to perceive. The teacher noticed more participation when the technology was not involved in the activities.

The two teachers who supervised the children in age range B appreciated the fact that the activities were run in small groups. Collaboration between children was noticeable. These activities could benefit from arranging mixed groups of children from age groups B and C. The teachers expected more curiosity for the IP (only one child asked to open the device to see what was inside). Increased interest in colours was noticed after the activities. The teacher assessed the suitability of these activities for children older than 4 years. The musical output produced by the device was too feeble.

The teacher following children in age range C also reported that the TUI sound output was too feeble and needed to be intensified but she appreciated the focus on sound, as in school they mainly tend to do activities involving visuals. The teacher suggested involving the whole body in the activities. This teacher also noticed that the children were committed to doing their drawing well, and that the drawings reflected whether the child perceived the enjoyment of the activities.

### 5.5.7. Observations

Age A

Children in age range A had to be guided into the activity but some interest in the activities was observed. In one technological session some children showed curiosity about the light under the IP. While the technological activity seemed to arouse children's interest, the non-technological activity seemed to be more difficult for the children as, in one non-technological session, the teacher had to support the children frequently to complete the activities.

Age B

In technological sessions, children in age range B showed signs of understanding of the colour-music association activities. In technological session 2, the children were asked about the IP's "likes and dislikes", this referred to the the fact that when the device was "liking" a colour, it emitted a melody. In this session, one child noticed that the melody played while the device was used for exploring rainbow colours was the same as the melody played during the exploration activity. A child tried to explain why the device made music by suggesting that it made music because "it was red inside". In one technological session, the children reflected on colours that made the music go slow or fast.

In a non-technological session some difficulties in performing the task were noticed. It was noticed that when children were asked to replicate the rainbow colour scheme with objects the task was not always easy at the first attempt.

Age C

In one technological session, children's noticeable behaviours related to the usage of the IP near their ear (probably because of the low volume of the sound output), they used it as a torch, and investigated its interior (some of them noticed the light of a red LED). Some children were observed looking over and under the device. They were questioning themselves about how the IP could be turned off (as it tended to play music in a loop if it was left on a colour it was programmed to detect). Children showed little interest in the musical output. They often left the IP emitting sound on the table (which was detected as a yellow colour).

In non-technological sessions with children in age range C no noticeable behaviour was observed.

## 5.6 Discussion

Findings derived by triangulating drawing data with other methods are summarized thus:

- children in age range A did not show interest in music. No music in the drawings of the technological session is reported. This is also confirmed by the teacher’s notes on the drawings not mentioning music. Teacher’s interviews report that the music output was weak.

- Age A depictions focused on the technological condition mainly focused on coloured items. Teacher’s questionnaires, too, report a lower level of attention in this age group during the activities with respect to children in age ranges B and C; interviews and observations confirm this finding.
- Non-technological elements identified in children’s drawings were in line with elements identified in the teacher’s notes while elements identified in the drawings tended to differ from the elements identified in the teachers’ notes.

Aside from understanding how drawing data sustain other findings in triangulation with other methods, discordant information was found in the following cases:

- high levels of engagement were reported in the smiley boxes rating activity in the technological condition but, in the teachers’ interviews, the teachers reported the children to be more engaged in the non-technological condition.
- Children in age ranges B and C acknowledge the presence of music in the drawing notes but they neglect to draw music.
- Drawing data in the technological condition reported quite a considerable number of human figures thus suggesting an interest in the social aspect of the activity but this information seemed to be contradicted by the teacher’s interviews stating that socialisation was more present in the non-technological condition.

The methods used in this study were the Smileyometer, children’s drawings, teachers’ explanatory notes on the drawings, collection of children’s ideas, attention questionnaires, observations and interviews (Table 21). Of these data; drawings, teachers’ notes, and children’s ideas were analysed and coded into categories that could help the interpretive process. The other methods were not transformed. Table xx summarises the methods adopted and their transformation for analytical purposes. Each method is then discussed. A limitation of the study presented is that the data set is not comprehensive (some data is missing).

**Table 21. Methods used in study 2.**

| Methods | Data extracted | Transformation of the data |
|---|---|---|
| Rating with Smileyometer | Measurement of engagement (rates) | - |
| Drawings | Qualitative codes | 1 degree of transformation |
| Teachers' notes | Qualitative codes | 1 degree of transformation |
| Verbalisations of ideas | Qualitative codes | 2 degrees of transformation (2 clusters of codes) |
| Attention questionnaire | Measurement of attention | - |
| Teachers' interviews | Summative evaluation of the learning experience | - |

### 5.6.1. Rating

In general, the rating with the Smileyometer boxes method tended to have an over-representation of positive ratings in both the technological and non-technological conditions. This is in line with previous literature (Zaman et al., 2013; Read & MacFarlane, 2006) that emphasises the children's tendency to give positive ratings. This may be influenced by their need to please adults and by the fact that they are evaluating playful activities. The high presence of positive rates may also have been due to the fact that, for the rating activity, we relied on the teacher's reading of the children's comprehension of the task. This may have affected results but had the practical advantage of speeding up the activity when children were hesitant.

From a practical point of view, it was challenging to perform the evaluations with children in age range A because they were not always aware of what they were doing and, consequently, needed support from the teacher. Another aspect worth mentioning was that the rating with Smileyometer boxes was frequently reported in the drawings, in 15/31 drawings, though it was not the main focus. This may be explained by the fact that the activity was presented in quite a enjoyable way. Overall, this method was not informative enough to gather a reliable evaluation of children's experiences with technology.

### 5.6.2. Drawing

Drawings alone were frequently cryptic, especially in the case of children in age range A, whose drawing abilities are limited.

The comparison of drawings in the technological and non-technological condition was useful to get a picture of what each child remembered of the experience proposed and identify which elements captured children's attention.

Drawing data were analysed and coded in order to identify elements that retained children's attention. This process led to the identification of specific items that were suggested by the design of the study. This allowed the inspection of the drawings with the same analytical lens and allowed the building of a quantitative estimate of the most relevant themes and clustering of this information by different age ranges. The evaluation of the degree of agreement between the two different coders on a sample of the whole dataset was useful to assess the reliability of the analysis.

### 5.6.3. Teachers' notes on drawings

Teachers' notes on the drawings were also analysed qualitatively and coded. The analysis of such data aimed to inspect information that can be derived from children's verbalisations, commenting on their own drawing. This type of data was analysed, adopting the same coding scheme as the drawing analysis for comparison.

Analysing the drawings and teachers' notes separately was useful to reflect on the limitations that the two approaches carry. For example drawing, though being familiar to children, may not be the easiest way for young children to express something as abstract as music. This is evident in the comparison of children's drawings and teachers' notes; children in the technological condition in age range A do not report music at all and children in age ranges B and C report music almost exclusively in the teachers' notes. On the other hand, the teachers' notes may sometimes present partial information, as children may consider it to be repetitive.

### 5.6.4. Children's design ideas

In this study, children's ideas were inspected for identifying categories that were not previously known, an approach to coding which differed from the one adopted in the case of the drawing analysis, where codes were inspired by the study setting.

Children were, in general, willing to express ideas for the redesign of the IP as, in most cases, each child expressed more than one idea, with children in the non-technological condition expressing nearly 2 ideas each. It was never the case that the number of ideas was less than the number of children participating.

A major interest in adding animate features or functions to the IP is present only in age range A, engaged in the technological condition, and in age range C, engaged in the non-technological condition. In the case of children in age range A, this may reflect young children's perception of the interactive IP as an animate object. Moreover, all of the ideas fell in the "human attributes" and "human functions" subcategories. This is in line with developmental theories assessing that young children's main interest is in humans, such as their parents. This result is also in line with make-believe play, the typical behaviour young children show when playing with toys and attributing fictional roles to them. In the case of the majority of children in age range C, undergoing the non-technological condition indicating an interest in making the IP animate, interpretation of this result has limitations due to the small sample size of this group of children.

In this case, the data were transformed once to inspect children's preference for animistic attributes and functions and were processed one more time to identify more specific patterns. The first degree of coding was able to identify a general preference in all the age ranges inspected for suggesting inanimate features or functions for the redesign of the IP, except in the case of children in the technological condition in age range A and children in the non-technological condition in age range C. These results showed a preference for animate features and functions. A limitation of the analysis and coding of children's suggestions is represented by it being a time-consuming task.

### 5.6.5. Attention questionnaires

The teacher’s questionnaire proved to be useful to assess children’s interest in the activity and to evaluate the degree of involvement of each child while performing the tasks. Despite this, this tool is relying entirely on the teacher’s knowledge of the children and her perception while making the judgement.

In general, this method is undemanding for the teachers but it is as informative as interviews evaluating teachers’ perceptions of the children’s experiences. This information was compared with summative evaluations assessing the children’s degree of understanding of the task, a comparison which confirms that children in age range A had difficulty with the activity.

### 5.6.6. Interviews

Interview insights were useful to highlight the teacher’s main concerns about the IP (for example all the teachers reported the issue of the IP having a low volume) and consider its application in educational settings such as the kindergarten and its implications (for example one of the teacher highlighted the complexity of the task for the children in age range A). Moreover, as stated in the previous section, the interviews were useful to identify children’s difficulties, as in the case of children in age range A.

## 5.7 Conclusion

In conclusion, by triangulating the data, the main finding that is repeated across different methods is that children in age range A showed signs of perceived increased difficulty in the technological condition, as their attention span was lower with respect to that of the children in the other age ranges. Furthermore, both the drawings and teachers’ notes neglected music and reported the IP few times, while often reporting coloured items.

# 6 - Study 3: Music-Colour Scales

**Abstract.** This chapter explored further drawings in triangulation with other research methods. The objective of the study was to confirm the findings of the previous study, which suggested that using drawing for evaluating multisensory environments is more challenging with children aged 3. Therefore, this chapter aims to answer the following research question:

- *What is the effect of age on drawing?*

With this question in mind a study similar to the previous one was run with the aim of evaluating children's experience with Interactive Pyramids (technological condition) and without them (non-technological condition). In the following study, children's drawings were collected after a task in which the concept of scale in the colour cues was emphasised by using palettes of colour based on a single colour. The drawings were then triangulated with other research methods to confirm the main findings.

## 6.1 Method

### 6.1.1 Participants

Seven groups of 3 to 5 children participated in 14 sessions. The sessions occurred within 3 workdays, with each group participating in both the technological and non-technological conditions. Each session lasted approximately 40 minutes. 14 children in age range A, 22 children in age range B and 15 children in age range C participated in the study (Table 22). The participants in this study were the same as those in the previous study.

**Table 22. Age Distribution of Participants across the study sessions.**

| | **Participants** | | |
|---|---|---|---|
| | **Age A** | **Age B** | **Age C** |
| **Technological condition** | 7 children, in 2 groups (4 and 3 children) | 11 children divided into 3 groups (two groups of 4 and a group of 3 children respectively) | 8 children divided into 2 groups (two groups of 4 children respectively) |
| **Non-technological condition** | 7 children divided into 2 groups (4 and 3 children respectively) | 12 children divided into 3 groups (three groups of 4 children respectively) | 7 children divided into 2 groups (4 and 3 children respectively) |

## 6.1.2 Location

The studies took place in the kindergarten rooms where children usually had classes. Each age group took part in the study in the room where they habitually had activities in order to make them feel comfortable.

## 6.1.3 Interactive Pyramids

The IP was the same as the one in the study described in chapter 5 but each IP was programmed to detect only one colour and its shades. For example, an IP could detect 5 different shades of blue: from the very light blue (blue1) to the darkest blue (blue5). Coloured cards were used to show the shades to the children (Figure 21). The IP used the same melody that was used in the last study (Chapter 5). The melody varied in speed, with the slowest speed corresponding to the darkest shade of blue (blue 5), and the fastest speed corresponding to the lightest shade of blue (blue 1).

For this study, 3 IPs were provided for the children. The first one was programmed to detect blue coloured items in 5 sub-tones (from light to dark blue - Figure 25). The other two IPs were mapped in a similar way: each of which was programmed to detect either green or red shades.

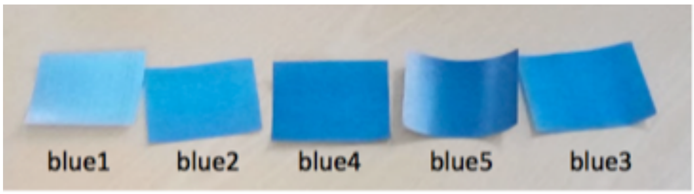



**Figure 25. Coloured cards used to demonstrate the shades of blue to children.**

### 6.1.4 Materials

Each room had at least one table with chairs; toys such as Lego bricks and boxed games; objects such as textiles, mini-kitchen utilities, and furniture; and children's drawings. The room was also equipped with materials for drawing, such as paper sheets and markers.

A set of coloured cards with 5 different shades of blue, red, and green (see example in Fig. 22) was provided for each group of children participating in the study with the IP (technological condition).

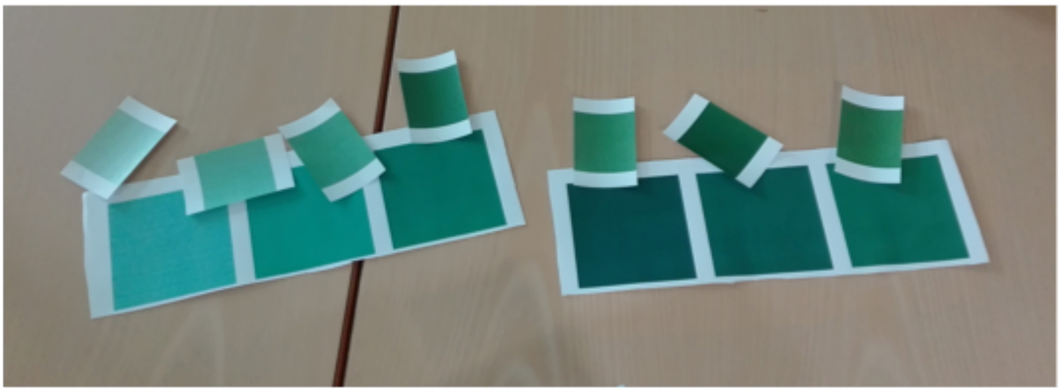


**Figure 26. Coloured cards used in non-technological condition in study 3.**

Two different sets of coloured cards were provided to the children in the non-technological condition (Figure 26): the first one consisted of two sheets of paper with each sheet having 3 items on each sheet, ranging from a light to a dark shade of the same colour; the second set consisted of 7 coloured cards of the same colour varying in colour tone (from lighter to darker).

## 6.2 Procedure

The study took place within 3 workdays, each group was observed for approximately 20 minutes (Table 23). Following the rational used in Study 2, both a technological and a non-technological condition were planned in order to observe more clearly the opportunities and the challenges offered by the IP.

**Table 23. Distribution of the sessions in study 3.**

| Day | Technological (26 children) | Non-technological (26 children) |
|---|---|---|
| **1** | 4 children, age range C (Session 9)<br>4 children, age range C (Session 10)<br>4 children, age range C (Session 11) | 4 children, age range A (Session 12)<br>3 children, age range A (Session 13)<br>4 children, age range B (Session 14)<br>3 children, age range B (Session 15) |
| **2** | 3 children, age range C (Session 16) | |
| **3** | | 4 children, age range B (Session 17)<br>4 children, age range B (Session 18)<br>4 children, age range B (Session 19)<br>4 children, age range A (Session 20)<br>3 children, age range A (Session 21)<br>4 children, age range C (Session 22) |

Three steps have been followed to run the study:

### 6.2.1 Step 1: initial activities

As a first prompt the children were asked if they remembered what they did the last time the research team visited them. They were then asked to fetch coloured objects in the room following the researcher's direction ("fetch blue and red") for 10-12 min and place them on the table grouping them by colour (active exploration).

### 6.2.2 Step 2: Main Task, Technological condition

In this condition, the children were asked to decode the interactive paradigm of 3 IPs with the same appearance but different behaviours (the first IP detected only blue coloured items, the second IP only green coloured items, and the third IP detected red coloured items).

Each child in the group was given a IP. Children were then asked to explore the objects on the table with the device and guess the rationale of the behaviour of the device. Children were shown a set of cards with single shades of the same colour (up to 6 shades for children in age C, 3-4 shades for children in age A) and were asked to use the device to guess the rationale behind the differences in the melody played by the device at each shade.

*Non-technological condition*

The children were asked to order coloured cards from the lighter to the darker shade. The children had to range two sets of coloured cards (Fig.1): the first one consisted of two sheets of paper with each sheet having 3 items on each sheet going from a light to a dark shade of the same colour; the second set consisted of 7 coloured cards of the same colour varying in colour tone (from lighter to darker). The first task consisted of putting the two sheets in the right order: from the lighter to the darker shade. The second task consisted of ordering from 3 to 7 coloured samples (the number of cards varied according to age group: 3 samples to children in age A, 5 samples to children in age B, 7 samples to children in age C) from the lightest to the darkest.

### 6.2.3 Step 3: evaluation

Each child was asked to rate the activity by putting a red coin in one of the 3 paper-based boxes with smiley faces, as in the study described in chapter 5 (Figure 15). The children were shown a set of 3 boxes, each having a different smiley face on it: happy - :) -, indeterminate - :| -, and sad - :( . Each child was then asked to rate the activity by putting a coin in one of the boxes. The coins were removed from the boxes after each session.

Children were then asked to draw what they had done. The teacher asked the child what he/she drew and the teacher present during the session made an annotation of the answer near to the drawn elements. This activity took approximately 10 minutes.

The teacher present during the session was asked to fill out a 5-point based questionnaire rating children’s attention throughout the session from “5 - very attentive” to “1 - distracted”. Each teacher completed the questionnaire after each group ended their study session.

Semi-structured interviews, aimed at gathering the teachers’ opinion on the proposed activities and the IP, were conducted at the end of the study.

## 6.3 Analysis

As in Study 2,  the analysis focused on data collected from the rating with smiley boxes, the analysis of drawings and the analysis of the teachers’ notes. The analytical procedure was the same as the one adopted in chapter 5.4 .

### 6.3.1 Teachers’ rating children’s attention

During each session with children, the teacher supervising the activities was given a 5-point Likert questionnaire (5 = very attentive, 1= very distracted) and asked to rate the children’s attention. Overall counts of ratings in both the technological and non-technological conditions were collected and compared.

### 6.3.2 Teachers’ interviews

The teachers’ interviews were analysed by identifying the main concerns and/or praises related to the experience with the device overall.
The interviews were recorded and transcribed. Emerging themes are reported in the results section.

Researchers’ observations were annotated during the sessions.

## 6.4 Results

This section reports the findings derived from the single evaluation methods adopted and from comparative analyses.

### 6.4.1 Rating with smiley boxes

Table 24 summarises the children's ratings of enjoyment in both conditions. More engagement was found in the technological condition. This result was quite consistent across the different age ranges.

Overall, the activity with IPs seemed to appeal to children. In general, the positive rating were over-represented, as in the study in Chapter 5.  Some data in the non-technological condition was missing because of time constraints during the data collection.

The rating activity was often found in children's drawings. This is probably due to the fact that the activity was enjoyable and that the children considered it to be something worth reporting. This issue would be worth further investigations by comparing different implementations of the Smileyometer.

**Table 24. Frequency of children's rating evaluating the degree of enjoyment of the activities in the technological and non-technological conditions.**

| Age | Technological condition | | | Non-technological condition | | |
|---|---|---|---|---|---|---|
| | :) | :\| | :( | :) | :\| | :( |
| A | 5/7 | 1/7 | 1/7 | 2/7* | 1/7* | 0/7* |
| B | 10/11 | 1/11 | 0/11 | 7/12* | 2/12* | 0/12* |
| C | 7/8 | 1/8 | 0/8 | 4/7 | 3/7 | 0/7 |
| Total | 22 /26 | 3 /26 | 1 /26 | 13 /26 | 6 /26 | 0 /26 |

*missing data

## 6.4.2 Drawing analysis

In this section the elements found in children's drawings and in the teachers' notes are discussed. A table containing the list of teachers' notes can be found in Appendix 8 (technological condition) and Appendix 9 (non-technological condition).

One coder analysed the list of notes and the full set of drawings. Double-coding was performed on 32% of the sample (Appendix 10). The coders independently marked the presence or the absence of specific elements in the drawings or in the notes. The agreement was 89% in the technological condition, whereas in the non-technological condition the value was 98%. The overall agreement between the coders was 93%.

Elements found in the drawings and in the notes were compared both in the technological condition and in the non-technological condition. Drawings of children in age range A mainly focused on coloured items in both conditions. In age range B drawings in the technological condition, children reported all the items in quite a consistent amount except for music. The drawings of children in age range B in the non-technological condition showed a decrease in the number of human figures. The drawings of children in age range C in the technological condition mainly focused on human figures and coloured items, while the occasions during which the IP and the music were reported were either absent or reported only once. Drawings of children in age range C in the non-technological condition mainly reported human figures, with a significant presence of human figures, coloured items and rating items. Overall, the music element was reported only once in the drawings of children in all the age groups while its presence in the notes was higher. In the teachers' notes music was reported in more than half the notes of children in age range B (6/11), half of the times in children in age range A (3/6) and not at all with children in age range C. Ratings in the notes were reported more frequently in the non-technological condition than in the technological condition.

The comparison between drawings and notes showed children's preferred means of reporting their experience (Table 25). Agreement between the items found in the drawings and the items found in the notes in the technological condition was reached more often in the case of children in age range C than with children in other age ranges. The items found in the drawings that were confirmed by the notes in age range B in the technological condition, were the same when related to ratings. For age range A, the analysis of drawings and notes resulted in the same findings in the case of the IP category and coloured items categories, while the other items were more present in the other age ranges.

**Table 25. Comparative table (tech condition).**

| Age | Drawings, notes | Human figures | IP | music | Coloured items | rating |
|---|---|---|---|---|---|---|
| A | drawings | **2 /6** | **1 /6** | **0 /6** | **6 /6** | **2 /6** |
| | notes | **4 /6** | **1 /6** | **3 /6** | **6 /6** | **3 /6** |
| B | drawings | **10 /11** | **9 /11** | **1 /11** | **7 /11** | **6 /11** |
| | notes | **9 /11** | **8 /11** | **6 /11** | **6 /11** | **6 /11** |
| C | drawings | **8 /8** | **1 /8** | **0 /8** | **6 /8** | **2 /8** |
| | notes | **8 /8** | **1 /8** | **1 /8** | **4 /8** | **2 /8** |
| | Total drawings | **20 /25** | **11 /25** | **1 /25** | **19 /25** | **10 /25** |
| | Total notes | **21 /25** | **10 /25** | **10 /25** | **16 /25** | **11 /25** |

In the non-technological condition, elements found in the drawings and elements found in the teachers' notes, overall, did not show noticeable differences (Table 26).

Complete agreement between all the items of the two datasets was found only in the case of children in age range C. In the case of children in age range B agreement was found only in the case of "coloured items". Agreement between the datasets related to age range A was found in "human figures", and "empty IP" categories.

Table 26. Comparative table (non-tech condition).

| Age | Drawings, notes | Human figures | Empty IP | Coloured items | Rating |
|---|---|---|---|---|---|
| A | drawings | **2 /7** | **0 /7** | **5 /7** | **1 /7** |
| | notes | **2 /7** | **0 /7** | **3 /7** | **6 /7** |
| B | drawings | **6 /12** | **1 /12** | **8 /12** | **9 /12** |
| | notes | **8 /12** | **0 /12** | **8 /12** | **8 /12** |
| C | drawings | **7 /7** | **0 /7** | **5 /7** | **4 /7** |
| | notes | **7 /7** | **0 /7** | **5 /7** | **4 /7** |
| | Total drawings | 15 /26 | 1 /26 | 18 /26 | 14 /26 |
| | Total notes | 17 /26 | 0 /26 | 16 /26 | 18 /26 |

### 6.4.3 Attention

Attention ratings were analysed only in the technological condition because of a lack of results in the non-technological condition resulting from a lack of time. The ratings of attention showed a relationship between attention and age: attention increased with age (Figure 27).

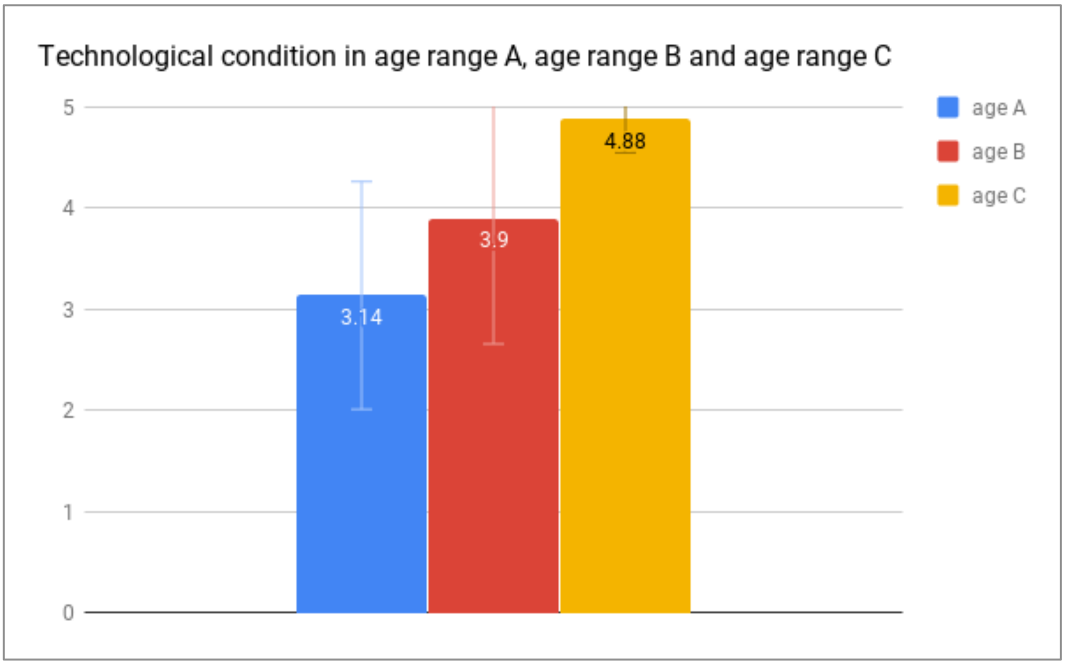



Figure 27. Attention scores for age range A, age range B, age range C.

### 6.4.4 Observational Data

Observations are reported by children's age in order to facilitate the comparison with the other research data.

#### 6.4.4.a Technological sessions

*Age Range A*

Children in age range A did not always participate in the activities, either because they refused to participate or because they were absent. Children of age range A in the technological session appeared to pay limited attention to the experience and quickly grew tired of it. They exhibited different behaviours: two children held hands while exploring the room and looking for the coloured items; the other two children explored the room on their own, one child seemed bored during the task. When asked, some of the children were able to explain the IP's behaviour. For example, a child was asked to explain why the IP did not emit a melody and correctly guessed that the IP (whose behaviour was programmed to detect only one specific colour) was put on the wrong colour. Nevertheless children's understanding of the IP's behaviour was not accurate: when exploring blue and green the children did not agree that the melody played was the same but only agreed that the beginning of the melody was the same. Moreover the children tended to not discriminate the different sounds made by the IP: for them the melody was always the same. The level of attention of children in this age range was variable: signs of boredom and distraction were observed. For example, when asked to take red and blue objects in the room, one child took a yellow object. The rating activity with the smiley boxes had to be frequently mediated by the teacher, as children often put the coin in a box whose meaning was misinterpreted.

*Age Range B*

For children in age range B, involved in technological sessions, slower music was more difficult to perceive than fast music. Overall, the children understood that the IP was reacting to one colour only. Moreover, fast music was sometimes perceived as hilarious by the children, as they laughed when the pyramid was making fast music. The IP was put purposefully by them onto the lighter colour to make fast music which made them laugh. In general, the children tended to perceive the colour shades as having similarities but they were able to say that the colours were different if guided with questions. Distinguishing fast music variations was sometimes difficult too. The focus on colour was well perceived by children that, on that day, were observed making spontaneous colourful drawings by the teachers.

Observational data from age range C are missing because of a lack of time to collect the data.

#### 6.4.4.b Non-technological sessions

*Age Range A*

In general the task proved difficult, specifically in the discrimination of intermediate shades. Children in age range A were involved in two non-technological sessions: in one session the teacher helped the children to reason about the gradation of the colours and in the other session the children detected the intermediate level between 3 shades of green. What seemed “reasonable” was to identify the two anchoring shades (the lighter and the darker shades). They confused the shade and named the intermediate shade a “light blue” and the lighter and the darker shades as “green”.

*Age Range B*

Children in age range B were involved in three non-technological sessions. Children in this age group were generally able to complete the tasks. In the first session the children had difficulties with putting the items in the right sequence. When asked, two children said that they preferred activities without the IP. In the second session  the children did not show any particular difficulties when ordering four shades and correctly assembling two pieces of sequence in the correct order. In the third session only one child was able to put 7 coloured shades in order, while the other children worked with 4 shades (two of them having difficulties with intermediate shades).

*Age Range C*

Children in age range C were involved in two sessions. Overall, this age group was able to complete the tasks without any particular difficulties. In the first session, the children had difficulties with ranging the 7 coloured shades but they performed well with 6 shades. In the other session, the teacher noticed that the children on that day tended to be unfocused. All the children in this session did the tasks correctly. Only one of them required more time to complete the tasks.

### 6.4.5 Teachers' interviews

The results from the teachers' interviews were the same as the ones reported in the previous study (chapter 5), as the interviews were performed after both studies were completed.

## 6.5 Discussion

The children in age range A differed from other age groups. Their drawings focused on colour and coloured items more often than the drawings of children in age ranges B and C. Children in this age range had verbalized more information. Depicted items that could be identified by the researcher were rarer; this can be explained by the children in this age being not proficient at drawing. In both technological and non-technological conditions the most reported item, both depicted and in teachers' notes, was colour. Observation of children in this age range highlights signs of boredom and distraction, a finding that is confirmed by teachers' questionnaires reporting a low level of attention for children in this age range and also by teachers' interviews reporting the children's difficulties with completing the task. On the contrary, almost all the children in age range A in the technological condition seemed to have rated the activity positively. This information cannot be compared with information in the non-technological condition because of missing data.

As in the previous study, music in the technological condition was rarely present in depictions of children in all the age ranges, but was slightly more present in the teachers' notes. This may be due to the fact that the IP musical output was weak and to the difficulty of representing something as abstract as music.

Children in age range B involved in the technological condition showed an interest in the IP in their depictions. This was also found too in the teachers' notes and in the observations reporting children noticing music changes.

Children in age range C reported quite a considerable number of human figures, both in the technological and in the non-technological condition, but more information on an increased interest in socialisation is missing in other research methods.

A reflection on triangulation as an approach for comparing different sources of data when evaluating young children's experience during a music-colour association task is presented below. The methods adopted, and their outcomes, are summarised in Table 27.

**Table 27. Methods used in the study to inspect young children's user experience.**

| **Methods** | **Data extracted** |
|---|---|
| Rating with Smileyometer | Measurement of engagement (rates) |
| Drawings | Qualitative codes |
| Teachers' notes | Qualitative codes |
| Attention questionnaire | Measurement of attention |
| Teachers' interviews | Summative evaluation of the learning experience |

### 6.5.1 Rating with Smileyometer

Results from the rating activity with the Smileyometer boxes, in both the technological and non-technological conditions suffered from an over-representation of positive rates, a tendency found in literature, in the study described in chapter 5 and also in the current study. This method thus proved to be uninformative when evaluating interactive technologies with young children.

### 6.5.2 Drawings

The analysis of depicted elements in the drawings reflected memorable elements of the experience, such as children's peers and colours. The drawing method was ineffective in detecting specific signs of engagement with the IP. Having few reported elements, however, such as the IP and the music confirms the difficulty of the task, as reported by researchers' observations.
The comparison of drawing data with teachers' notes highlighted, as in the current study, that children may have had difficulty in representing abstract things such as music, as this element is noticeably more present in the teachers' notes rather than in the drawings.

### 6.5.3 Teachers' notes

Teachers' notes were complementary to drawings as they reported items that children may have had difficulty to depicting, such as music. In the other cases, the items found in the teacher's notes did not differ consistently from the items found in the drawings (an example is the case of coloured items).

### 6.5.4 Attention

It would be useful to compare results of the questionnaire where children show more evident signs of distraction. In general, in the technological condition, it is noticeable that the mean value of attention rates grows in line with the age of the children. In general, this method relies on the subjective perception of the the teacher and, in this case, the evaluation was done by 5 different teachers who may have different metrics.  It must be also noted that each followed a specific age group across the year, thus affecting the reliability of the analysis. Overall, this method is not very informative with respect to other methods, but its main advantage is that it has low demands in terms of time.

### 6.5.5 Researchers' observations

Observations were able to highlight children's main difficulties, when interacting with the IP. For example, children were sometimes confused by the IP detecting colours that fell outside the range they were programmed for as in the case of a floor whose colour was very similar to the yellow the IP was programmed to recognise. Observers were able to report signs of boredom and thus act as indicators of children's attention.

Teachers' interviews did not, overall, show major disagreements with those of the researchers. For example signs of boredom were reported both by the teachers and the researchers.

## 6.6 Conclusion

The study confirmed that the drawings by age range A children were less informative than the drawings of other age groups. This may be the consequence of the stage of development they are in

In general, all methods, if analysed separately, reported only partial information about the experience with IP. Drawings were useful to assess elements of the interactive experience that retained their attention and to evaluate the presence of each element in respect to the others. Observations alone were mainly useful to identify evident signs of boredom or difficulties in using the IP. The teachers' interviews were, instead, useful to give a general overview of the peculiarities of each age range and to evaluate the main faults of the IP. The rating activity with the Smiley boxes assessed the overall level of user satisfaction with the IP, while the teachers' attention ratings were focused on the children's attention. Drawings, in triangulation with other data were successful at clarifying some information that reflected children's specific abilities, such as their ability to draw which was more evident when music was the element to be reported.

# 7 – Discussion

**Abstract.** This thesis investigated the analysis of drawings as a trustworthy research method for exploring the UX in CCI. To this aim, three studies evaluated drawing in triangulation with other research methods. Findings confirm the utility of drawing in assessing young children's **most memorable elements of the interactive experience** they participated in. Nevertheless, limitations of using drawing with young children, especially children aged 3 years, must be acknowledged. The studies also produced a number of practical observations, with implications for future basic and applied research in CCI.

## 7.1 Introduction

Understanding children's UX is important for designing interactive products that are engaging, a characteristic that is critical for the success of such products (Read et al., 2002). UX in this context is a concept that comprehends the child considered as adults instead of being passive (Green and Hogan 2005). For this reason, it is critical to assess children's personal perception of an experience they have been a part of. Especially in the case of young children, the communication of perceptions and thoughts may be difficult because abilities such as language are still in development. In this context, the familiarity of drawing for children can be considered a facilitator both for recalling memories and for building a relationship (Jolley, 2010).

The three studies reported in this thesis provided a methodological evaluation of drawing for assessing the quality of young children's UX. We thus reflect on these to assess, qualitatively, an interactive experience from the child perspective.

The thesis' main contribution included verifying drawing as a trustworthy method to assess the quality of young children's UX. In particular, children aged 3-6 have been investigated in this context. A focus has been put on children age 3 years as they seemed to present more criticalities.

## 7.2 General Framework

This discussion brings together results from the three empirical studies reported in the thesis and uses them to provide an initial answer to the research question:

**RQ1. Is drawing a *trustworthy* research method to evaluate young children's experience?**

This research question was addressed by using drawings during the evaluation phase of two interactive systems - Children's Orchestra and Interactive Pyramids - and by comparing results derived from the analysis of the drawings with results derived from the analysis of other research methods.

The first study allowed us to explore drawing as a method for keeping track of children's longitudinal experience in a technological multisensorial environment in the kindergarten context. In this study, it was difficult to evaluate the contribution that drawing data could provide to confirm findings when used in triangulation with other methods, because drawings were analysed conjointly with teachers' observations. For this reason, a more focused analysis was run in study 2 (chapter 5).

Study 2 distinguished the process leading the analysis of drawing data and teachers' notes, together with other methods such as teacher's interviews, attention questionnaires, the Smileyometer and observations. This study highlighted that analysing younger children's drawings presented criticalities, derived by the fact that children were not proficient either in drawing and in other abilities, such as language and writing. Findings from the previous study were confirmed by a third study (chapter 6) with similar characteristics to study 2.

As a summative reflection on the empirical work described in this thesis, the following research question was addressed:

**RQ2. What elements of the experience do drawings describe?**

Drawings and notes proved useful to identify the key elements of the child experience, supporting findings from the literature review on the analysis of children's drawings assessing that children draw what captured their attention (Di Leo, 1970; Xu et al., 2009). However, children's age was found a critical factor to determine the trustworthiness of drawings as a tool to evaluate the child experience. Children aged 4 or more tended to draw the elements of the experience that drew their attention (Di Leo, 1970) while children aged 3 proved more problematic, as their drawings were found often unrelated to the context of the experience in analysis and their depictions were criptic without the teachers' notes.

A summary of the research questions addressed by this thesis, its related empirical work and consequent findings can be found in the table below (Table 28).

**Table 28. Research questions and the related empirical studies designed to answer them.**

| RQ | Related study | Findings |
|---|---|---|
| 1 - *Is drawing a trustworthy method to evaluate young children's experiences?*<br><br>*1.1 - Does knowledge extracted from drawing data sustain the findings of other research data?* | 1 (chapter 4) - Music-movement associations with Children's Orchestra | Drawings, in association with the teachers' notes, are useful to identify the elements that are most interesting to the children. |
| 1 - *Is drawing a trustworthy method to evaluate young children's experiences?*<br><br>*2 - What elements of the experience do drawings describe?* | 2 (chapter 5) - Music-colour association with the Interactive Pyramids | Drawings alone are a trustworthy research method with children aged 5 years. Understanding of 4-year-olds' drawings is facilitated by the teachers' notes but they are not strictly necessary. 3-year-olds' drawings necessitate the teachers' notes for their interpretation. |
| *2.1 - What is the effect of age on drawing?* | 3 (chapter 6) - Music-colour scales with the Interactive Pyramids | 3-year-olds necessitate the teachers' notes for their interpretation. |

The main characteristics of the experimental work (the type of input and output of the interactive systems, the evaluation methods, and the different actors involved) are summarised in Table 29 in order to better identify the research contributions.

**Table 29. Overview of conducted studies.**

| | Input | Output | Methods | Actors |
|---|---|---|---|---|
| **Children's Orchestra (chapter 4)** | Movement-based | Music-based | Drawings and notes, teachers' interviews, behavioral observations | Child+teacher, Teacher researcher |
| **Rainbow scale (chapter 5)** | Visual cue | Sound-based | Drawings, teachers' notes on drawings, teachers' interviews, behavioural observations, rating boxes | Child-based, researcher-based, teacher-based |
| **Single colour scale (chapter 6)** | Visual cue | Sound-based | Drawings, teachers' notes on drawings, teachers' interviews, behavioural observations, rating boxes | Child-based, researcher-based, teacher-based |

## 7.3 Approach

Trustworthiness of drawing as a method to evaluate children's experience was empirically tested in triangulation with other research methods. Triangulation, the systematic comparison of research data derived from different research methods was adopted to analyse qualitative data and to reflect on the role of the researcher in this process (Creswell & Miller, 2000). The systematic analysis of research data and the acknowledgement of the existence of multiple realities is in line with the post-positivist research tradition (Mackenzie & Knipe, 2006).

The chosen approach aimed to understand young children's experiences. In particular, this thesis viewed children's experiences as holistic and its main aspects as elements to be collected in order to construct their perspective. This process is inferential and may lead to multiple interpretations. The role of the inquirer is, therefore, crucial for determining findings. Despite this, the relevant role of the researcher may emphasise a specific viewpoint through which research data are interpreted. This may constitute a limitation of the approach but can be overcome by involving more than one researcher in the analytical process.

The empirical work described in this thesis focused on drawing in triangulation with other research data, such as verbal and survey methods with both teachers and children, and researchers' observations (example in Table 30). Data collected for triangulation has been analysed to assess convergent information and, thus, determine findings. This process allowed for comparison of different datasets and allowed the identification of redundant information. An example of this triangulation can be found in Table 30.

**Table 30. Example of triangulated data in study 2.**

| **Triangulation** | | |
|---|---|---|
| **Method 1** | **Method 2** | **Method 3** |
| Drawing | Teachers' notes | Teachers' interviews |
| Low presence of drawn musical elements. | Low presence of annotated musical elements. | Weak musical output of the IP was reported. |
| **Finding:** music was not a central element of the interactive experience. | | |

## 7.4 Results

In general drawings were useful in identifying the elements that were most important to the children. Differences in trustworthiness of drawing data in the different age ranges analysed were observed. In particular it was evident that drawing data and teacher's notes often complemented each other, as children's abilities to draw differed according to their developmental stage. The analysis of drawings of children aged 3 years, whose drawing ability falls between fortuitous realism and failed realism according to Luquet (in Jolley, 2010), were found to report different items in the teacher's notes (Table 31).

**Table 31. Results in study 2 and 3 age range A.**

| Age range | Item | Study | Condition | Notes | Drawings | Notes - drawings |
|---|---|---|---|---|---|---|
| A | Human Figures | Study 2 | tech | 2 /7 | 2 /7 | 0 |
| | | | non-tech | 0 /4 | 0 /4 | 0 |
| | | Study 3 | tech | 4 /6 | 2 /6 | 2 |
| | | | non-tech | 2 /7 | 2 /7 | 0 |
| | IP | Study 2 | tech | 3 /7 | 3 /7 | 0 |
| | | | non-tech | 1 /4 | 1 /4 | 0 |
| | | Study 3 | tech | 1 /6 | 1 /6 | 0 |
| | | | non-tech | 0 /7 | 0 /7 | 0 |
| | Music | Study 2 | tech | 0 /7 | 0 /7 | 0 |
| | | | non-tech | | | |
| | | Study 3 | tech | 3 /6 | 0 /6 | 3 |
| | | | non-tech | | | |
| | Coloured items | Study 2 | tech | 5 /7 | 5 /7 | 0 |
| | | | non-tech | 3 /4 | 4 /4 | -1 |
| | | Study 3 | tech | 6 /6 | 6 /6 | 0 |
| | | | non-tech | 3 /7 | 5 /7 | -2 |
| | Rating | Study 2 | tech | 1 /7 | 1 /7 | 0 |
| | | | non-tech | 5 /7 | 5 /7 | 0 |
| | | Study 3 | tech | 3 /6 | 2 /6 | 1 |
| | | | non-tech | 6 /7 | 1 /7 | 5 |

Children aged 4 years drawing age fell between failed realism and intellectual realism according to Luquet (in Jolley, 2010). Empirical data show that the teachers' notes are still useful for the interpretation of children's drawings in this age range (Table 32).

**Table 32. Results in study 2 and 3 age range B.**

| Age range | item | Study | Condition | Notes | Drawings | Notes - drawings |
|---|---|---|---|---|---|---|
| B | Human Figures | Study 2 | tech | 8 /9 | 5 /9 | 3 |
| | | | non-tech | 3 /4 | 0 /4 | 3 |
| | | Study 3 | tech | 9 /11 | 10 /11 | -1 |
| | | | non-tech | 8 /12 | 6 /12 | 2 |
| | IP | Study 2 | tech | 5 /9 | 9 /9 | -4 |
| | | | non-tech | 4 /4 | 4 /4 | 0 |
| | | Study 3 | tech | 8 /11 | 9 /11 | -1 |
| | | | non-tech | 0 /12 | 1 /12 | -1 |
| | Music | Study 2 | tech | 5 /9 | 2 /9 | 3 |
| | | | non-tech | | | |
| | | Study 3 | tech | 6 /11 | 1 /11 | 5 |
| | | | non-tech | | | |
| | Coloured items | Study 2 | tech | 6 /9 | 5 /9 | 1 |
| | | | non-tech | 4 /4 | 4 /4 | 0 |
| | | Study 3 | tech | 6 /11 | 7 /11 | -1 |
| | | | non-tech | 8 /12 | 8 /12 | 0 |
| | Rating | Study 2 | tech | 5 /9 | 5 /9 | 0 |
| | | | non-tech | 3 /4 | 3 /4 | 0 |
| | | Study 3 | tech | 6 /11 | 6 /11 | 0 |
| | | | non-tech | 8 /12 | 9 /12 | 1 |

Children aged 5 years fell into intellectual realism according to Luquet (in Jolley, 2010). Empirical data show that the teachers' notes are not necessary for the interpretation of children's drawings in this age range (Table 33).

**Table 33. Results in study 2 and 3 age range C.**

| Age range | Item | Study | Condition | Notes | Drawings | Notes - drawings |
|---|---|---|---|---|---|---|
| C | Human Figures | Study 2 | tech | 4 /4 | 4 /4 | 0 |
| | | | non-tech | 3 /3 | 3 /3 | 0 |
| | | Study 3 | tech | 8 /8 | 8 /8 | 0 |
| | | | non-tech | 7 /7 | 7 /7 | 0 |
| | IP | Study 2 | tech | 1 /4 | 4 /4 | -3 |
| | | | non-tech | 2 /3 | 2 /3 | 0 |
| | | Study 3 | tech | 1 /8 | 1 /8 | 0 |
| | | | non-tech | 0 /7 | 0 /7 | 0 |
| | Music | Study 2 | tech | 3 /4 | 0 /4 | 3 |
| | | | non-tech | | | |
| | | Study 3 | tech | 1 /8 | 0 /8 | 1 |
| | | | non-tech | | | |
| | Coloure d items | Study 2 | tech | 1 /4 | 0 /4 | 1 |
| | | | non-tech | 3 /3 | 3 /3 | 0 |
| | | Study 3 | tech | 4 /8 | 6 /8 | -2 |
| | | | non-tech | 5 /7 | 5 /7 | 0 |
| | Rating | Study 2 | tech | 1 /4 | 1 /4 | 0 |
| | | | non-tech | 3 /3 | 3 /3 | 0 |
| | | Study 3 | tech | 2 /8 | 2 /8 | 0 |
| | | | non-tech | 4 /7 | 4 /7 | 0 |

Among the actors of the research studies presented in chapters 4, 5 and 6, the teachers were the reference figure for the children in the kindergarten. Together with researchers, the teachers' evaluations of children's experiences with Children's Orchestra and the Interactive Pyramids constituted a valuable research resource, thanks also to their extensive knowledge of the children. For example, teachers' information was key when some researchers' observations failed to interpret children's behaviour: in study 3 one child suddenly started to cry during the activities because - as the teachers explained - she felt pressurised to succeed at the proposed tasks with the IP. This opens important ethical issues to CCI. On the other hand, this ease of interpreting children's behaviour can be compared to an information repository where children's behaviours are added and stored with the purpose of being retrieved at request. This practice-led behaviour of the teachers makes them active seekers of elements they know and can recognise but less interested in decoding ambiguous items in the children's drawings such as "magic" elements (music, sound).

Each method adopted in triangulation provided a specific contribution to determining findings. Drawings were collected after each interactive session with the children and were mainly useful for ascertaining elements that were more memorable to children. In addition drawings are useful to children. In line with literature on drawing, depicted elements were useful to facilitate children in recollecting their experiences and, thus, organising their thoughts (Jolley, 2010).

The teachers' annotations on the children's drawings, which were collected after the children had completed their drawing and consisted of reporting the brief explanations of what children depicted, were particularly useful to complement information that would have not been evident in the drawings alone. In most cases the annotations linked together the depicted elements into coherent narratives that reported a specific frame of the experience.

The survey method adopted to measure young children's engagement was a 3-item based Smileyometer realised with boxes, where a coin expressing the children's personal preference was inserted. This method was often reported in children's drawings, thus reporting **children's interest in the activity**. It would be interesting to investigate further how much the look and feel of the Smileyometer and the voting mechanics influenced the outcomes derived from this method. However, I propose this line for future research as the major issue with this method was the over-representation of positive rates, a finding that is in line with previous literature assessing that children in the pre-operational stage (Piaget & Cook, 1952), (N=113 aged 2-7), tend to report extreme rates when asked to evaluate a computer game (Zaman et al., 2013). In the empirical work discussed in this thesis, the rating activity with the Smileyometer boxes highlighted a major presence of positive rates in all age ranges. These results, however, might have been affected by the teachers often intervening when the children showed signs of hesitation or doubt.

The survey method was adopted to describe teachers' perception of children's attention. The findings resonates with the children drawings, but had limited utility in udertanding where the attention was focused. In the specific case of the studies presented in this thesis, 5 different kindergarten teachers each evaluated a specific subset of children. This allowed the teachers to assess more reliably their judgement of each child's level of attention more reliably, as they had learned to recognise each child's behaviour throughout the year. On the other hand, having 5 different teachers to rate the different samples of children must be acknowledged, as different individuals may have different scales of measurement. In general, survey methods were not very informative on the quality of the experience but confirmed different levels of attention, detected by methods such as behavioural observations and drawing analysis, according to the different age group the children belonged.

Teachers' interviews were useful to monitor the overall performance of the whole group and to spot the main difficulties, for example the low volume of the IPs. Overall, this method was able to provide a general picture of the children's reception of the interactive system and to enable the teachers to give their evaluation of the learning aspects and suggestions for improvement. Interviews were also useful to confirm children's different attention levels. Researchers' observations were most useful to identify children's behaviour with the IP at hand, such as putting the IP to their ear, and to confirm the major issues already identified by the teachers.

## 7.5 Contribution

Drawing as a research method in CCI offers the opportunity to involve children in research investigations as sentient beings whose characteristics are acknowledged and considered. This is particularly relevant when the researcher is approaching a context such as the kindergarten where he/she need to introduce himself and establish a cooperative research environment with the stakeholders (Mazzone et al., 2010). Farrell (2005) (in Markopoulos et al. 2008) summarises that research with children is ethical when there is respect for other people, the benefits are maximised and the harms are minimized and benefits and unavoidable harms are distributed as fairly as possible. Markopoulos (2008) gives a more extensive overview of topics that are critical when performing ethical research with children, with practical advice on cultural issues, ethical selection of participants, and consent for video and photo records (Iivari & Kinnula, 2016).

## 7.6 Conclusion

This thesis contributed to the CCI community with empirical understanding of drawing as a method of qualitatively evaluating young children's experiences. Comparisons of drawing data with other types of data, such as interviews with teachers and field observations, increased researchers' confidence in the veracity of research findings to arrive at the definition of more trustworthy research findings. In this sense, this thesis promotes rigour in the analytical process and contributes to the debate on valid and reliable research methods in CCI research. Future work will further investigate the drawings of interactive experiences in multi-sensorial contexts and would further clarify to what extent young children's limited drawing proficiency influences their capacity to provide a reliable depiction of their interactive experiences. In addition, as depicted items might be ambiguous, especially in the case of children aged 3 years, further investigation on the methods that would reduce these ambiguities is needed.

Practical implications for future research imply that analysing children's drawing is a trustworthy resource when ascertaining the quality of children's experience, but it is highly demanding in terms of time and interpretation effort. This would not make them the most efficient tool to rely on when assessing children's experience. Nevertheless, drawing has the merit to be a method that is in line with children's sensitivity and may actively favour their event recall, which is in line with previous child development literature (Jolley, 2010). Such positive aspects of the drawing method can be applied to the Child-Computer Interaction domain, especially in the case of future research looking for research methods that are more respectful of children's characteristics.

The experimental work presented in this thesis presented several limitations. The chosen approach, triangulation, was emphasised the researcher's analytical role and, therefore, focused on his interpretation of children's drawings. Another limitation was constituted by the practical constraints of organising and running a study in a kindergarten; this forced the researcher to mediate between practical constraints deriving from not interfering much with daily routines. This is far from having conditions whose full control is given to the researcher. Nevertheless, operating in such a naturalistic context offered the opportunity to interact with its emerging needs.

Future research aiming to identify methods for generating trustworthy understanding of children's quality of interactive experiences should foster the debate around the appropriateness of research methods to inquire into children's experiences. This is critical because children do not fully master some abilities and, therefore, methods adopted in research with adult participants are not suitable. A more child-centred research, in particular with young children, is therefore advocated. Special attention must be devoted to children's limited understanding of complex tasks, limited vocabulary, limited physical abilities, limited attention, and the influence of key adults such as their parents.

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# APPENDIX

**Appendix 1: Semi-structured 1 to 1 interview: plot.**

Good morning and thank you for your time.

This interview aims to reflect on the musical experience your pupils recently had.

1. To begin I would ask you to tell me the path that brought you to become a school teacher.

2. Would you like to tell me something about the crucial activities you run as a teacher?

3. Would you like to tell me how your work as a teacher changed over time?

4. Did you participate to projects that are similar to the one you participated before? Would you like to talk about it?

5. If I would ask you to describe me your role inside the experimentation with Children's Orchestra...

6. First impression about your experience with Children's Orchestra.
   i. Did you find it difficult to interact with the system? Would you use it by yourself?
   ii. If yes. Have you got ideas or suggestions for improving the system?
   iii. If you could go backwards, what would you change?
   iv. What did you like most?
   v. What did you like least?

7. Did you observe differences between the group that used Children's Orchestra and the group that did not use it?

8. Did you observe particular dynamics between children during the experimentation? At a social level?
9. Did you observe particular dynamics between children after the experimentation?

10. How do you evaluate the experience from the point of view of children's learning?

11. From your point of view as a teacher? Do you think there are elements that can be in line with the activities already brought forward at school?

12. Did you observe something in particular in the drawing activity that the children did after every session with Children's Orchestra?

13. Did you notice differences between the groups?

14. Looking at the drawings did you notice that the group that did not use Children's Orchestra had the tendency to draw the notes? What is your opinion?

15. Were the children curious about Children's Orchestra? Did they ask questions?

16. Have you got comments in particular?

**Appendix 2: Percentage of the presence of themes in the drawings in Child Orchestra and in Children Chorus (Statistical relevance **p<.0005; N.S. no significativity).**

| Theme | Presence in Children’s Orchestra (%) | Presence in Children’s Chorus (%) |
|---|---|---|
| Music N.S. | 73% | 67% |
| Movement** | 44% | 23% |
| Objects** | 84% | 36% |
| People** | 73% | 27% |

## Appendix 3: Technological condition. Teacher's notes.

| Session | Child | Teacher's notes |
|---|---|---|
| 1 (tech) | CD | "I say: why does it emit signal when on the floor?" "After also CC tries" |
| | CA | "CB, CC, CD, CA" "I put the coin in the box" |
| | CC | "I am looking for objects" |
| | CB | "I am looking for objects" CA |
| 2 (tech) | BA | "Boxes", "coins", "the cup", "the volcanos that made music", "the rainbow colours" |
| | BC | "The box where I put the coin (happy)" "All the rainbow colours we found" "The volcano discovered the colour of the items we found" |
| | BN | "The volcano with an object I put on it" "The boxes where we had to put the coins" "I put the coin in the happy box" |
| | BG | "The volcano" "The boxes where we had to put the coin" |
| 5 (tech) | AN | "The happy box" "The colour" "the pyramid" "the rainbow" |
| | AE | "I was playing" "The rainbow" |
| | AI | "The rainbow" |
| | AK | "The rainbow colours" "The mountain (pyramid)" "The table" |
| 7 (tech) | BI | "The table" "I am drawing the boxes, the little mountain (IP)" "The boxes: happy, sad, happy" |
| | BS | "I am making the pyramid play" "the music" |
| | BM | "I am laying "this" to see if it makes sounds" "That thing that had water inside" "the little table" |
| | BH | "I am putting "dog" on the rainbow to listen to the music" |
| | BO | "The pyramid", "the music", "me" |
| 8 (tech) | AG | "Home", "mum", "the grass" |
| | AF | "AF house", "AF going inside the house", "the grass" |
| | AH | "The games/toys I brought", "It is me playing", "the volcano" |

## Appendix 4: Teacher’s notes in non-technological condition.

| Session | Child | Teacher’s notes |
|---|---|---|
| 3 | BP | “The rainbow. We made it with violet, light blue, green, yellow, red, and white” “the pyramid to make things, to become a table, a bird..” |
| | BK | “The red colour” “the violet” “the cup” “the pointy roof” “the rainbow” “the magic pyramid I wanted to transform in a bird’s beak” “these are the boxes with the coins to put inside if he liked it of if he disliked it” |
| | BJ | “The rainbow we took the colours” “we made the pyramid become things” “the boxes to put the coin down” |
| | BR | “The boxes to put the red round down” “the rainbow with violet, light blue, green, yellow, orange, and red” “the brown pyramids” |
| 4 | CF | “We are putting the red rounds in the boxes to see who liked or disliked the game” “the magic object” “the rainbow” “the faces” “me, CH, CG” |
| | CH | “The boxes to put the red rounds” “the rainbow” “I look at how we did the rainbow” “me, CF, CG” |
| | CG | “The rainbow we made with foulards, legos, and all the things we found in the room” “the faces where we put the coins” “the magic tent” “me, CF, CH” |
| 6 | AA | “The boxes: sad, less sad, happy” |
| | AB | “The rainbow” |
| | AH | “These are the white squares” “the rainbow” |
| | AM | “The roofs” “the red cup” |

**Appendix 5: Agreement between coders (c1, c2) in the drawings in technological and non-technological condition - chapter 5.**

| Session | Child | Coder (C1,C2) | Human figures | IP | music | Coloured items | rating |
|---|---|---|---|---|---|---|---|
| 2 (tech) | BA | c1 | 0 | 1 | 0 | 1 | 1 |
| | | c2 | 0 | 1 | 0 | 1 | 1 |
| | BC | c1 | 0 | 1 | 0 | 1 | 1 |
| | | c2 | 0 | 1 | 0 | 1 | 1 |
| | BN | c1 | 0 | 1 | 0 | 1 | 1 |
| | | c2 | 1 | 1 | 0 | 0 | 1 |
| | BG | c1 | 0 | 1 | 0 | 1 | 1 |
| | | c2 | 1 | 1 | 0 | 0 | 1 |
| 8 (tech) | AG | c1 | 0 | 0 | 0 | 0 | 0 |
| | | c2 | 0 | 0 | 0 | 0 | 0 |
| | AF | c1 | 0 | 0 | 0 | 0 | 0 |
| | | c2 | 1 | 0 | 0 | 0 | 0 |
| | AH | c1 | 1 | 1 | 0 | 1 | 0 |
| | | c2 | 1 | 0 | 0 | 0 | 0 |
| 4 (non-tech) | CF | c1 | 1 | 1 | | 1 | 1 |
| | | c2 | 1 | 1 | | 1 | 1 |
| | CH | c1 | 1 | 0 | | 1 | 1 |
| | | c2 | 1 | 0 | | 1 | 1 |
| | CG | c1 | 1 | 1 | | 1 | 1 |
| | | c2 | 1 | 1 | | 1 | 1 |
| 6 (non-tech) | AA | c1 | 0 | 0 | | 1 | 1 |
| | | c2 | 0 | 0 | | 1 | 1 |
| | AB | c1 | 0 | 0 | | 1 | 0 |
| | | c2 | 0 | 0 | | 1 | 0 |
| | AM | c1 | 0 | 1 | | 1 | 0 |
| | | c2 | 0 | 0 | | 0 | 0 |
| | AH | c1 | 0 | 0 | | 1 | 1 |
| | | c2 | 0 | 0 | | 1 | 1 |

## Appendix 6: Attention rating in the technological condition.

| | Mean | StDev |
|---|---|---|
| **Age Range A** | 3.28 | 0.88 |
| **Age Range B** | 4.77 | 0.68 |
| **Age Range C** | 4.75 | 0.43 |

## Appendix 7: Summary of teachers' questionnaire rating in the non-technological condition.

| | Mean | StDev |
|---|---|---|
| **Age Range A** | 4.25 | 0.83 |
| **Age Range B** | 4 | 1.22 |
| **Age Range C** | 4.33 | 0.47 |

## Appendix 8: Teacher's notes in technological condition.

| Session | Child | Teacher's notes |
|---|---|---|
| 9 | CB | CA wanted to take the yellow can. I took it instead |
| | CA | I am putting the coin in the happy face. CD put the coin here. CB puts the coin in the happy face. |
| | CD | CC. It is me putting the coin in the "so,so" face. CC coin |
| | CC | I am taking the red objects. CD is going to take a red thing |
| 10 | CH | I am looking at CF. CF Putting the red and pink things on the table. CG |
| | CE | I put down the green cards |
| | CF | A pyramid making different **musics**. It is me putting the cards from the lightest to the darkest. |
| | CG | Me and CE arranging the light blue cards. CE |
| 11 | BA | It is me putting the coin. The pyramids were making **music**. |
| | BN | I was putting the coin in the happy box because I liked to do these works. The pink colour that was not making **music** because it wanted the light blue one |
| | BG | The box that was **singing** about the light blue colour. The happy box. The sad one. The so so one. |
| | BC | Me putting the coin in the smiling box. |
| 12 | AI | I did the rainbow. Yellow, red, orange, violet, light blue, green |
| | AE | It is me. The rainbow. |
| | AK | The differently coloured cards. The colours. The one that was playing **music**. I do not remember which ones were playing music |
| 13 | AC | The sun, the volcano makes **sounds**, the happy box, the box that is a little bit happy |
| | AA | The volcano that **plays** only on these reds. The very happy face, the sad one, the less sad one |
| | AF | Himself makes the games. This is sad, this is happy. He plays the game. He goes to take the colour. |
| 14 | BJ | I was taking the pyramid and had put the pyramids on the squares and on the dark blue, light blue the pyramid **was working**. The three boxes we put the coins: one mine, one of BO, one of BK in the happy box, and in the serious one the coin of BB |
| | BO | The slow **music**. I look at the pyramid that is singing. |
| | BK | The squares of different colours. The **singing** pyramids. I liked putting down the coins. |
| | BB | The green coloured squares did not do anything |
| 15 | BM | I am looking at the pyramid when it was open |
| | BI | The little papers. The little mountains. I am doing the drawing. |
| | BS | I am making the pyramid play **music**. |

## Appendix 9: Teacher's notes in non-technological condition.

| Session | Child | Teacher's notes |
|---|---|---|
| 16 | CB | "The cubes, the coin, I put the coin in the little cube, CA, CE" |
| | CA | "Me, CE, CB. We are putting the coin in the boxes" |
| | CE | "The coloured cards, I put the yellow ones" |
| 17 | BA | "Colours, dark green, light green, lighter green. Happy. My coin. A little bit.. And a little bit.. Sad" |
| | BR | Happy box, dark green, light green, serious, sad |
| | BH | Dark green, light green, water green, dark green, darker green, green that is a little bit dark and a little bit light |
| | BI | "Cardboard that is so so.. Water green, a little bit lighter, a little bit darker, a little bit like the green of the sea, light green, little coin .. so, so/normal ...face that does not smile... happy" |
| 18 | BJ | I put the colours in order from the lightest to the darkest |
| | BK | Dark, light, I take the dark colour |
| | BM | Me putting down the dark colour |
| | BC | I put the colours in order, from the darkest to the lightest |
| 19 | BO | I put the coin in the happy face |
| | BB | I put down the money in the "I liked it a little" box |
| | BG | The serious box, the happy box, the sad box. I put the coin in the serious box |
| | BS | I am about to put the coin in the serious box |
| 20 | AI | The angry mouth. The face that is a little bit happy and a little bit angry. The happy face |
| | AE | It is me, I am playing. These are the boxes. This is happy, sad, angry. To put the one I liked |
| | AN | These yellows. A dark one. This is light. This is like that one. The boxes to put a red round |
| | AH | The happy face, this is a little bit happy, a little bit sad. Where there were the colours. The yellow colours: a dark one, a light one. This one is like that one. The face that it did like nothing |
| 21 | AG | The happy box |
| | AK | The sheets coloured differently. Brown, brown, red. The table |
| | AM | Me. I play with the boxes |
| 22 | CH | Boxes. It is me putting the green cards in order |
| | CF | The boxes where I put the coin. It is me putting the cards in place from the lightest to the darkest |
| | CD | It is me mixing the colours |
| | CC | It is me putting the cards in order, with the lighter and the darkest |

**Appendix 10: Degree of agreement between two coders in technological condition - drawn elements.**

| Session | Child | Coder (C1,C2) | Human figures | IP | music | Coloured items | Rating |
|---|---|---|---|---|---|---|---|
| 13 (tech) | AC | c1 | 0 | 0 | 0 | 1 | 1 |
| | | c2 | 0 | 0 | 0 | 0 | 1 |
| | AA | c1 | 0 | 0 | 0 | 1 | 1 |
| | | c2 | 0 | 1 | 0 | 1 | 1 |
| | AF | c1 | 1 | 0 | 0 | 1 | 0 |
| | | c2 | 1 | 0 | 0 | 0 | 0 |
| 14 (tech) | BJ | c1 | 1 | 1 | 0 | 1 | 1 |
| | | c2 | 1 | 1 | 0 | 1 | 1 |
| | BO | c1 | 1 | 1 | 1 | 1 | 0 |
| | | c2 | 1 | 1 | 1 | 1 | 0 |
| | BK | c1 | 1 | 1 | 0 | 1 | 1 |
| | | c2 | 1 | 1 | 0 | 1 | 1 |
| | BB | c1 | 0 | 0 | 0 | 1 | 0 |
| | | c2 | 0(1???) | 0 | 0 | 0 | 0 |
| 16 (non-tech) | CB | c1 | 1 | 0 | | 0 | 1 |
| | | c2 | 1 | 0 | | 0 | 1 |
| | CA | c1 | 1 | 0 | | 0 | 1 |
| | | c2 | 1 | 0 | | 0 | 1 |
| | CE | c1 | 1 | 0 | | 1 | 0 |
| | | c2 | 1 | 0 | | 1 | 0 |
| 18 (non-tech) | BJ | c1 | 1 | 0 | | 1 | 1 |
| | | c2 | 1 | 0 | | 1 | 1 |
| | BK | c1 | 1 | 0 | | 1 | 0 |
| | | c2 | 1 | 0 | | 1 | 0 |
| | BM | c1 | 1 | 0 | | 1 | 0 |
| | | c2 | 1 | 0 | | 1 | 0 |
| | BC | c1 | 1 | 0 | | 1 | 1 |
| | | c2 | 1 | 0 | | 1 | 1 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 21 (non-tech) | AG | c1 | 0 | 0 | | 1 | 0 |
| | | c2 | 0 | 0 | | 0 | 0 |
| | AK | c1 | 0 | 0 | | 1 | 0 |
| | | c2 | 0 | 0 | | 1 | 0 |
| | AM | c1 | 1 | 0 | | 0 | 0 |
| | | c2 | 1 | 0 | | 0 | 0 |

| DOCTORAL PROGRAMME IN<br>INFORMATION AND COMMUNICATION TECHNOLOGY |
|---|

**Doctoral candidate**

**Cristina Core**

| | |
|---|---|
| Cycle | **30°** |
| Thesis | **Drawing the User Experience of Young Children** |
| Advisor | **Antonella De Angeli (University of Trento and University of Lincoln)** |
| Co-advisor | |

## 1. List of publications

- Core, C., Conci, A., De Angeli, A., Masu, R., & Morreale, F. (2017). **Designing a Musical Playground in the Kindergarten.** In *Proceeding of the International Conference of British HCI* – Sunderland (UK)

- Masu, R., Conci, A., Core C., Morreale, F., & De Angeli, (2017). A. **Robinflock: a polyphonic algorithmic composer for interactive scenarios with children.** 14th Sound and Music Computing Conference. – Espoo, Finland.

- Conci, A., Core, C., & Morreale, F. (2015). **Weighting Play and Learning in Interaction.** *Play and Learning Experience (PALX) Workshop.* CHItaly conference – Rome.

- Bordin S., Core C., De Angeli A., De Uffici N., Kazhamiakin R., Noël S., Pistore M., Zacco G. (2013). **ViviTrento: apps for the smart city.** *Demo presented at CHItaly 2013*, Trento.

- Bordin S., Core C., De Angeli A., De Uffici N., Kazhamiakin R., Noël S., Pistore M., Zacco G. (2013). **A mobile community for a smarter Trentino.** *Workshop on People Centered Smart Territories: Design, Learning and Analytics, Smart City Exhibition 2013*, Bologna, Italy.

## 2. Research/study activities

Training abroad:

- 2015, Summer school "Designing Human Technologies" – Roskilde (DK)
- 2015, Summer school "Research Methods in Human-Computer Interaction" – Cyprus (CY)
- 2016, Winter school "Tangible Interaction studio" – Fribourg (CH)

Mobility:

- 2016 (from October to December), mobility period spent at "Eindhoven University of Technology" – "User Centred Engineering" research group (NL) led by Prof. Panos Markopoulos
- 2107 (July, September, October), mobility period spent at "University of Central Lancashire" – "Child-Computer Interaction (ChiCI)" research group (UK) led by Prof. Janet Read

Projects:

- participation to Inf@nzia DIGItales project

Teaching:

- 2015/2016 tutoring for bachelor course "Human-Computer Interaction" at DISI

Other:

- student volunteer during COOP conference 2016
- reviewer for IDC 2015 conference