Acquisition of Joint Attention and Social Abilities through music Tangible User Interface: children with Autism Spectrum Condition and the Reactable experience

Lilia Villafuerte Bazán

MASTER THESIS UPF / 2011

MASTER THESIS DIRECTOR

Dr. Sergi Jordà

MUSIC TECHNOLOGY GROUP

UNIVERSITAT POMPEU FABRA

Acknowledgements

This thesis would not have been possible without the help of people related and unrelated to research on technology with autism. First of all, I would like to express my deep and sincere gratitude to Sergi Jordà, tutor of this research, for giving me all the independence, professional support and respect to carry out this project. Thanks as well to the Department of Music and Technology at the Pompeu Fabra University, to Carles F. Julia and Sebastián Mealla, for the conversations and their time spent in solving technical problems with the Reactable. Thanks to the company Reactable Systems, for providing the research material and technical equipment needed for the project.

I am grateful also to Ulysses Bernardet for all the conversations that helped redirect this project to a more pragmatic perspective, and for the input on the methodological approach. My gratitude likewise to Carme Basil Almirall for the bibliographic information, the questions and the good energy deployed in our online and offline conversations. Thanks to the directors of the centers: AMPANS, Er-NIU and Centro Ciel for their support, logistics and access to the parents who collaborated in the research. Thanks also to the psychologists and therapists involved in the development of the experiments. Especially, my heartfelt thanks to Cristina Moreno, Gemma Estruch, Rosalina Reñé and Francisco Urbistondo, for the time invested for the success of this project.

Furthermore, I would like to show my gratitude to the musicians Dani Rappa and Ken Dee, for all the material created selflessly for the project, and for supporting the daily work with children. Particular thanks to Milena Markova for the hours, days and weeks of video analysis work; to Laura Malinverni for being there with the children when needed, and especially to Anna Font, who lost entire weekends and Friday nights for emotional, intellectual and material support with the quantitative analysis of data. Anna, Milena, Dani and Laura are the best professionals and friends with whom I've been able to count on. I am forever in your debt.

Finally, this project has only been possible thanks to the mothers and fathers of children with ASC who participated in the investigation, and to all those people "who love someone with autism" who contacted via email, Twitter and social networks to send feedback and messages of support to the project.

Abstract

This study assessed the potential of the Reactable, a musical tangible user interface, to help in the acquisition of joint attention abilities and social interaction in children with Autistic Spectrum Conditions (ASC). With this purpose, nine children with ASC participated in the research, the sample being its own control group, and a simple subject design was developed. The type of design was ABA (Basic Withdrawal). A repeated measures comparison design within subjects was used. The no-intervention baseline phase (A) was 20 minutes of free play session in their regular school space. The intervention phase (B) was three sessions guided by a therapist with the Reactable. The no-intervention withdrawal phase (A) was 20 minutes of free play session with the same conditions as the no-intervention baseline. All the material was video-recorded, and the 100% of the material was analyzed. In addition to the statistical analysis, this study used qualitative methodological tools for analysis of outlier subjects and detection of atypical behavior for future research. The results show a significant increase in the composite variable social interaction and in turn-taking target behavior during the sessions with the Reactable. The theoretical implications of these acquisitions, as well as a discussion of the results, are included in this thesis.

Keywords

Autism Spectrum Condition (ASC); Autistic Disorder: Empathy; Autistic Disorder: therapy; Collaboration; Behavior therapy; Joint Attention; Music Therapy; Tangible Interface; Social skills training.

Table of Contents

Page

List of Figures

Page

List of Tables

Page

1. INTRODUCTION AND MOTIVATION

1.1 Problem Statement

Autism is a condition that affects approximately 1 in every 155 people worldwide. Out of this population, 60% are below 50 IQ points on a scale of 0 to 100. Below this amount the person is considered to have moderate to severe disability. Classic autism and Asperger´s syndrome share three features in their diagnosis: social communication difficulties (reading the meaning of body language, inability to attribute intentions to others, inability to understand metaphors, absence of joint attention, etc.), unusual interest in specific areas of knowledge (obsession with certain topics, sometimes called islands of knowledge), repetitive and ritualistic behavior (Baron-cohen, 2008). There are currently three theories that seek to explain the phenomenon of autism. These include: The theory of mind-blindness (Simon Baron-Cohen, Leslie, & U Frith, 1985), the weak central coherence (WCC) theory (Uta Frith, 1989), and the empathizing - systemizing (E-S) theory (Simon Baron-Cohen, 2009). However, none of these have shown results able to explain the 100% of cases of people with autism spectrum condition (ASC). With this vision as a starting point, this study is based on the idea shared by Peeters, Riviere and H. Asperger, that an appropriate educational intervention improves the quality of life of people with ASC, even if their IQ is below 50 points (Asperger, 1944-1991; Peeters, 2008; Riviere, 2001).

Among the major development impairments that affect children with ASC, the variables that limit communication development are the lack of joint attention (JA) abilities and social competence (SC). Joint attention allows children with typical development (TD) to share interests around an object, a person or an event. In addition to positioning the child in its environment, joint attention is the basis on which language develops. Studies have shown that the acquisition of joint attention through behavioral therapies in children with ASC facilitates language development. The absence of SC creates states of social aloofness, inability to maintain communication sequences, separating children with ASC from their peers. There is evidence about the acquisition of joint attention and social competence for children with ASC in music therapy interventions and therapy game. Therapies associated with play facilitate the acquisition of joint attention and social competence through the creative use of objects and give better results for long-term acquisition of SC.

Just as they have difficulties in social and communication area, people with ASC have strengths in their development that may enable them to develop alternative communication strategies. The present study focuses on two of them. On the one hand, people with ASC have a qualitatively different development with the use of objects compared to those with typical development. This involves the exploration of objects through taste, smell and caress (Klin, Jones, Schultz, & Volkmar, 2003; Rowland & Schweigert, 2009; E. Williams, 2003). On the other hand, even when people with ASC have difficulties in understanding emotions in typical social communication, they can process affective information through music. Furthermore, they have better processing and pitch memory than TD people (P Heaton, B Hermelin, & L Pring, 1999; Pamela Heaton, 2003, 2009).

Tangible user interfaces (TUI) enhance cooperative and associative play sequences in children with ASC, reducing time and repetitive solitary activities (Farr, Yuill, & Raffle,

2010). The Reactable is a TUI that allows the intuitive and collective creation of complex musical pieces. Hence, the present study investigates the Reactable because it is a tangible tool in addition to being a musical instrument, and it has previously been tested in typically developing children returning positive results.

The objectives of this research are:
1. Creating an exploratory study about musical TUI and the acquisition of social abilities and joint attention in children with ASC.
2. Testing the Reactable as a possible tool for improving social competence in children with ASC.

The first part of this report elaborates on the theoretical concepts of Autism Spectrum Condition, which support and give meaning to the development of research. The second section explains the methodology used to achieve the research goals and describes the design of the experiment in detail. The third chapter reports the statistical results of the analysis of 100% of video recorded in the experiments, as well as qualitative results of the children who participated in the sample which showed more dissimilar results, aimed at future studies. Finally, the results of quantitative and qualitative analysis are discussed, to then describe the potential implications in a theoretical level and recommendations for future studies.

1.2 Background

This chapter describes the theoretical framework of this research. The reality of research around Autism Spectrum Condition, and the theoretical perspective from which ASC is focused in this research are reviewed. Following, the importance in the development of children with ASC in the absence of joint attention skills and social competence are described. Finally, the report will focus on how the qualitatively different use of objects and the special ability for music that children with ASC have, allow the development of interventions that facilitate the acquisition of the variables of JA and SC.

a) The Reality of Autism Spectrum Condition (ASC) Research

Since Leo Kanner's first description on the characteristics of a "new" children's disease in 1943, much has been researched about autism without even reaching a consensus on its causes and its specific characteristics which differentiate it from cognitive impairments. The foundational paper "Autistic disturbance of affective contact" (Kanner, 1943) identifies three variables related to qualitative development that define autistic behavior: disorders in social relationships, disorders in communication and symbolic language, and insistence on invariance. German researcher Hans Asperger in his article "'Autistic psychopathy' in childhood" (Asperger, 1944-1991) adds to Kanner’s description: strange communicative patterns (prosodic and pragmatic anomalies), obsessive-compulsive character and tendency to be guided by uncontrollable inner impulses. These last two definitions are widely used in the diagnosis of autism by health professionals. Thus, the Diagnostic and Statistical Manual of Mental Disorders IV-TR (DSM-IV) (American Psychiatric Association, 2000), includes Kanner’s three dimensions for the detection of people with Autistic disorder, while the characteristics defined by H. Asperger are included in Asperger's disorder.

- The Pervasive Developmental Disorders

The Pervasive development disorders (PDD) belong, according to DSM IV, to the category of communication disorders. According to the manual of the American Psychiatric Association, PDD are divided in up to five categories. In addition to Autistic disorder (see Table 1), also known as classic autism, the other development disorders included are Rett's disorder, the childhood disintegrative disorder, Asperger's disorder and the pervasive developmental disorder not otherwise specified (including atypical autism). Those categories are not static and should not be considered as a fixed framework for diagnosis.

Diagnostic Criteria for 299.00 Autistic Disorder

I) A total of six (or more) items from (A), (B), and (C), with at least two from (A), and one each from (B) and (C):

(A) qualitative impairment in social interaction, as manifested by at least two of the following:
1. marked impairments in the use of multiple nonverbal behaviors such as eye-to-eye gaze, facial expression, body posture, and gestures to regulate social interaction
2. failure to develop peer relationships appropriate to developmental level
3. a lack of spontaneous seeking to share enjoyment, interests, or achievements with other people, (e.g., by a lack of showing, bringing, or pointing out objects of interest to other people)
4. lack of social or emotional reciprocity (note: in the description, it gives the following as examples: not actively participating in simple social play or games, preferring solitary activities, or involving others in activities only as tools or "mechanical" aids)

(B) qualitative impairments in communication as manifested by at least one of the following:
1. delay in, or total lack of, the development of spoken language (not accompanied by an attempt to compensate through alternative modes of communication such as gesture or mime)
2. in individuals with adequate speech, marked impairment in the ability to initiate or sustain a conversation with others
3. stereotyped and repetitive use of language or idiosyncratic language
4. lack of varied, spontaneous make-believe play or social imitative play appropriate to developmental level

(C) restricted repetitive and stereotyped patterns of behavior, interests and activities, as manifested by at least two of the following:
1. encompassing preoccupation with one or more stereotyped and restricted patterns of interest that is abnormal either in intensity or focus
2. apparently inflexible adherence to specific, nonfunctional routines or rituals
3. stereotyped and repetitive motor mannerisms (e.g. hand or finger flapping or twisting, or complex whole-body movements)
4. persistent preoccupation with parts of objects

II) Delays or abnormal functioning in at least one of the following areas, with onset prior to age 3 years: (A) social interaction (B) language as used in social communication (C) symbolic or imaginative play
III) The disturbance is not better accounted for by Rett's Disorder or Childhood Disintegrative Disorder

Table 1: Diagnostic criteria for autistic disorder in the DSM-IV

If a line was drawn to represent the various pervasive developmental disorders covering the whole autism spectrum, at one end of the spectrum would lay Rett's disorder. Rett's disorder is a genetic disease, a mutation on chromosome X. Associated to mental retardation in females, it shows from the sixth to the eighth month of age manifesting with the absence of functional hands movements, then, gradually with loss of speech, and the developing of micro-cephalic, autism, ataxia, intermittent hyperventilation and stereotypic hand movements (Amir et al., 1999).

At the other end of the spectrum lies Asperger syndrome. Although there is an ongoing debate about whether or not it should be included in the Autistic disorder spectrum, it is considered a separate disorder where the main difference is, people with Asperger syndrome do not have mental retardation, IQ is within or even above the average of the population with normal development and there is no significant delay in the acquisition or the use of language. However, the use of language shows some abnormalities related to its pragmatic use, including for example difficulty in understanding metaphors or subtext (Rundblad & Annaz, 2010), or their language being too correct and formal, creating distance with their conversation partners (Vanderbruggen et al., 2010).

Between the two ends of the spectrum, childhood disintegrative disorder and pervasive developmental disorder not otherwise specified (including atypical autism) can be found. The childhood disintegrative disorder is characterized by a setback in the development of the child after the two years of age. This setback must happen in two of the following five areas: expressive and receptive language, social skills, sphincter control, lack of play and motor skills. It is worth noting that there is a specific category within the autism spectrum that encloses all cases that are difficult to diagnose, as explains the DSM-IV, named Pervasive developmental disorder not otherwise specified (including atypical autism). This category leaves evidence of the complexity of ASC diagnosis:

> This category should be used when there is a severe and pervasive impairment in the development of reciprocal social interaction or verbal and nonverbal communication skills, or when stereotyped behaviour, interests and activities are present, but the criteria are not met for a specific Pervasive Developmental Disorder, Schizotypal Personality Disorder or Avoidant Personality Disorder. For example, this category includes 'atypical autism' presentations that do not meet the criteria for Autistic Disorder because of late age of onset, atypical symptomatology, or sub-threshold symptomatology, or all of these. (American Psychiatric Association, 2000, p. 84).

- The Autism Spectrum

The autism spectrum as term was first coined in the study "Severe impairments of social interaction and associated Abnormalities in children: Epidemiology and classification" (L Wing & J Gould, 1979). The result of this research showed that autistic traits are not only unique to people with developmental disorder, but are also found in individuals who have suffered genetic or metabolic alterations, epilepsy in infancy, etc. According to Wing & Gould, there are four variations of the autistic spectrum:

1. Disruption in social recognition capabilities.
2. Disorder in social communication skills, including lack of proto-declarative and joint attention (S Baron-Cohen, Allen, & Gillberg, 1992).
3. Disorders in the skills of imagination and social understanding, including difficulty in understanding non-verbal language and metaphors (Rundblad & Annaz, 2010).
4. Repetitive patterns of activity.

Furthermore, other internal and external variables exist that influence the expression of these variations of the autistic spectrum. The internal variables are:

1. Intelligence quotient (IQ): does the patient have low IQ and mental retardation? Individuals with ASC may have moderate or severe mental retardation, 60% of cases have an IQ below 50 points out of 100
2. The patient's gender: for every 4 cases of autism only one is a woman, not counting Rett's syndrome, which only affects women.
3. The patient's age.

Important external variables would be:

1. The type of treatment (behavioral, affective, physiologic).
2. The involvement of the family: there is evidence that the involvement of siblings helps to improve social competence of children with autism (Bass & Mulick, 2007).

In order to determine the level and type of autism type of a person with ASC, tables of diagnosis and treatment with up to twelve areas of development, each with its own gradations to cover the total ASC, are used (Riviere, 2001). In Fig. 1, a summary of the different types of PDD is shown, giving evidence of the complexity in the diagnosis of the total autism spectrum.

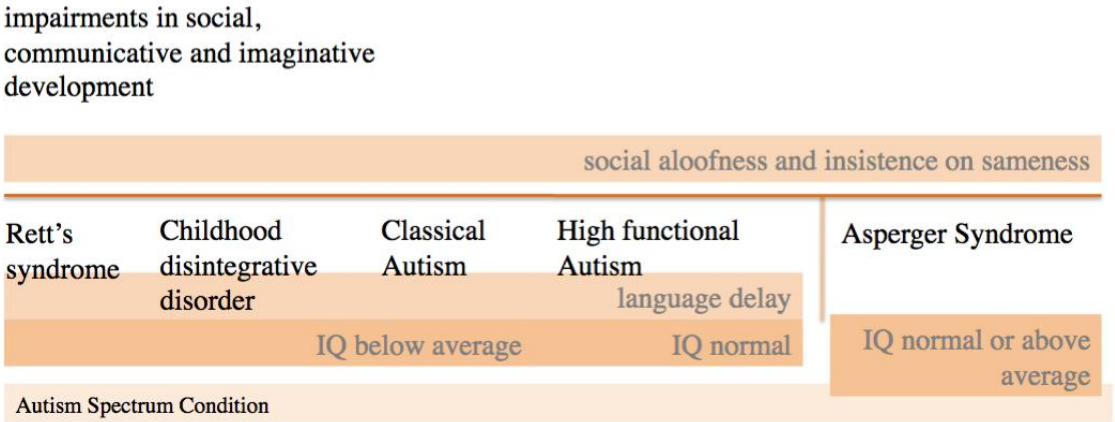

Fig. 1: The Autism Spectrum Condition

To better understand the differences between people with typical development (TD) and individuals with ASC, it is necessary to dwell on the description of the autistic disorder by the DSM-IV. This book uses the recurrent word "qualitative" (see Table 1), referred to an intrinsic characteristic of the pervasive developmental disorder, so there are differences between this kind of children and TD children that go beyond a delay in development classified as normal. As explained by Theo Peeters, these qualitative differences are profound and determining features that structure being autistic. “When we say that people with autism have a different cognitive style, we simply mean that their brains process information differently. They listen, feel and see, but their brains use that information differently” (Peeters, 2008, p. 15). To illustrate this idea, Wing & Gould’s (1979) research should be observed. This study compared a population with retardation or abnormalities but without autistic traits (more than half of whom were severely retarded) and a comparison group of mentally retarded children with autism. The results showed that 77 percent of children with mental retardation played fiction games, however 99 percent of children with autism did not. Consequently, these results indicate that autism is not a problem related to cognitive retardation, but to a different development of cognition. The differences are not only found in processing and creating social information, but also 90 percent of people with ASC have different perceptual abilities than typically developing population (Leekam, Nieto, Libby, Wing, & Gould, 2007). For instance, they may have a visual acuity above average, compared to that of birds of prey (E. Ashwin, C. Ashwin, Rhydderch, Howells, & Simon Baron-Cohen, 2009) or in the auditory system, better memory and tone processing abilities (Pamela Heaton, 2003; Mottron, I Peretz, & Ménard, 2000). Therefore, in contrast to how the traditional psychology sees the Autism as a Disorder, within the scope of this thesis, autism will be considered as a life condition and consequently, it will be studied from a cognitive perspective.

- Cognitive Theories about ASC

In the history of the development of theory about the causes or the innate characteristics of autism, three are the most extensively studied cognitive theories. One of the most widespread is "The theory of mind-blindness" (ToM) (Simon Baron-Cohen et al., 1985), which describes that people with ASC fail in the ability to attribute mental states to others. Baron-Cohen, Leslie, and Frith (1985) found that 80 percent of study participants were unable to solve tests related to the attribution of mental states to people ("I think he thinks"). If indeed, the lack of this ability was the most striking feature of autism, where does the remaining 20 percent that were able to pass the test stand? With the intention to prove that even people with Asperger syndrome would not be able to pass the ToM tests, Baron-Cohen crated a new test based on a second level of attribution of mental states (“I think he thinks she thinks”) in which 100 percent of participants with autism failed to pass the test (S Baron-Cohen, 1989). However, in subsequent studies in which Asperger population was included in the sample, the results showed that 73 percent of the sample passed the ToM test on the second level of false belief (Bowler, 1992). This theory has finally been ruled out to explain 100 percent of ASC cases.

Another of the most widespread theories, the Weak Central Coherence (WCC) claims that people with ASC are characterized by a weakness of lack of global consistency. This means that these individuals process information focusing on details or parts. Thus,

a person with ASC, rather than understanding the abstraction of the concept "bicycle," focuses on the details and parts that make up the object (Happe, 2005). However, this theory cannot cover the whole autistic spectrum, as people with Asperger syndrome and high functioning ASC people are able to grasp complex abstractions, build structures and develop concepts around objects.

As a response to this theory, Simon Baron-Cohen (2009) attempts to construct a theory of autism from a positive perspective, instead of focusing on the shortcomings of this syndrome, seeks specific features of autism that might help people with ASC develop strategies to better understand the world. His hypothesis claims that people with ASC, even non-verbal individuals, are not lost into details, as the WCC theory claims, but rather use these ritual and repetitive behaviors to look for patterns (structures) that allow them to establish a connection with the world surrounding. This model of thinking is defined as systemic:

> Strong systemizing is a way of explaining the non- social features of autism: narrow interests; repetitive behaviour; and resistance to change/need for sameness. This is because when one systemizes, it is best to keep everything constant, and to only vary one thing at a time. That way, one can see what might be causing what, and with repetition one can verify that one gets the very same pattern or sequence (if p, then q) every time, rendering the world predictable. (Simon Baron-Cohen, E. Ashwin, C. Ashwin, Tavassoli, & Chakrabarti, 2009, p. 1378).

The empathising-systemising (E-S) theory could explain how people with IQ levels below average, with serious problems of social communication and empathy; in contrast, have the ability to develop musical talents, or memorize large amounts of data (Crane, Linda Pring, Ryder, & Beate Hermelin, 2010).

Nevertheless, the E-S theory is very recent and therefore, it is in the process of checking and testing to prove if it is most suitable to explain the mystery which it is still autism. Cognitive theories that attempt to explain autism from a holistic perspective, that is, attempting to describe with one single question all cases in all stages of the life of a person with autism, have failed. It is important to understand that each different theory sheds light on a new aspect towards understanding ASC. With no consensus on the causes or innate unique characteristics of the syndrome, it is essential from a pragmatic perspective to approach ASC from education. Since H. Asperger (1944), interventions related to the acquisition of social skills, independence and language have proved their capacity of improving the quality of life of people with ASC. An early diagnosis and an appropriate treatment at child age can be the fundamental for a person with ASC and an IQ over or equal 50, to be able to become independent. (Asperger, 1944-1991; Riviere, 2001; Peeters, 2008)

Of all the difficulties in the development of people with ASC, the objective of this thesis is to study in depth the acquisition of joint attention and social competence skills, both essential to improve the quality of life of people with ASC. In the next section, the two concepts and their importance in the life of people with ASC will be described.

- Joint Attention and Autism

The absence of joint attention is one of the more complex deficits and with more negative consequences in the development of children with ASC, since it affects areas such as language, play and social interactions. Joint attention is the ability to share with another person a common focus to objects, events and people. This involves the ability to obtain, maintain and shift attention. Joint attention serves as a referencing tool through the use of mutual gazes (focusing on the same object) and / or gestures of communication such as pointing, shaking his head, etc. Sharing attention on something, not only helps individuals communicate, but also helps in the development of social abilities, such as bonding, as well as taking into account the other person's point of view when making decisions. Finally, joint attention skills predict future language development (Strauman, 1994; Tomasello & Farrar, 1986). The more relevant variables of joint attention and the target behavior that are studied in the research are: eye contact with another person, pointing and follow-pointing.

For a person with autism, with deficits in joint attention, keeping direct eye contact with another person can become a great challenge. People with typical development share large quantities of non-verbal emotions through eye contact interaction. If a person with autism is unable to interpret this information or, in its most severe degree, to even keep direct visual contact with an object or a person, she is in a clear communicative disadvantage compared with a typically developing person. Not only that, but also when they have not developed the ability to point and show interest in an object, they tend to seek attention from an adult through yelling or, alternatively, they take the person to the object of interest. The lack of pointing skills isolates the child in their ability to seeking attention for their needs. There is evidence that the interventions with children with ASC with emphasis on developing non-verbal communication skills; help to improve and promote the development of language and social skills (Whalen, Schreibman, & Ingersoll, 2006). That is why the interventions focused on joint attention improvement in children with ASC are relevant in the pursuit of improving their quality of life.

- Social Competence in children with ASC

One of the most significant features of children with ASC is that they lack strategies to cope with social communication with peers. Even for those adults with autism who have developed a functional language similar to people with typical development (High Functional Autism and Asperger syndrome), understanding and maintaining social communication with peers can be frustrating because of the amount of non-verbal information that is transmitted during interaction. Not only this, their rigidity and lack of perspective on the other, important features in this population, makes social development much more difficult for people with ASC (Burke, Kraut, D. Williams, & Ave, 2010). For children in preschool age or with a cognitive capacity that does not allow any non-verbal communication, their social competences can be made explicit in the ability to initiate or join sequences of play with peers and respond positively to sequences of turn-taking (Mundy et al., 2003). The control of turn-taking skills is important as it helps the child wait and be attentive to the needs of others, thus enabling them to make decisions to interact. The anxiety generated by the absence of this variable on the behavior of a child with ASC, makes it difficult for the child to interact with their peers and to develop verbal language skills (Mundy, Sigman, Ungerer, & Sheran, 1986).

Successful interventions have been carried out, such as game therapy and music therapy, which have shown positive results with an impact on the life of the child in learning social competence and developing joint attention abilities. The aim of the next section is to describe the state of research in these fields, the reason for its relevance to the development of this study and the interventions in which these areas of intervention intersect with technology.

1.3 State of the Art

a) Music Therapy Applied to ASC

The appreciation of music, in the same way as language, requires a dedicated brain organization. This includes visual-spatial processing, memory, auditory and verbal processing. Thus, for example, musical processing of pitch and rhythm depend on a series of operations that involve right auditory cortex, while the extraction of musical time puts into work more widespread and bilateral neural networks (Isabelle Peretz & Zatorre, 2005). Even if a person suffers from mental retardation, this does not preclude their ability to enjoy music, or to develop a creative talent. People with ASC, even those with an IQ below 60, may be more able to develop musical language than verbal language.

In contrast to what one might think, people with ASC, can process affection to a musical stimulus, in comparison with the information associated to verbal language or social behavior (P Heaton et al., 1999). There is evidence that people with autism have better processing and pitch memory than typically developing people, this can be translated as a skill in the development of musically related tasks. (Pamela Heaton, 2003; Pamela Heaton, Beate, & Linda Pring, 1998; Isabelle Peretz, 2002) Therefore, it can be argued that people with ASC are prepared to develop musical skills and to become involved in activities where music is a means of communication.

For this research, Bruscia's Music Therapy concept is used. Music Therapy is "a systematic process of intervention where the therapist helps the client to promote health, using musical experiences and the relationships that develop through them as dynamic forces of change" (Bruscia, 1998, p. 20). Music is a means with a flexible and adaptable structure, allowing the generation of exchange spaces that can reach all sorts of people regardless of intellectual or educational level.

Juliette Alvin found three levels where music can positively impact the lives of people with ASC. Each level must be guided by the therapist, taking into consideration the patient's own timings, and at the same time avoiding forcing the search for short-term objectives. These three levels are:

1. Non-verbal communication: music can satisfy the needs for non-verbal communication.
2. Relationship with the environment: music can allow growing awareness around the music and human interaction.
3. Self-esteem: music may be used to strengthen self-esteem and turn into a means for personal creative expression (Alvin & Warwick, 1992).

When working with individuals with ASC, the main purpose is traditionally focused on the improvement in social interaction abilities. The variables associated to this improvement are eye contact, joint attention, establishing connection with another person, learning reciprocity and turn taking (Lopez, 2009). There are two work methodologies in music therapy that have been used with people with ASC:

1. 'Dialoguing' is a process where therapist and patient communicate through their musical play (Bruscia, 1987).
2. Musical 'frame working' where the therapist provides a functional musical structure where the child's musical play fits (T Wigram, 2004).

The structure, predictability and at the same time flexibility found in music, allow awareness of the needs and intentions of the other, generated from an interaction, for example taking turns with the instruments or by giving a shared meaning to the use of objects. The latter might help the person with ASC build a shared order of space and social interaction.

Far from what one might think, people with ASC tend to enjoy improvisational therapies. Nonetheless, in order to have a therapy with a positive influence in their learning of social skills, a structure from which they can start creating needs to be generated, thus encouraging their creative skills (T Wigram & C Gold, 2006). Studies conducted with improvisational music therapy show an improvement in the joint attention variables in preschool children. Kim, Wigram & Gold compare an intervention with game therapy following the Early Social Communication Scales (ESCS) protocol, with an improvisational music therapy intervention. The ten participants of the study were randomly assigned to each treatment. A group received improvisational music therapy sessions, and a second group received game therapy sessions, with a total of twelve sessions of thirty minutes. Each session is divided into two sections, one with a structure and the other one completely free. In both sessions, the same joint attention variables are measured (eye contact and turn-taking). The comparative results provide evidence that improvisational music therapy improves the acquisition of joint attention (Kim, Tony Wigram, & Christian Gold, 2008).

Music therapy applied to autism has a tradition of more than forty years. The majority of studies have been longitudinal case studies. Little research work has been carried out with large samples, or including follow up on the children's development outside of the music therapy, that is, evaluation of whether improvements in children have been replicated subsequently in other areas such at home or at school. Any intervention with a person with autism, because of the syndrome's own nature, requires a long-term adaptation of the child. Furthermore, the changes that occur during these periods are often difficult to measure, due to the complexity of the variables involved. The work with children with autism is such complex, music therapy follows the path of adapting to the child, with his or her own rhythms and emotional needs, as opposed to behavioral therapies in which structures, objectives and timeframes are imposed by the therapist. Music therapy, then, stands as a methodology flexible to the child. For this reason, even though music therapy has shown interesting results in a number of studies, it is difficult to replicate the methodology of the most interesting studies, or to even evaluate if only music therapy has been the trigger for the child improvement (Accordino, Comer, & Heller, 2007; C Gold, T Wigram, & Elefant, 2006; Simpson & Keen, n d).

b) Object Interaction and Therapy in ASC Children

Children's interaction with objects reflects an understanding of how these play a social role and / or function within the world around them. The manipulation of objects, the way objects are accessed and how attention is shared around them, positions the self and the object. Children with ASC have a different development regarding the use of objects. Not only is it a delay with respect to the acquisition of skills both functional and social, but also a qualitative difference in their relationship with them. Thus, for example, people with ASC have trouble in sorting and classifying objects. This delay in development can be overcome, by learning a posteriori, meaning that the learning will not be intuitive, but instead will need outside intervention. From a qualitative point of view, people with ASC tend to use objects in a ritual, repetitive way, without functional use and often obsessive. Additionally, they prefer an approach to objects with a predomination of exploration of through taste, smell and caress (Rowland & Schweigert, 2009; E. Williams, 2003). The relationship of typically developing children with objects, especially in the use of toys, plays an important role in the acquisition of social and cognitive skills. Understanding the development of children with ASC and their relationship with objects allows focusing the interventions around game therapy and toy use, which can help in the development of social skills.

The use of reward is present in most behavioral therapies focused on improving social skills in children with ASC. Although, these interventions show positive results, these improvements in behavior often have a short life. One of the most interesting interventions developed in the last ten years, related to the learning of social skills, is the work of Daniel Legoff. Legoff turns LEGO© sets into tools for group work, in children with Asperger syndrome and high functional ASC children (HFASC). This is a long-range study, conducted on a sample of 47 children for three years, where the sample was its own control group. Throughout these three years, children received 12 structured sessions where each participant had an assigned role directly aimed the construction of complex shapes. The sessions were composed of groups of 6 to 7 children, and were directed by the same researcher. The goal was to track the evolution of social competence, by measuring the following indicators: initiation of social contact with peers, duration of social interaction, decrease in autistic aloofness and rigidity. The results were positive, since it showed an improvement in social skills for all children outside the controlled playing space. Nevertheless, it is important to note that only the first variable improved in the first six sessions of intervention, whereas the remaining two variables needed a period of almost two years (Hendrix, Herk, Verhaegh, & Markopoulos, 2009; LeGoff, 2004a; Legoff & Sherman, 2006). The success of the LEGO© therapy has led to testing it in other interventions focused on the improvement of social skills, such as The Social Use of Language Programme (SULP). Unlike the spontaneity of the learning process with the LEGO© therapy, SULP is a highly hierarchical learning tool, with an inflexible curriculum. The results of these studies in a sample of twenty children with high functioning autism and Asperger syndrome give evidence of an improvement in autism-specific social interaction scores (Gilliam Autism Rating Scale) when the LEGO© therapy is applied for 18 weeks over SULP therapy (Owens, Granader, Humphrey, & Simon Baron-Cohen, 2008). It is important to note that both interventions were made with verbal ASC children. These results show evidence that interventions related to play, collaborative work and objects can generate an improvement in long-life acquisition of social competences.

c) Technology and Social Intervention with ASC Children

People with ASC make an extensive use of technology, as it becomes a filter that allows them the appropriation of the world from two levels. On one hand it allows sorting the stimuli, generating a structure that is easy to interpret; on the other hand, it becomes a perfect mediator that generates the lag required to interpret and communicate, given the speed of information they receive from people with typical development (Burke et al., 2010; el Kaliouby et al., 2006; Konstantinidis et al., 2009; Putnam et al., 2008). Interventions towards joint attention and social abilities improvement, have used successfully technologies such as video modeling, robots, tabletops, tangible user interfaces (TUI) and virtual reality, amongst others (Giusti, Zancanaro, Gal, & Weiss, 2011; Parsons & Mitchell, 2002; Robins & Dautenhahn, 2010; Robins, Dickerson, Stribling, & Dautenhahn, 2004).

Tangible user interfaces (TUI) are a branch of Human Computer Interface (HCI) technologies that allow manipulating and transforming digital information through the use of physical objects.

> Tangible Bits allows users to "grasp & manipulate" bits in the center of users' attention by coupling the bits with everyday physical objects and architectural surfaces. Tangible Bits also enables users to be aware of background bits at the periphery of human perception using ambient display media such as light, sound, airflow, and water movement in an augmented space. The goal of Tangible Bits is to bridge the gaps between both cyberspace and the physical environment, as well as the foreground and background of human activities. (Ishii & Ullmer, 1997, p. 1).

The TUIs as a technology have proved to be more accessible and intuitive for young children compared to other technologies. These can improve the learning process, as they are more entertaining, and also facilitate collaborative work processes. In the latter regard, TUIs allow sharing space between users, increasing the visibility of actions, enabling the possibility of monitoring other participant's work. Allowing multiple points of access to the interaction generates spaces for a more effective turn taking. TUIs focused for people with special needs may promote co-located cooperative work. (Boussemart & Giroux, 2007; Hornecker, 2011; Marshall, Rogers, & Hornecker, 2007)

- ### Tangible User Interfaces Applied to ASC

W. Farr has developed one of the most interesting studies regarding the use of tangible technologies in the improvement of social competences. In this study, two types of interventions are compared: LEGO© therapy and the use of a tangible and programmable toy called Topobo©. Topobo© is a 3D constructive assembly system with kinetic memory. Children can create dynamic biomorphic forms like animals and skeletons, and after that, assign them movements through manipulation, so that afterwards, these creatures can repeat the movements independently. The results of the study, with a sample of six ASC children and six children with typical development (TD), show that playing with TUI reduces solitary play sequences, facilitating

collaborative and associative play (Farr, Yuill, & Raffle, 2010; Solos, Parkes, & Ishii, 2004)

- Musical Tangible User Interface Applied to ASC

Within the musical technologies designed to help people with various disabilities, those that have been tested with ASC population will be reviewed. The Soundbeam, an invisible keyboard expanded, is an ultrasonic beam that sends sound messages each time the user moves the body or the fingers in the space. This technology has been tested as therapy in children with ASC for seven years, finding positive results in the area of social behavior and communication. The research was conducted through longitudinal case studies and no studies with large samples exist. (Ellis & Leeuwen, 2000)

The Music Cre8tor is an interactive music composition system controlled by motion sensors, specifically designed for children with disabilities. It is designed for 2 to 4 people to work simultaneously, and sound patterns are triggered by body motion. There are no studies with ASC children published, whereas it is a very configurable system that allows for a personalized therapy for each kind of disability (Rigler & Seldess, 2007).

The Mediated (A Multisensory Environment Design for an Interface between Autistic and Typical Expressiveness) is an interactive environment that generates real time stimuli (visual, aural and vibrotactile). This technology was designed for children with severe autism and no verbal communication. In a study with ninety ASC non-verbal children, the results show the children do not need external motivation to interact with the technology (N. Parés et al., 2005). Further studies around the acquisition of variables associated with social communication and creativity with non-verbal ASC children are pending.

2. METHODS

2.1 Design and Development Criteria and Strategies

a) The Reactable System

The Reactable is a collaborative musical instrument that enables the collective and intuitive creation of complex musical pieces. As a technology, it belongs to the group of TUI (Tangible user interfaces). Studies have shown the capacity for these types of tools to promote teamwork in children with typical development. The Reactable was conceived as an intuitive multiuser instrument, aimed for everyone, capable of allowing the construction of musical pieces in an almost immediate way. The system is a circular table top (see Fig. 2) where users can interact, both through direct contact with the table, and through objects called pucks (see Fig. 3) grouped in four categories: generators, sound effect (audio filters), controllers and global objects (see Fig. 4).

Fig. 2: The Reactable (TUI)

Fig. 3: Reactable pucks

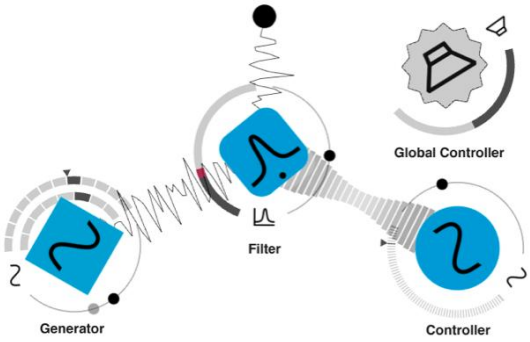

Fig. 4: Reactable puck categories

Each object category has a set of symbols assigned, that the Reactivision software can read. For the system to be activated, one of the objects must be placed on the table. The software reads the symbol by means of an infrared camera, and depending on the position or proximity to other neighboring pucks, it activates the function of a determinate symbol (see Fig. 5).

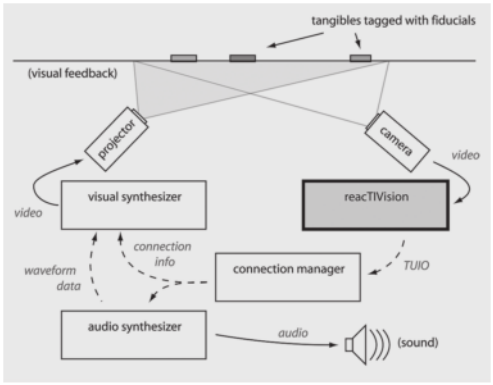

Fig. 5: Reactable software

b) The Hypotheses

This thesis was designed to test the following hypotheses:

Ha: The collaborative use of the Reactable improves ASC children's joint attention.

H0: The improvement of ASC children's joint attention is not related with the collaborative use of the Reactable.

Ha: The collaborative use of the Reactable improves ASC children's social skills.

H0: The improvement of ASC children's social skills is not related with the collaborative use of the Reactable.

To test the hypothesis that the collaborative use of the Reactable improves the ASC children's social skills and joint attention, the present study used a set of variables to measure and identify different aspects of both variable acquisitions.

c) Measures

The Early Social Communication Scales (ESCS) (Mundy et al., 2003) and Legoff (LeGoff, 2004b) parameters for his studies about game and social communication were used in ABA measurement. To validate these two hypotheses, composite variables were measured: joint attention and social interaction. These variables were formed by a group of target behaviors. The behavior of each individual sample was analyzed during the experiment, in which the duration and frequency of target behaviors were measured. These target behaviors are important variables for the future development of joint attention and social interaction in the child.

The Early Social-Communication Scales (ESCS) is a structured measure for non-verbal communication skills. This clinical tool uses three categories to classify the skills of a non-verbal child:

1. Joint Attention Behavior: refers to the child's non-verbal capabilities to share awareness around an object or event.
2. Behavioral Requests: refers to skills in using non-verbal behaviors such as asking for help to obtain objects or events.
3. Social Interaction Behaviors: refers to the capacity of the child to engage in turn-taking interactions with others.

For the purpose of this research, the definition of the variables was based on the measurement of joint attention and Social interaction behavior. Thus, to verify the validity of hypothesis 1, the collaborative use of the Reactable improves ASC children's joint attention, the composite variable joint attention was created (Table 2). The target behaviors that were used to measure joint attention composite variable were:

Initiation of Joint Attention (IJA):
Low-level behavior (IJAL)

1. **Eye contact**:
    a. **Description**: The child has to make eye contact and alternate it between the Reactable and the therapist.
    b. **Type of measure:** Frequency and duration.

High-level behavior (IJAH)

1. **Pointing**:
    a. **Description**: The child must point and make gestures that indicate the child's intention to share the experience of the Reactable play with the therapist.
    b. **Type of measure:** Frequency.

Responding to Joint Attention bids (RJA):

1. **Respond to pointing**:
    a. **Description**: RJA refers to the number of times (frequency) in which the child follows the therapist's pointing gesture correctly.
    b. **Type of measure:** Frequency

Composite Variables		Target behavior	Description	Measure
Joint Attention	Initiating Joint Attention (IJA)	Eye contact	Eye contact and alternate it between the Reactable and the therapist	Frequency and duration
		Pointing	Point and make gestures that indicate the child's intention to share the experience	Frequency
	Responding to Joint Attention (RJA)	Respond to pointing	Follow the therapist's pointing gesture correctly.	Frequency

Table 2: Coding scheme for joint attention composite variable

To verify the validity of hypothesis 2, the collaborative use of the Reactable improves ASC children's social skills, the composite variable social interaction was created. The target behavior that was measured for Social interaction ability was based on Initiating Social Interaction (ISI) (LeGoff, 2004b) and Responding to Social Interaction (RSI) (Mundy et al., 2003). For the scope of this research, Legoff's description of Self-initiated social contact was used. In Legoff's research with game therapy and Social competence (SC) in ASC children, the results gave evidence about an improvement in social skills in both itineraries of the therapy: the long path (12 sessions) and the short one (6 sessions). Nevertheless, for the short LEGO(c) therapy path the only variable confirmed was Self-initiated social contact, and this is the reason for this study was included. Finally for ESCS, RSI variable is related to the tendency to initialize turn-taking sequences (Table 3). The target behaviors that were measured for Social interaction composite variable were:

Initiating Social Interaction (ISI):

1. **Self-initiated social contact:**
    a. **Description:** It involves either verbal or nonverbal communication or a clear attempt to communicate with the therapist. It is not a reciprocal response to the therapist's approach.
    a. **Type of measure**: Frequency

Responding to Social Interaction (RSI)

2. **Turn taking:**
    a. **Description**: An event involving a sequence of playing turns alternating between the child and the therapist. They only will be taken into account if the kid needs no help with his/her turn taking.
    b. **Type of measure:** Frequency

Composite Variables		Target behavior	Description	Measure
Social Interaction	Initiating Social Interaction (ISI)	Self-initiated social contact	Involves either verbal or nonverbal communication or a clear attempt to communicate with the therapist.	Frequency
	Responding to Social Interaction (RSI)	Turn taking	The kid needs no help with his/her turn taking	Frequency

Table 3: Coding scheme for Social interaction composite variable

2.2 Experimental Design and Set-Up

a) Participants

Eight boys and two girls aged between 6 and 11 years with an ASC diagnosis, who had no previous experience in music therapy or play therapy, were recruited over four months from ER-Niu school, AMPANS and Centro CIEL in Barcelona and Manresa cities (Spain). Parents gave informed consent for their children to be involved in the study. One of the children, Sergi, has not been taken into account in the Reactable session analysis, because he suffers from psychosis, which did not allow him to enjoy the sessions. Therefore, the total sample analyzed was n= 9 (see Fig. 6). The participants had a mean chronological age of 9 years old (age from 5- 11 years old) when they entered the trials. Six children were non-speaking, another three were verbal with a varying degree of language skills.

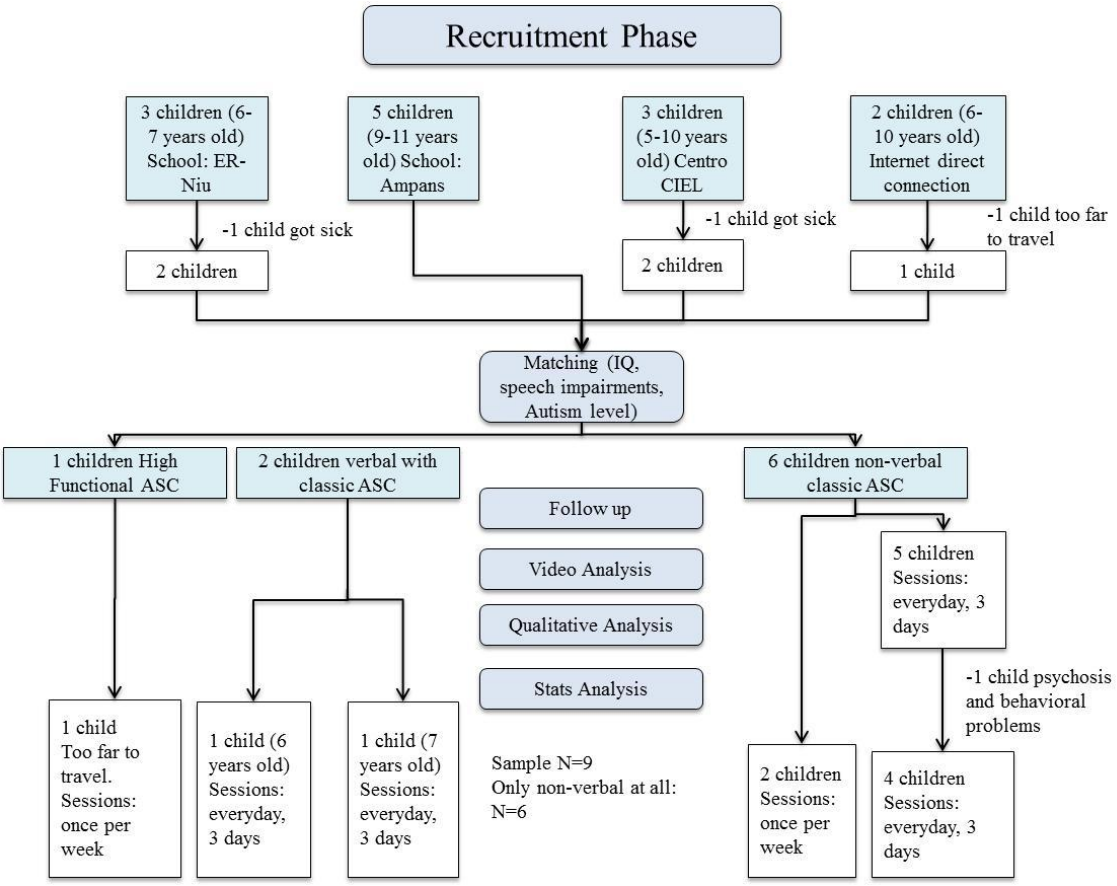

Fig. 6: Recruitment phase for n = 9

b) Procedure

A Single subject design was used to validate the two hypotheses. The type of design was ABA (Basic Withdrawal). A repeated measures comparison design within subjects was used. The no-intervention baseline phase (A) was 20 minutes of free play session in their regular school space. The intervention phase (B) was three sessions guided by a therapist with the Reactable. The frequency of the sessions was once per day for seven participants, whereas the three remain children had one session per week. This last group was only able to participate if the intervention once a week, as that was their frequency of assistance to their own educational center. The no-intervention withdrawal phase (A) was 20 minutes of free play session with the same condition than the no-intervention baseline (see Fig. 7). Each child had a previous personal ten-minutes training session with the Reactable. This session was not taken into account for the results, due to the main characteristics of Autism: changes, new tasks or spaces can turn out to be very stressful to the child, and each child needs special personalized attention in the approach to new experiences. During the sessions, each child worked with their own personal therapist; in all cases, these had been working with the children enough time for participants to feel comfortable. To avoid subjective interference, no session was directed by the researcher. Each therapist had received a twenty-minutes training session with the Reactable prior to the experiments. In total, eight graduated therapists and two professional graduated musicians took part in the research team.

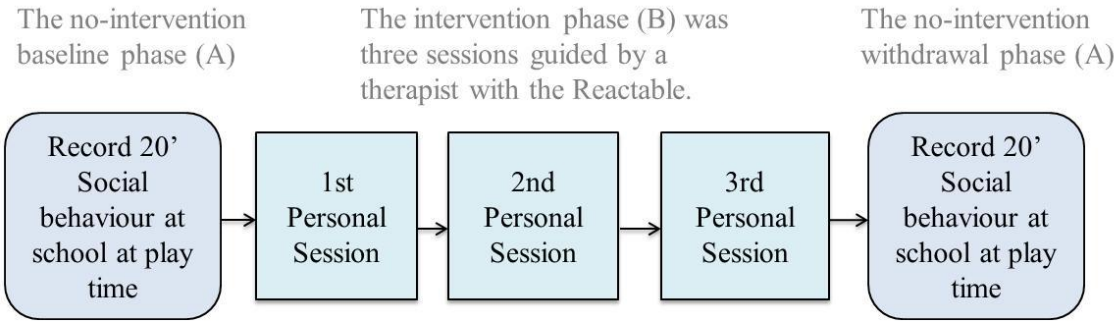

Fig. 7: Sessions conducted for each subject

c) Sessions

Play sessions for six children were conducted during one week, on a daily frequency. The remaining three children participated during one month, with sessions every week. Standardized instructions were given across the three sessions, with the same structure were conducted for each subject. Each session was programmed for a maximum time of thirty minutes. Eight participants had an ASD with IQ impairments, ranging from not speaking at all, to a low level of oral functional communication. For these participants, the time of the session was flexible, in the sense that if a child started suffering an anxiety crisis, the therapist then ended the session. The mean session duration per child was 20.89 minutes. The structure of the sessions was the following (see Fig. 8):

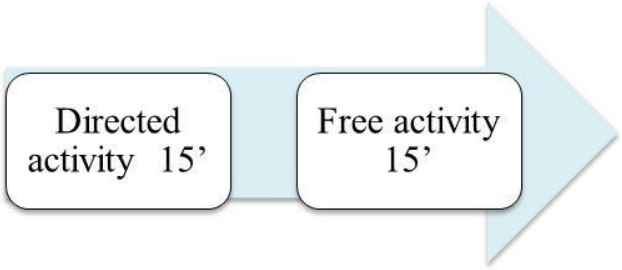

Fig. 8: Session structure

- Directed activity: The first fifteen minutes were guided by the therapist. The therapist gave instructions regarding turn-taking and interaction with the Reactable. Her role was to define flexible objectives around takings decision for music creation, and additionally give orders such as "now we work together", "it is your turn", "choose your piece".

- Free activity: the session remaining time was free time for the participant to explore and initialize interaction with the therapist. In this section, the therapist works as a facilitator, helping the child only when it is needed.

d) Musical Material

Two professional musicians composed three songs for each session, which were randomly assigned to each child. The songs were separated into organized loop pieces: melody, glitches, cartoon sounds, percussions, and bass. Those loops were assigned to

the four Reactable loop objects. Eight of the nine children only worked with four pieces (loop objects). To avoid the combination of the pieces resulting in an out of tone melody, the loops were composed in major key (C), which would ensure the overall effect to be eclectic while also pleasant. The samples consisted of various melodic patterns from a variety of ethnic and orchestral instruments. Each loop was chosen for its distinctive phrasing, and the ability to blend pleasantly with any other given loop/loops. All loops were 120bpm, which was considered an appropriately lively tempo in order to stimulate interest in the given tasks. Annex II, music section, includes the list of loops that were used during the sessions. The three songs created especially for the experiment are available at: http://www.villafuerte.info/tesis/Anexos/SoundFiles

2.3 Procedures Used to Obtain Data and Results

All sessions were video-recorded and stored on MiniDV tapes. Eighteen hours were recorded and one hundred per cent of the video material was subjected to detailed analysis.

a) Quantitative Tools

VCode software was used for video coding (see Fig. 9), with a coding scheme shown in Table 2 and Table 3. This software was specially designed for video coding and has been previously tested in studies with non-verbal children with ASC (Hailpern, Karahalios, & Jim Halle, 2009; Hailpern, Karahalios, James Halle, Dethorne, & Coletto, 2009). For our research, two researchers analyzed the target behaviors related with joint attention and social interaction. A total of 108 hours of video analysis (18 h recorded x 6 h analysis) were carried out by each video coder. Mundy and Legoff's protocols for defining what mean the target behaviors and measure definition were used (LeGoff, 2004a; Mundy et al., 2003).

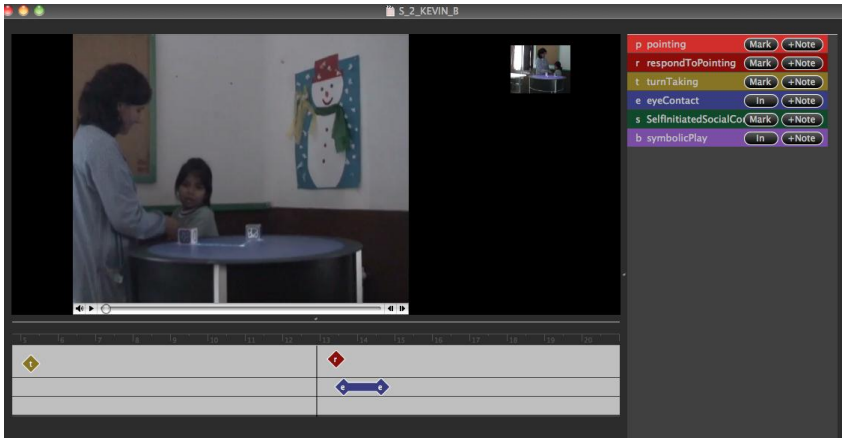

Fig. 9: VCode Interface

b) Qualitative Tools

In addition to the video material recorded for statistical analysis, this research used qualitative methodological tools. The objectives for the use of this tool were:

1. Gather qualitative information on the children's behavior to analyze outliers: information relating to the difficulties in learning new tasks, data on possible random behavior around work with the Reactable, information about their communication needs with others and their ability to explore objects.

2. Identify behaviors unrelated to the study's target behaviors that could nevertheless provide information for future studies about communication in non-verbal subjects.

To achieve these objectives, the following tools were used:

1. Fieldwork (Ethnography): Extra information was coded in video analysis (about speaking or non-verbal communication when the child needed help, felt frustrated or was enjoying the Reactable).

2. In-depth interviewing: Extra information about children was collected through an interview with their own therapist.

3. RESULTS

The totality of the recorded material was analyzed in order to elaborate the research results. Each subject went through a total of five sessions, two sessions of social play in a family and peer environment (SB – session baseline and SW – session withdrawal) and three intervention sessions with the Reactable (T1, T2 and T3). Five video pieces were recorded for each subject. With a sample of nine subjects, a total of 45 pieces were analyzed with VCode software. The analysis was carried out by two raters. The results of the statistical analysis and values for inter-rater agreement are reported in the quantitative analysis section. In addition to the data collected through video analysis and subsequent statistical tests, 9 interviews were conducted with the children's tutors, recording a total of X minutes. Additionally, the primary observer took notes on the behavior of the sample during the experiments. The results of the five children with more dissimilar behaviors are reported in the single subject analysis section.

3.1 Quantitative Analysis

Analyses for composite variables (joint attention, social interaction), as well as for the individual variables, were conducted for all subjects and for the non-verbal subjects group. The analysis was based on the data gathered by the primary observer, although inter-rater reliability tests were carried out to compare the measurements of both observers. Two separate tests were conducted for each group and target behavior: intervention sessions analysis (session 1, session 2 and session 3), and baseline vs. withdrawal comparison.

Shapiro-Wilk tests were conducted to evaluate normality for each combination of session and variable. Repeated measures analysis of variance tests were conducted for intervention sessions in which data was found normally distributed, whereas Friedman tests were conducted for intervention sessions with non-normal distributions. Baseline vs. withdrawal sessions were compared with Wilcoxon signed-rank tests, as the data was not normally distributed.

a) Joint Attention

The objective of measuring the composite variable joint attention is to verify the validity of the first hypothesis:

Ha: The collaborative use of the Reactable improves children with ASC´s joint attention.

The improvement of joint attention, calculated as the sum of eye contact frequency, pointing and respond to pointing, was tested for all 9 subjects, and separately for the 6 non-verbal subjects.

- All Subjects

Reactable sessions analysis
A Friedman test was conducted to evaluate the effect of the Reactable sessions (session 1: *Mdn* = 25.33, session 2: *Mdn* = 37.94, session 3: *Mdn* = 76.01) on joint attention for all subjects (N = 9). The test was not significant χ^2 (2, N = 9) = 2.89, p = .236, indicating the median for joint attention did not differ significantly among sessions.

Baseline vs. withdrawal
A Wilcoxon signed-ranks test was conducted to evaluate the difference in medians for joint attention between baseline (*Mdn* = 16.00) and withdrawal (*Mdn* = 13.14) sessions for all subjects (N = 9). The test was not significant, Z = -0.14, p = .889, indicating the median for joint attention did not differ significantly among sessions.

These results indicate that **Ha hypothesis is rejected**, and hence according to the tests, the improvement of ASC children's joint attention is not related with the collaborative use of the Reactable.

- Non-Verbal Subjects

Reactable sessions analysis
An ANOVA repeated measures was conducted to evaluate the effect of the collaborative use of the Reactable on joint attention for non-verbal subjects (N = 6) (session 1: M = 59.89, SD = 59.22, session 2: M = 59.26, SD = 40.55, session 3: M = 84.58, SD = 50.14). The test was not significant, $F(2,10) = 1.40$, p = .292, indicating the mean values for joint attention did not increase significantly with Reactable session time.

Baseline vs. withdrawal
A Wilcoxon signed-ranks test was conducted to evaluate the difference in medians for joint attention between baseline (*Mdn* = 16.08) and withdrawal (*Mdn* = 10.58) sessions for non-verbal subjects (N = 6). The test was not significant, Z = -0.524, p = .600, indicating the median for joint attention did not differ significantly among sessions.

These results indicate that **Ha hypothesis is rejected**, and hence according to the tests, the improvement of ASC children's joint attention is not related with the collaborative use of the Reactable.

- Results for First Hypothesis

Results for hypothesis: **The collaborative use of the Reactable improves children with ASC´s joint attention.**

Therefore, after the analysis of both groups (all subjects and non-verbal subjects), hypothesis “The collaborative use of the Reactable improves children with ASC´s joint attention for all subjects and non-verbal subjects” is rejected.

b) Social Interaction

The objective of measuring the composite variable social interaction is to verify the validity of the second hypothesis:

Ha: The collaborative use of the Reactable improves ASC children's social skills.

The improvement of social interaction, calculated as the sum of turn-taking and self-initiated social contact, was tested for all 9 subjects, and separately for the 6 non-verbal subjects.

- All Subjects

Reactable sessions analysis
An ANOVA repeated measures was conducted to evaluate the effect of the collaborative use of the Reactable on social interaction for all subjects. The test was significant, $F(2,16) = 5.36$, $p = .017$.

Post hoc tests using the Bonferroni correction revealed that **social interaction increased between session 1** ($M = 33.78$, $SD = 20.93$) **and session 3** ($M = 48.49$, $SD = 21.20$), $p = .046$. There was no significant difference in social interaction between sessions 1 and 2 (session 2: $M = 39.12$, $SD = 22.28$), $p = .824$, or between sessions 2 and 3, $p = .180$ (Fig. 10).

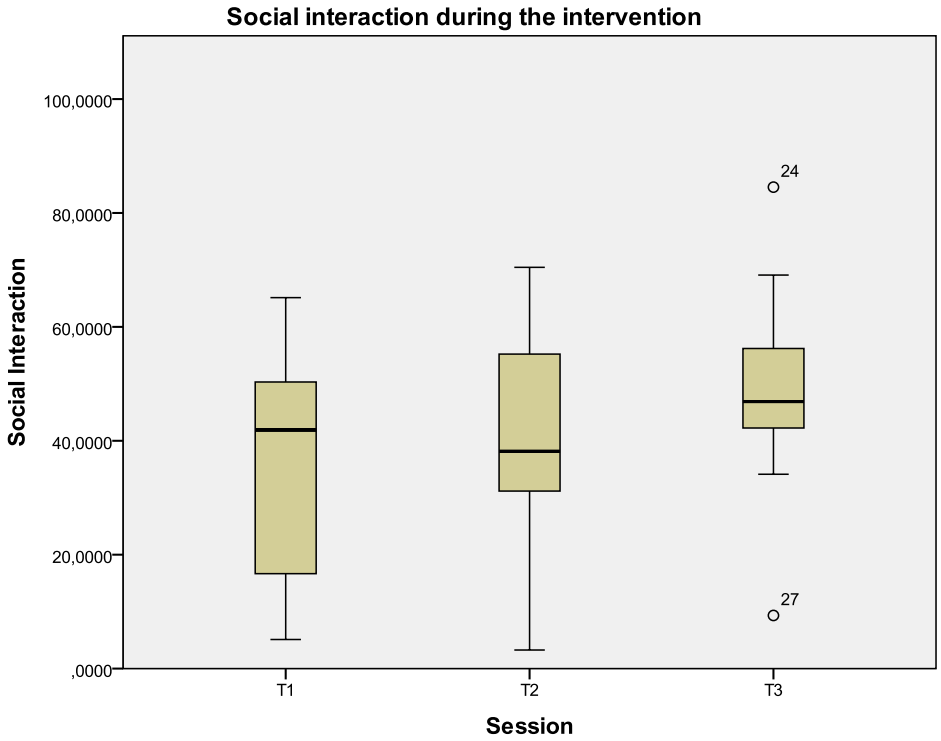

Fig. 10: Frequency of the composite variable social interaction for all subjects.

These results indicate that **Ha hypothesis is confirmed**: the collaborative use of the Reactable improves ASC children's social skills for all subjects within the Reactable session.

Baseline vs. withdrawal

A Wilcoxon signed-ranks test was conducted to evaluate the difference in medians for social interaction between baseline (*Mdn* = 6.00) and withdrawal (*Mdn* = 4.67) sessions for all subjects. The test was not significant, $Z = -0.77$, $p = .441$, indicating the median for social interaction did not differ significantly between baseline and withdrawal sessions.

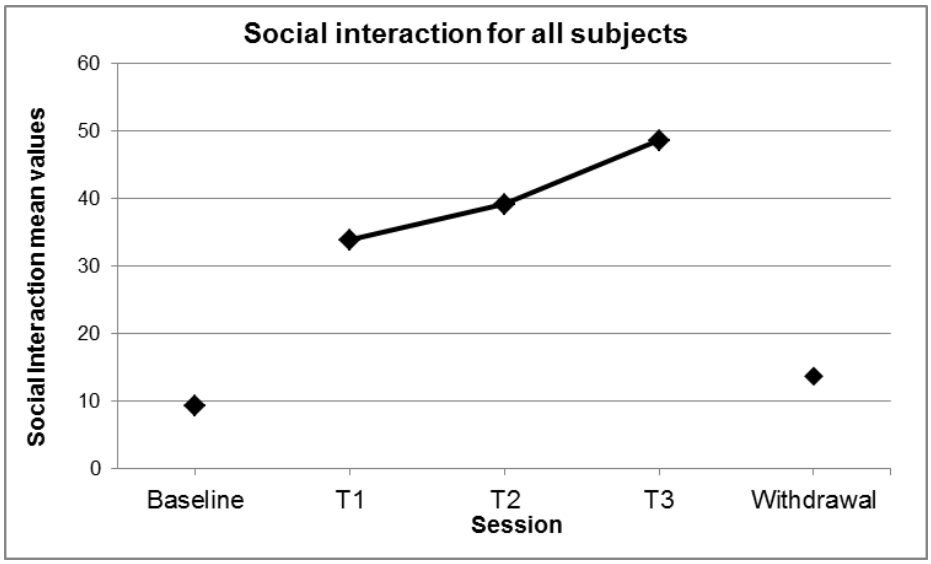

Fig. 11: Frequency for social interaction variable, comparing SB and SW vs. Reactable sessions, N = 9

- Non-Verbal Subjects

Reactable sessions analysis

An ANOVA repeated measures was conducted to evaluate the effect of the collaborative use of the Reactable on social interaction for non-verbal subjects. The test **results show marginal significance**, $F(2,10) = 3.31$, $p = .079$. The mean values obtained for each session are: session 1 ($M = 30.05$, $SD = 20.40$), session 2 ($M = 32.49$, $SD = 23.84$) and session 3 ($M = 43.78$, $SD = 20.59$). Note that the sample in this case includes only 6 subjects, which could mean the sample is too small to obtain statistical significance at the $p < .05$ level.

Post hoc tests using the Bonferroni correction revealed that the mean social interaction values did not differ significantly between sessions ($p = 1$ for sessions 1 and 2, $p = .24$ for sessions 1 and 3, $p = .24$ for sessions 2 and 3).

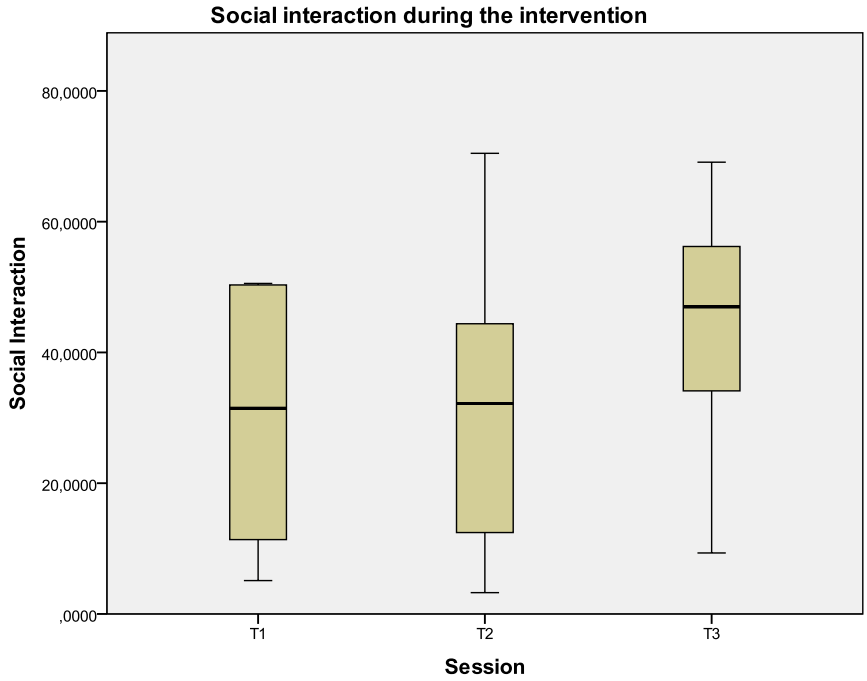

Fig. 12: Frequency of the composite variable social interaction for non-verbal subjects.

Baseline vs. withdrawal

A Wilcoxon signed-ranks test was conducted to evaluate the difference in medians for social interaction between baseline (*Mdn* = 2.09) and withdrawal (*Mdn* = 3.45) sessions for non-verbal subjects. The test was not significant, $Z = -0.524$, $p = .600$, indicating the median for social interaction did not differ significantly between baseline and withdrawal sessions.

- Results for Second Hypothesis

Results for hypothesis 2: The collaborative use of the Reactable improves ASC children's social skill, is confirmed only for all subjects group and inside the Reactable intervention.

c) The Turn-Taking Target Behavior

Individual variable analyses were conducted for the Reactable sessions, and for baseline vs. withdrawal comparison. The only individual variable that presented statistically significant positive results was turn-taking.

- All Subjects

Reactable sessions analysis

An ANOVA repeated measures was conducted to evaluate the effect of the collaborative use of the Reactable on turn-taking for all subjects. The test was significant, $F(2,16) = 7.16$, $p = .006$.

Pairwise comparison post hoc tests with Bonferroni correction were conducted. **Turn-taking increased from session 1** (*M* = 28.76, *SD* = 16.80) **to session 3** (*M* = 42.69, *SD*

= 16.59), p = .047. Turn-taking increased as well **from session 2** (M = 32.18, SD = 16.61) **to session 3** (M = 42.69, SD = 16.59), p = .019. There was no significant increase from session 1 to session 2.

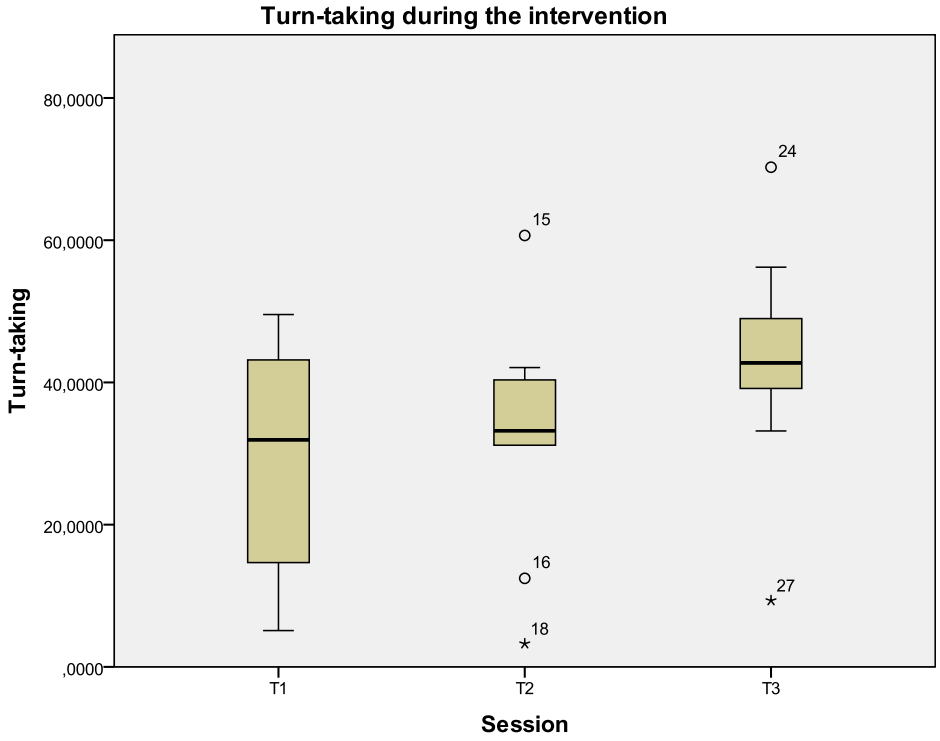

Fig. 13: Frequency of the turn-taking target behavior for all subjects.

Therefore, the increment between session 1 and session 3 is significance with p = .047 and between session 2 and session 3 with p = .019

Baseline vs. withdrawal

A Wilcoxon signed-ranks test was conducted to evaluate the difference in medians for turn-taking between baseline (Mdn = 1.00) and withdrawal (Mdn = 0.00) sessions for all subjects. The test was not significant, Z = -0.21, p = .833, indicating the median for turn-taking did not differ significantly between baseline and withdrawal sessions. See Fig. 14 for the increase of turn-taking during the Reactable sessions, compared to the baseline and withdrawal sessions.

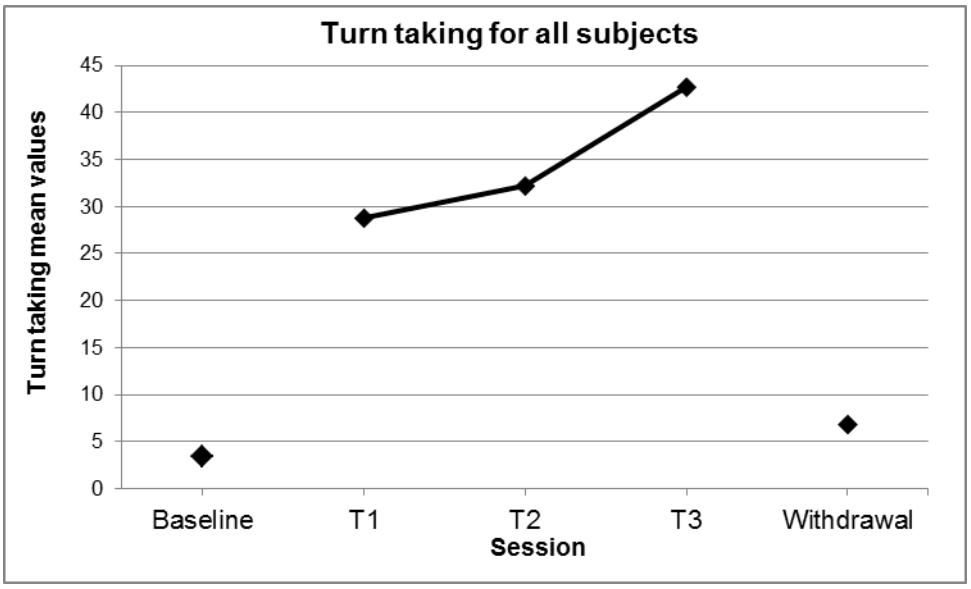

Fig. 14: Evolution of frequency between SB and SW vs. the Reactable sessions

- Non-Verbal Subjects

Reactable sessions analysis

An ANOVA repeated measures were conducted to evaluate the effect of the collaborative use of the Reactable on turn-taking for non-verbal subjects. The test **results show marginal significance**, $F(2,10) = 3.75$, $p = .061$. The mean values obtained for each session are: session 1 ($M = 26.59$, $SD = 17.83$), session 2 ($M = 26.04$, $SD = 14.86$) and session 3 ($M = 38.27$, $SD = 16.25$). Note that the sample in this case includes only 6 subjects, which could mean the sample is too small to obtain statistical significance at the $p < .05$ level.

Pairwise comparison post hoc tests with Bonferroni correction were conducted. **Turn-taking increased from session 2** ($M = 26.04$, $SD = 14.86$) **to session 3** ($M = 38.27$, $SD = 16.25$) **with marginal significance**, $p = .082$. There was no significant difference from session 1 to session 2, $p = 1$, or session 1 to session 3, $p = .336$.

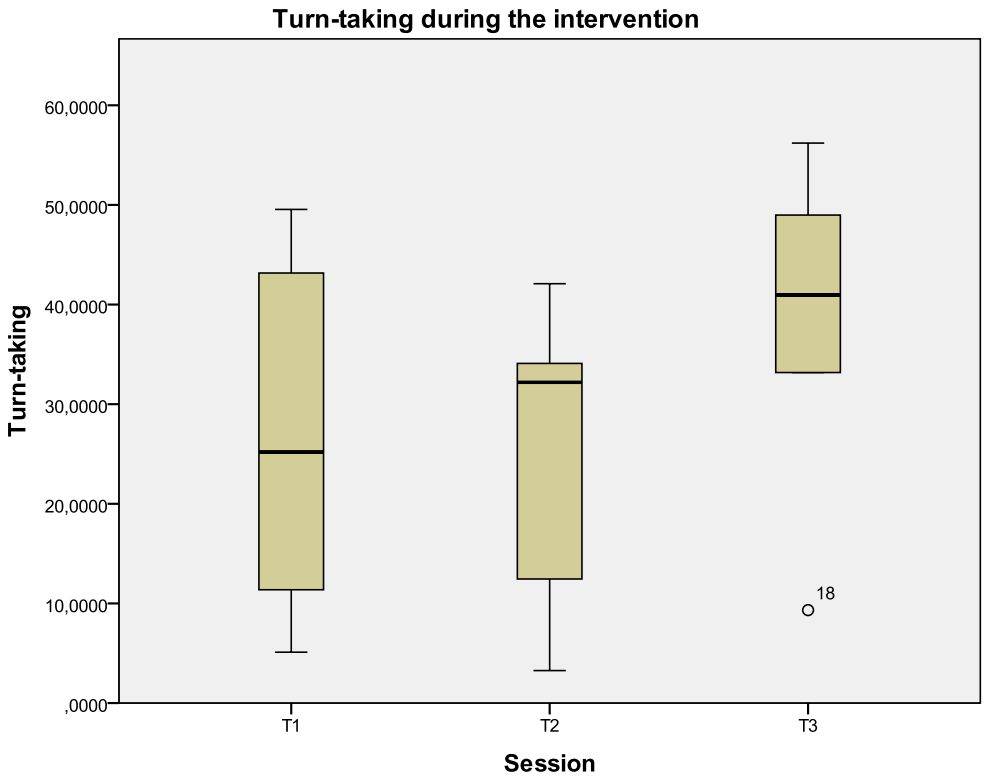

Fig. 15: Frequency of the turn-taking target behavior for n=6 inside the Reactable sessions

Baseline vs. withdrawal

A Wilcoxon signed-ranks test was conducted to evaluate the difference in medians for turn-taking between baseline (*Mdn* = 1.59) and withdrawal (*Mdn* = 1.00) sessions for non-verbal subjects. The test was not significant, Z = -0.542, p = .588, indicating the median for turn-taking did not differ significantly between baseline and withdrawal sessions.

Thus, we can report that the acquisition of the target behavior improves during Reactable sessions for all subjects with p = .019, and for non-verbal subjects, the increase between sessions is marginally significant with p = .082.

The complete data and tests for all variables can be found in Annex I.

d) Inter-Rater Agreement

Intraclass correlation coefficients (ICC) were used to determine levels of agreement in perception of behavior between the two raters (primary and secondary), who analyzed all video-recorded sessions. ICC tests were conducted for each target behavior, using the two-way random effects model single measure reliability (agreement), ICC (2,1) (Cicchetti & Rourke, 2004).

- Social Interaction Variables

For **turn-taking**, the level of agreement was found to be good during the Reactable sessions (ICC level 0.69), and excellent for baseline and withdrawal sessions (0.91). For **self-initiated social contact**, the level of agreement was found to be good during the Reactable sessions (0.63), and fair for baseline and withdrawal sessions (0.42).

- Joint Attention Variables

For **eye-contact** frequency, the level of agreement was found to be excellent during the Reactable sessions (0.95), and fair for baseline and withdrawal sessions (0.46). For **pointing**, the level of agreement was found to be poor during the Reactable sessions (ICC level 0.21), and good for baseline and withdrawal sessions (0.63). For **respond-to-pointing**, the level of agreement was found to be fair during the Reactable sessions (ICC level 0.44), and very poor for baseline and withdrawal sessions (-0.13).

3.2 Single Subject Results

a) Subject 1: S1 (11 years old)

S1 has ASC and is fully non-verbal. Even if she is learning to use the word "Yes", she has no functional or symbolic language that allows her to communicate. Tutors consider S1 to have the cognitive capacities to develop some sort of communication; however, she is still in a learning process. S1 has not developed play skills with other children, and does not explore toys or people out of her own initiative. In the video analyzed during the initial play session (Fig. 16), S1 keeps working in solitary activities, without paying attention to any of the other two present children. Tutors report she suffers anxiety symptoms when facing random objects, turning the introduction of new activities unpredictable, and very often leading to self-injure. This makes teachers work very slowly with her, requiring extra time and resources to initiate any type of new activity.

Fig. 16: S1 is playing alone during the SB session

Interview with the therapist:
00:05:24
“She takes your hand, if she wants something that is very far, [...] if she wants to go to the bathroom”[...]
00:05:47

Always the same routine, the same behavior. When she can't do something she tries to do, that's when she starts hitting herself.[...]She doesn't even look at you, she doesn't point.
00:06:35
"What she verbalizes is the frustration."

During the interventions, S1 went from self-injuring out of anxiety, to enjoying the experience, by notably improving her joint attention and social interaction skills. In Fig. 17, significant improvements between session T1 and T3 during the Reactable intervention can be observed. The chart shows an evolution in turn-taking and self-initiated social contact (SISC) with a 22.63 % and 60.76 % improvement, respectively. On the other hand, in variables related with joint attention, the improvement exists only in the pointing variable (159 %). No improvement exists in respond-to-pointing, and a decrease in eye contact frequency was observed.

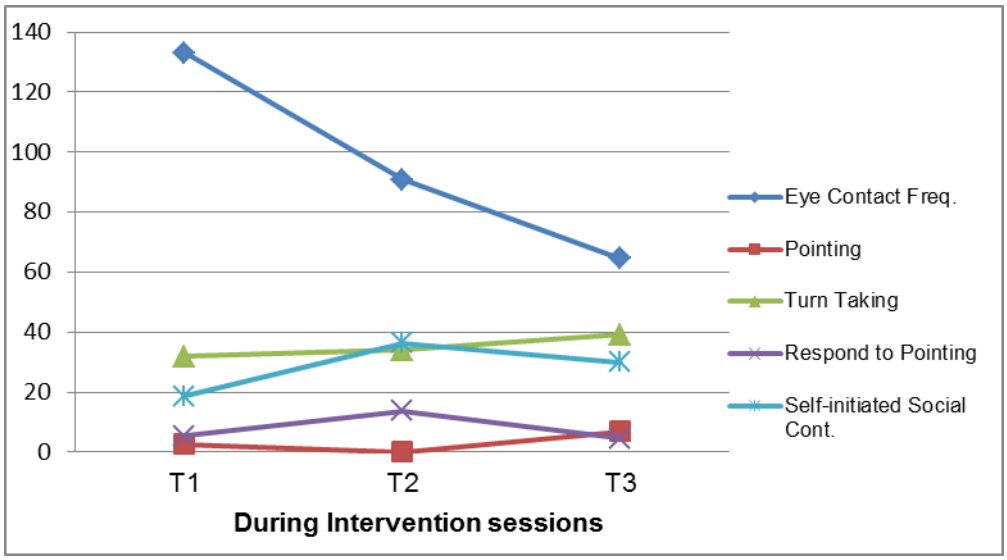

Fig. 17: Subject 1, improvement in all target behavior within the Reactable sessions

It is important to report that S1 uses eye contact during sessions 1 and 2, to show her anxiety to the therapist, just before she starts to self-injure (Fig. 18). This behavior was reduced from Session 1 to Session 3 inside the Reactable sessions, and S1 improved her social behavior with the Reactable. Another observed behavior is the continued use of objects in the following way: the child touches the pucks with her face, to later share them with the therapist (Fig. 19).

Fig. 18: S1 in an anxiety moment

Fig. 19: S1 during session 3 with the Reactable

Fig. 20 shows a 366 % improvement in SI variable during sessions out of the Reactable. It is interesting to note that after the analysis of the video material for post-intervention (SW), S1 shows a behavior previously undetected by therapists: the child initiates turn-taking sessions with another child through a musical toy. This behavior was also observed in two other subjects (S2 and S6), reviewed in subsequent sections of the report.

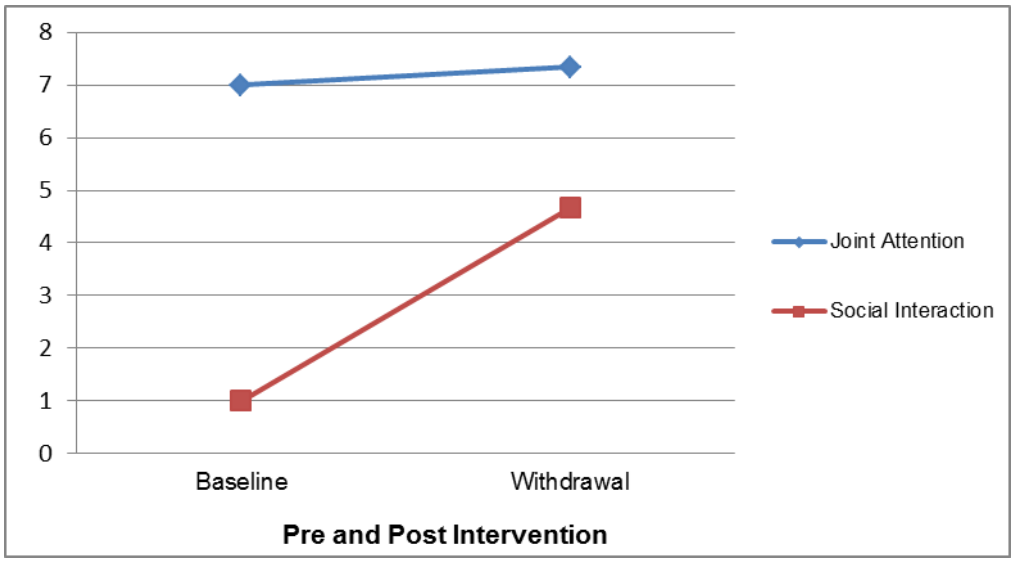

Fig. 20: Subject 1, joint attention and social interaction variables, in baseline vs. withdrawal

b) Subject 2: S2 (11 years old)

S2 has ASC and is fully non-verbal. She does not have functional nor symbolic language skills. During the pre-intervention session, she does not establish any kind of communication or contact with the other two children sharing her playing space. During the Reactable sessions, from the beginning, S2 does not show rejection to the new activity, and shows her intention to explore. The therapist explained during the interview that S2 has a high willingness to explore objects:

00:04:44
"She explores. She is curious about manipulative material, [use of] colorful objects"

00:06:56
"She likes plastic material. If she likes the object, she finds it hard to control herself. She seeks and explores things."

The results of the acquisition of JA and SI skills for S2 are very suggesting and encouraging, for an intervention with only three sessions, as she increases here eye contact frequency from 1 to 23, turn-taking in an 82.7 %, and pointing in a 133 %.

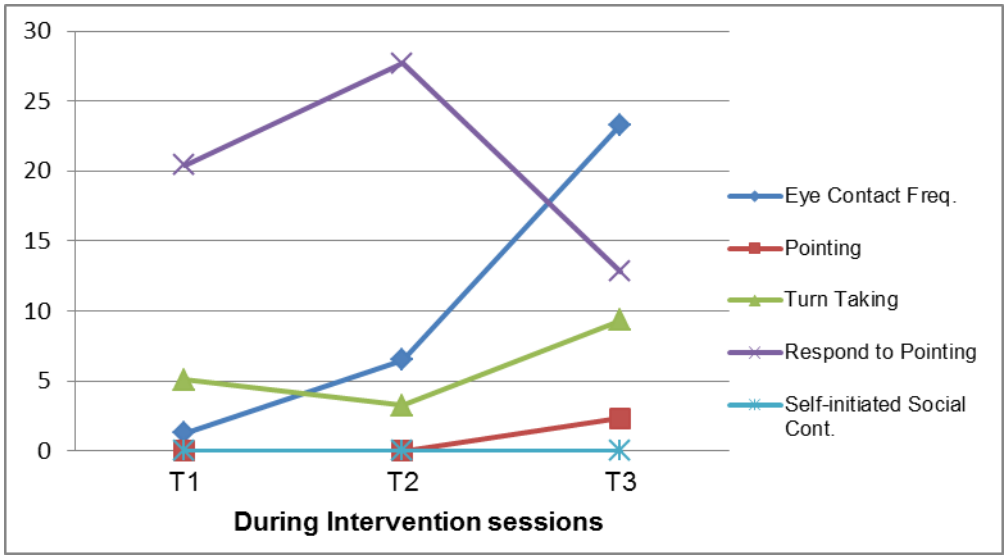

Fig. 21: Subject 2, improvement in all target behavior within the Reactable sessions

The video analysis shows that frequency of occurrence of target behavior for JA and SI variables is low compared to other children, however, the difference in behavior between sessions out of the Reactable play (SB and SW), and the Reactable intervention is high: 297 % increase for JA and 408 % increase for SI during the intervention sessions.
Fig. 22 shows the evolution of composite variables SI and JA during the Reactable sessions.

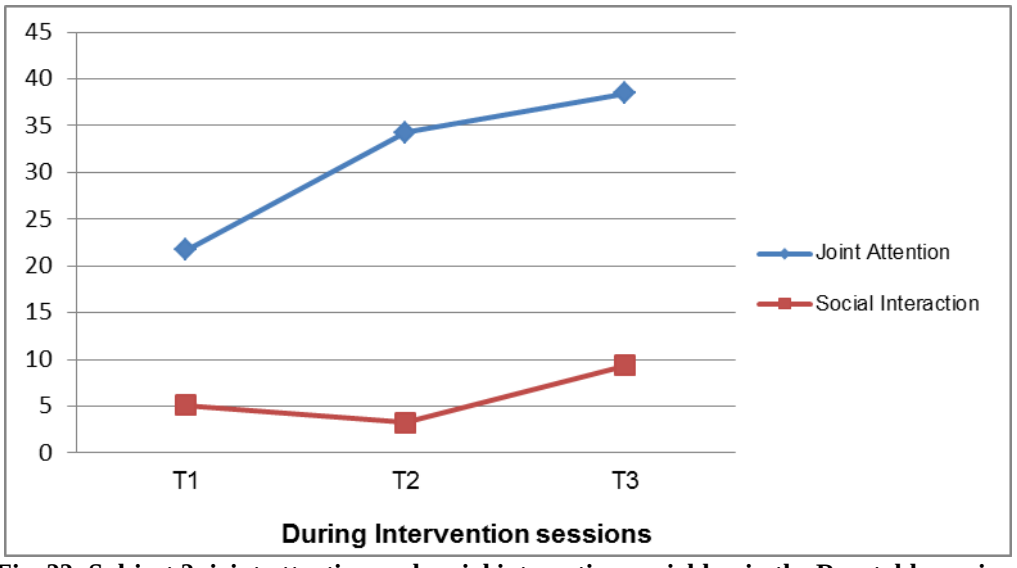

Fig. 22: Subject 2, joint attention and social interaction variables, in the Reactable sessions

The results of the pre and post intervention play sessions show an improvement of JA and SI in a 386% and 131% respectively (Fig. 23).

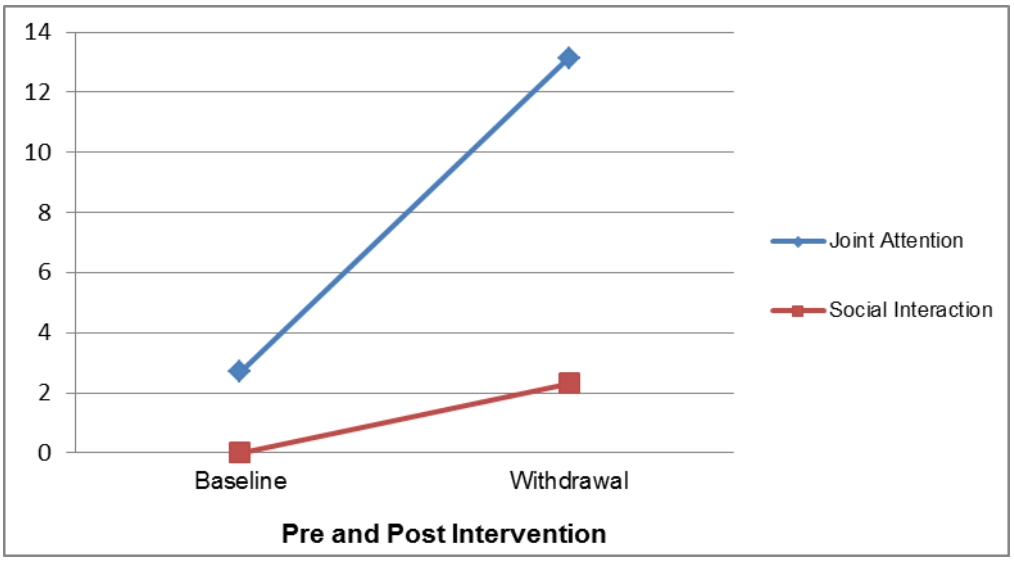

Fig. 23: Subject 2, joint attention and social interaction variables, in baseline vs. withdrawal

Additionally, a spontaneous turn-taking sequence with another child playing with a musical toy can be observed in the post intervention session (from 00:22:36, Fig. 24). This is a new and spontaneous behavior in the child, according to the therapists.

Fig. 24: S2 starts a turn-taking sequence with a peer

c) Subject 3: S3 (11 years old)

S3 has ASC and is fully non-verbal. He does not have functional language skills, nor does he elaborate any word, as his therapist reports, he only produces random sounds. He shows an obsessive behavior with objects, but his main problem is attention deficit. In tasks in which he shows interest, his therapist reports an average attention span of 3 minutes. Therapists have tried giving medication to help with this problem, but it has not been possible. S3 has a predilection and skills for computers, although he cannot use them as a means of communication. During the pre and post intervention sessions, he only improved in eye contact target behavior by 25%, (see Fig. 25). During these play sessions, S3 showed interest in other kids, however, he did not participate nor tried to establish communication. On the other hand, during the Reactable sessions, S3, such as S2, had a significant increase in almost all JA and SI variables: 330 % increase in turn-taking, 594 % in eye contact, an increase from 1 to 33 in pointing frequency, and even an improvement in respond-to-pointing frequency from 0.8 in the first session to 41.58 in the last session (see Fig. 26).

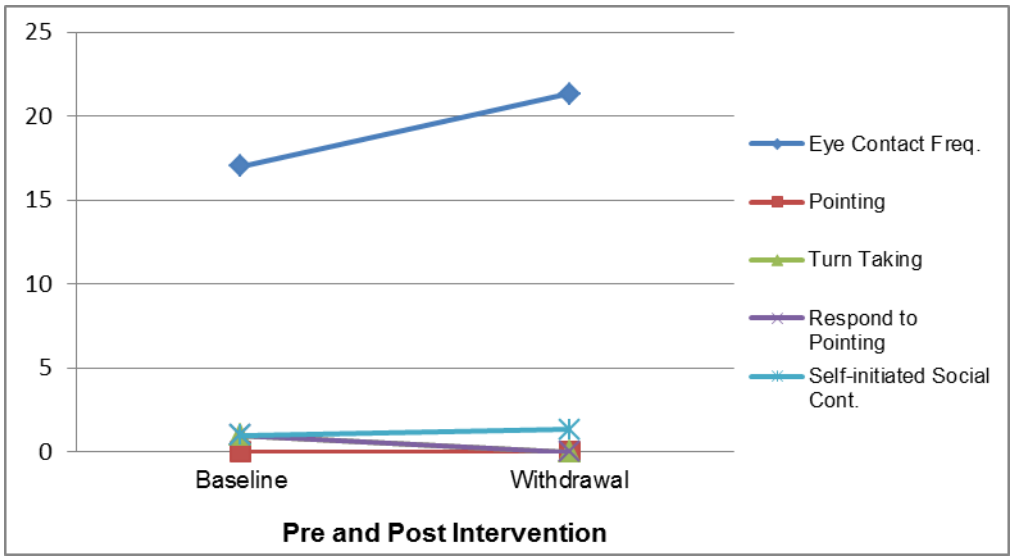

Fig. 25: Subject 3, improvement in all target behavior between baseline vs. withdrawal sessions

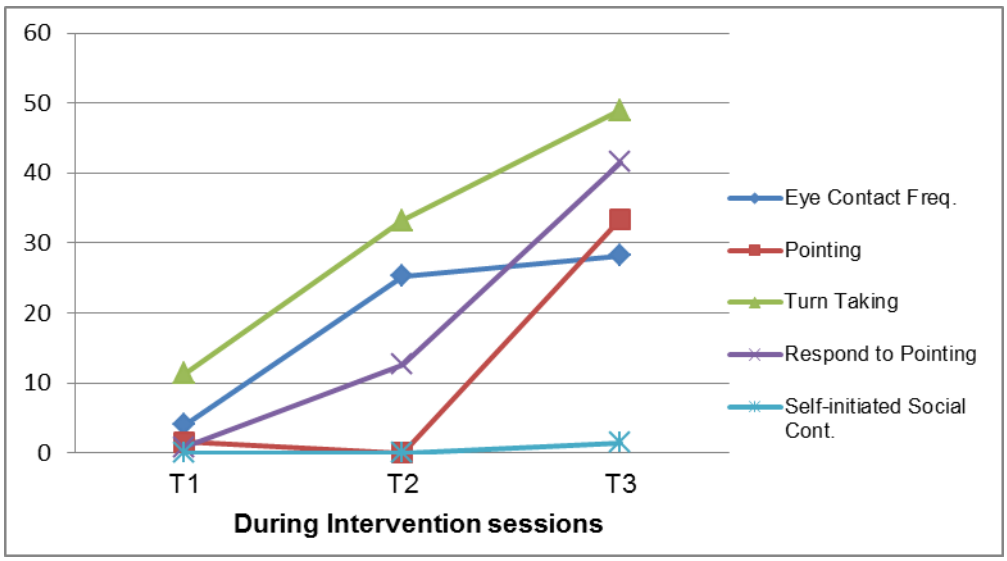

Fig. 26: Subject 3, improvement in all target behavior within the Reactable sessions

Although S3 has no verbal language skills, during the intervention with the Reactable he showed a non-verbal communication attempt with the therapist, in an effort to explain to the therapist the functioning of the Reactable. Such behavior can be observed in session 3, 00:22:50 (Fig. 27). S3's computer skills allowed him to understand the technical functioning of the Reactable: Fig. 28, from 00:04:41 in session 2 show how he explores the table, while observing the behavior of the laptop connected to it.

Fig. 27: S3 working with the Reactable

Fig. 28: S3 investigates how the Reactable works

Finally, the improvement in the composite variables of JA (1487 %) and SI (343 %) from session 1 to session 3 of the intervention is encouraging for future interventions (Fig. 29).

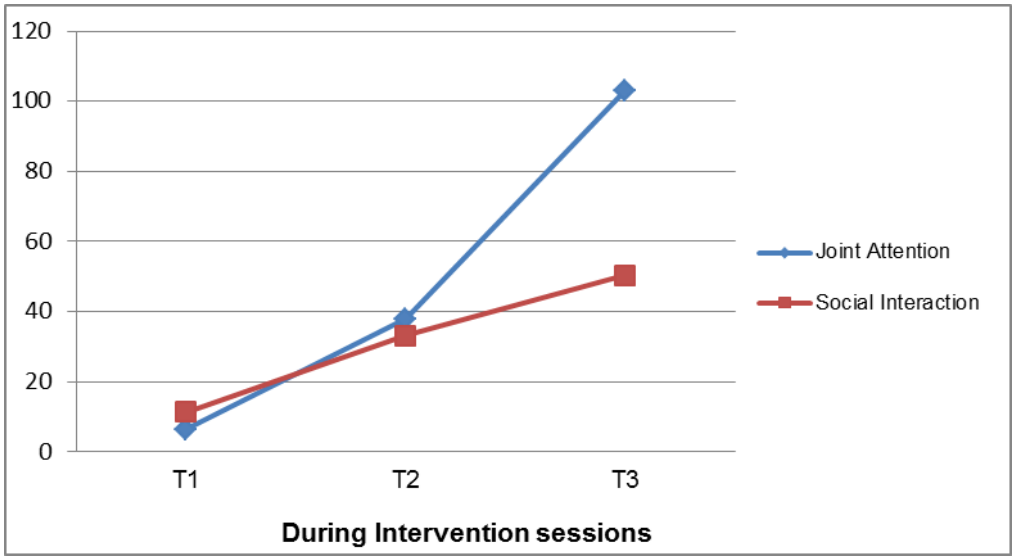

Fig. 29: Subject 3, joint attention and social interaction variables, in baseline vs. withdrawal

d) Subject 4: S4 (7 years old)

S4 has a diagnosis of pervasive developmental disorder (classic autism, for DSM-IV). His language skills, as his therapist reported, are reduced, non-functional and his communication is not spontaneous. He is learning to recognize letters, and he attends one day a week at a typically developing children school. S4 has no symbolic play skills. His therapist reported:

00:05:12
"[...]I have never seen him play with a toy car, he has no significant symbolic play. No little cars game or city game[...]"

During the Reactable Sessions, S4 showed an improvement in target behaviors: 45.07 % increase in turn-taking, 206 % in pointing, 141 % in respond-to-pointing (see Fig. 30). In the composite variables, the improvement is of 46.11% in joint attention, and 29.78% in social interaction (see Fig. 31).

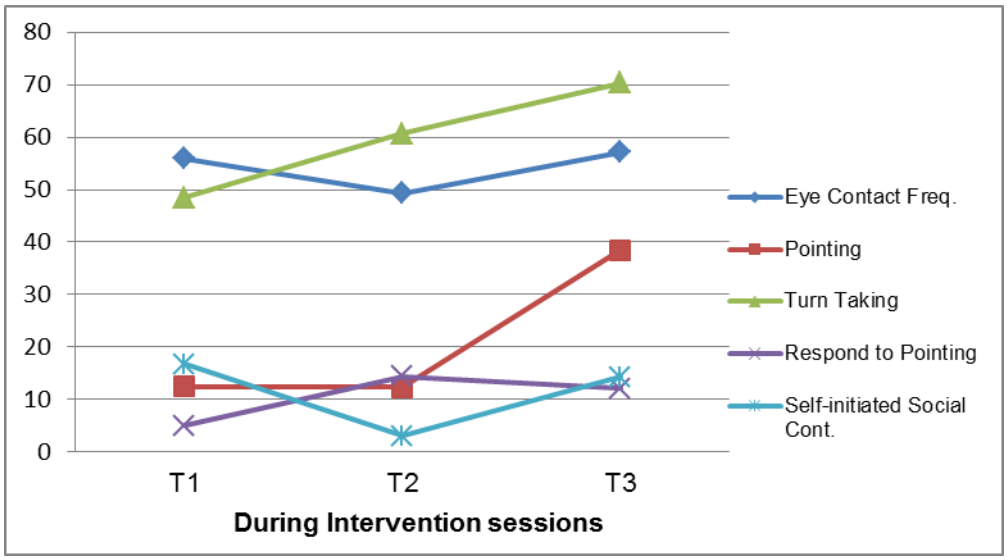

Fig. 30: Subject 4, improvement in all target behavior within the Reactable sessions

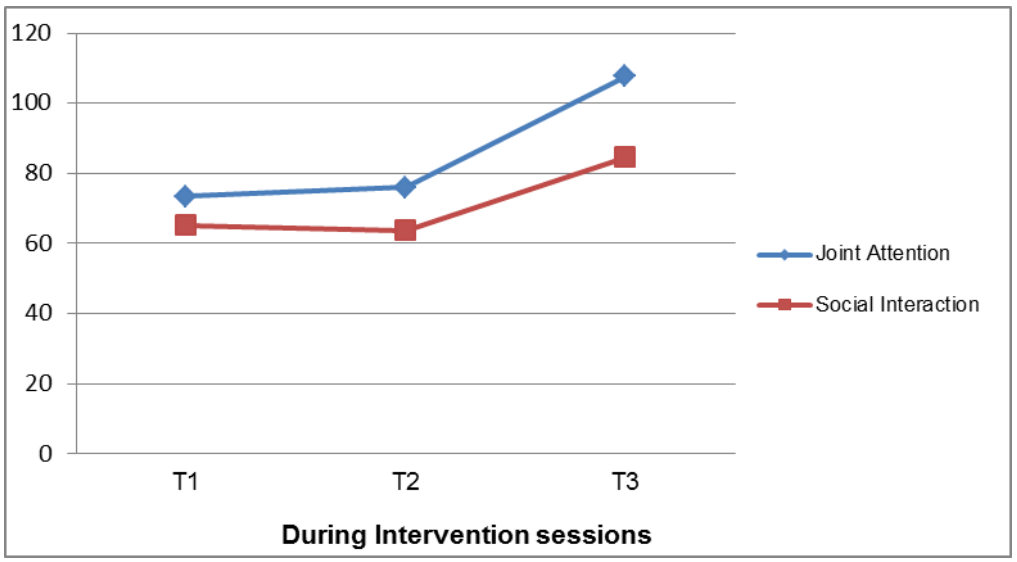

Fig. 31: Subject 4, joint attention and social interaction variables, in baseline vs. withdrawal

S4 showed an exceptional behavior during the Reactable sessions. He established symbolic play sessions with his therapist around the sound "cartoon water" that had been randomly assigned to session 1. The therapist reported in the interview that this type of play had not been found in the kid before. This behavior is being reported as, even though anecdotal, it could be important for future studies (Fig. 32).

Fig. 32: S4 pretending the Reactable is a pool

e) Subject 5: S5 (10 years old)

S5 is a High Functional ASC, has verbal language skills, but shows difficulties with pragmatic and prosodic use of language. He has acquired joint attention skills, although, he has trouble controlling his frustration at waiting in turn-taking sequences.

During the first Reactable session, S5 requested to work with more pucks, including generators, effects and filters. In each session, he notably improved in the musical use of the tool. His tutor reported to the researchers that S5 had never taken formal music studies, and was surprised by the talent shown with the Reactable (Fig. 33).

Fig. 33: S5 in a complex turn-taking musical sequence

Independently from the abilities discovered during the intervention, S5 improved in his turn-taking skills (196.01 % increase from session 1 to session 3), and eye contact target behavior (73.66 % from session 1 to session 3), as Fig. 34 shows. The values in composite variables increase from session 1 to session 3: 34.81 % increase in joint attention, 181.33 % increase in social interaction, see Fig. 35. Finally, the researcher can report, according to field notes and after the complete qualitative observation, that S5 requires a special evaluation around his probable skills as musical autistic savant.

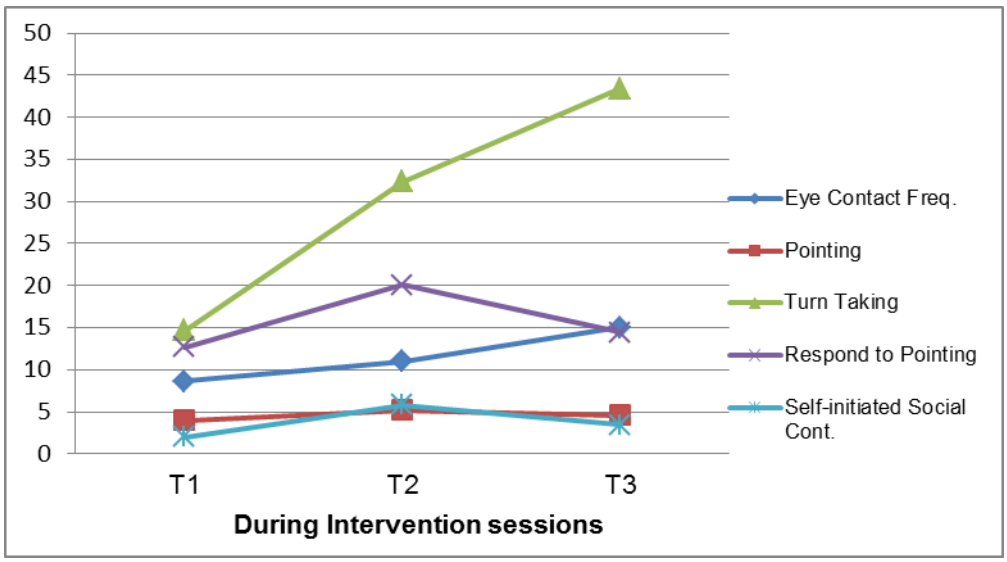

Fig. 34: Subject 5 improvement in all target behavior within the Reactable sessions

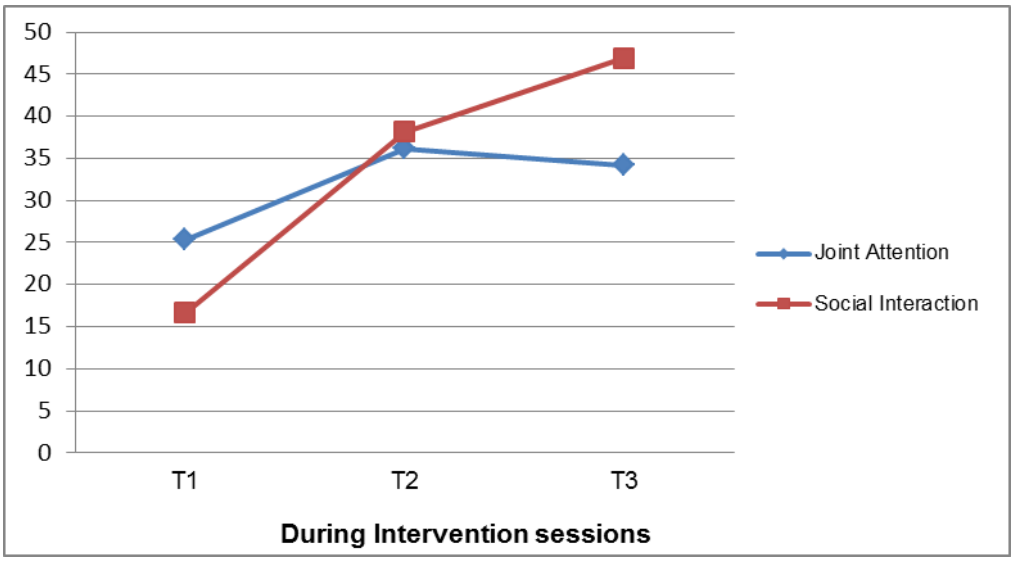

Fig. 35: Subject 5, joint attention and social interaction variables, in baseline vs. withdrawal

Finally, the detailed results of the remaining four subjects for each target behavior and composite varibles can be found in Annex I.

4. DISCUSSION AND CONCLUSION

This section will discuss the findings around the development of the experiment, as well as the analysis of the results and the theoretical assumptions related to the quantitative and qualitative information collected during the research process.

4.1 Strengths and Opportunities in the Design of the Experiment

In the design and implementation of the experiment, difficulties related to working with a complex and heterogeneous population were encountered. To prevent this from interfering with the outcome, the collection of qualitative data was included, and the sessions were designed with flexibility for better adaptation of the intervention with children with ASC. In order that future researchers can replicate the experiment performed, we report in this section the strengths and opportunities identified in the development of the experiment.

a) The Experiment Design Flexibility

One of the characteristics in the behavior of all people with ASC is fear of change. This means they are not flexible to the environment, and thus the assimilation of new tasks, situations or people can trigger episodes of stress and anxiety. To feel comfortable with a new activity, each child with autism requires a different amount of time and personalized assistance. These variables are related to the degree of autism as well as the IQ. For this reason, the experiments were designed with a maximum duration of 30 minutes. This implied, in practical terms, that the duration of each session with the Reactable was flexible. Thus, the therapist had the power to control the duration of the Reactable sessions, ending them when the child was showing interest in leaving the work room or if there was evidence of stress or anxiety. This decision was positive for the development of the sessions, since the children were certain they could end the session whenever they wanted. Then, they could anticipate to the session and feel more and more comfortable. This decision was important in the design of the experiment, since the extent of treatment and the difficulty in the recruitment of children with ASC in Barcelona, could hinder the approach of the sample to a new activity with the programmed time. This flexibility allowed 9 of the 10 children who participated in the study to carry out the experiment with successfully. The end result gives an average duration of 20.89 minutes for the sessions with the Reactable, and a statistically significant improvement in the variables related to the acquisition of social skills.

b) Work with Therapists

The ASC is a set of features in the development of communication and social skills that cover a spectrum of people. For the DSM-IV, autism is split up in five disorders, which complicates its diagnosis and treatment. Dealing directly with a child with fully non-verbal autism or with no functional language skills is extremely complex. Knowing when children need to go to the bathroom, whether they are afraid, or if a scream is an expression of happiness or anxiety, is part of a long-term learning process by the

therapist. In a non-verbal child without joint attention, communication of orders, rules and structures of behavior is done through repetition and pattern, this is usually a lengthy process. Understanding the needs of a child with ASC involves months or even years of daily work. For this reason, and to achieve the objectives of this research, close work with therapists and teachers of each recruited child was carried out during the experiment. Each child with ASC of the sample worked with his usual therapist during sessions with the Reactable. Each therapist had prior knowledge of working with child from 6 months to 3 years before the start of the sessions with the Reactable. The latter facilitated the children's positive approach to the research activities. All therapists involved in the research, were specifically trained in the use of the Reactable. This training was focused on two areas: 1. use of the tool, 2. assignments and directions to be given to children involved in the experiment.

However, personalized training sessions of 20-30 minutes training was insufficient for some therapists to understand how the Reactable works. The therapist's difficulties with technology created a frustrated interaction with children in some cases. To avoid this behavior, 10 minutes before each session the basic concepts of the Reactable use were reminded to the therapists. In this sense, the fieldwork carried out outside the Reactable sessions with therapists facilitated the exchange of information. In this respect, qualitative research methodology played an important role both for the collection of extra information and for identifying potential needs of therapists and children. Anecdotally, evidence was gathered of the capacity of one of the non-verbal subjects (Subject 3), in the use of the Reactable system, and how after a therapist error, the subject tries to instruct the therapist on what she should do.

c) The Reactable for Children with ASC

While working with the Reactable gave positive results in the acquisition of social skills for children with ASC, it is important to point out some requirements for specific work with them that were identified during the investigation and should be considered in future research.

- Hardware

The Reactable hardware should be more robust for children with specials needs. Children with ASC often have erratic physical behavior: pushing the Reactable or lying on it was a commonly observed behavior. This dismantled the Reactable walls, revealing the inner workings of the machine or alternatively, by pushing the mirror leaning against one wall, deconfigured the Reactable. The use of soft pucks might be considered: throwing the puck on the table or out of it when working with the Reactable was a standardized behavior. A few pucks had to be replaced after being repeatedly dropped. In addition, children with autism explore objects in a qualitatively different form than typically developing children, this including oral examination or rubbing objects with the face (Rowland & Schweigert, 2009). These two behaviors could become dangerous to the health of children in the absence of a therapist with extensive experience working with the child.

- Software

A graphical user interface and configuration accessible to the therapists could be implemented in future. In the interviews, the therapists showed interest in continuing to work with children and the Reactable. They also expressed their intention to explore with the child the sounds that allow them to learn emotions through sound, or that it can serve as a complement to their schooling (learning of letters, objects, animals). However, they explained they felt unable to configure the Reactable directly from the computer, as the application is currently designed.

d) Musical Material and Symbolic Play

One of the strengths in working with the Reactable and with the children with ASC evaluated, was that the material was composed especially for the sessions and was structured around the intervention with the Reactable. Three songs were created, divided in loops grouped by percussion, bass, melodies, cartoon sounds, glitches. These loops have the same rhythmic structure, facilitating the combination of pieces in harmony. Thus, all the interaction of children with the Reactable generated musically pleasing results. This facilitated the children's exploration of the elements during the intervention. But also, cartoon sounds were especially used by tutors to draw attention to children when they had trouble focusing on the activity. Anecdotally, but not less important, one of the children, in the sample, showed an incipient symbolic play: S4 (7 years old) initiated symbolic play with the therapist around water-related cartoon sounds. It is worth noting that the therapist said in an interview later that S4 suffers from fears related to learning to swim. However, he enjoyed the play with the Reactable, he wanted to "drink" and "immerse" in the Reactable like it was a swimming pool. Future studies related to the sound can be directed toward investigating the possibilities in learning symbolic play and imagination in children with autism, although the experience of this research recommends this area of study for populations of children with high functioning autism and Asperger's.

4.2 Conclusions on the Results

The population with ASC is very diverse, 90% of it have some kind of difference at the perceptual level (vision, hearing, touch), 60% have IQ below 60 points, and those who also have attention deficit hyperreactivity disorder (ADHD) are 4 times more likely to suffer more aggressiveness than typically developing population, among other difficulties (Clark, Feehan, Tinline, & Vostanis, 1999; Montes & Halterman, 2007). Studies about play therapy interventions (LEGO therapy) returned positive results in the improvement of social competence (SC) in samples of children with ASC verbal and / or Asperger's or HFA (Legoff & Sherman, 2006; Owens et al., 2008). However, in this exploratory with the Reactable, the sample consisted of a random group of children with ASC school age, with a high degree of language disability (sample of 9 children, 6 of them are completely non-verbal and have no JA skills). Working with a random sample of population that is very diverse and complex could be an added difficulty for the purposes of research. However, quantitative analysis results showed there was a statistically significant improvement in the composite social interaction during sessions with the Reactable. These data are relevant, not only because of the characteristics of the sample but also for the duration of treatment, since statistically significant

improvements were observed in just three working sessions. This should be viewed with caution, because the variables of joint attention need more treatment time in order to observe improvements (Naoi, Tsuchiya, Yamamoto, & Nakamura, 2008; Whalen & Schreibman, 2003; Whalen, Schreibman, & Ingersoll, 2006). Therefore, for future studies related to the Reactable or similar tools, more work sessions should be scheduled.

a) Theoretical Turn-Taking Improvement Implications

Of all the target behaviors observed, only turn-taking as an individual variable improved significantly during treatment sessions with the Reactable. Although these results cannot be considered conclusive given the size of the sample, there is evidence that collaborative use of the Reactable facilitates the acquisition of non-verbal and social abilities in turn-taking. The absence of spontaneous engagement in social imitation limits the ability of people in the development of social communication. If that is generated, the child has the ability to engage in turn-taking sequences, develop non-verbal communication and then initiate social communication. The acquisition of turn-taking, then, becomes a milestone in the development of children and their future learning abilities (Stephens, 2008; Tomasello & Farrar, 1986) The development of turn-taking skills is also related to the awareness of "the other one". In order to correctly perform a sequence of turn-taking, it is necessary to infer the intentions, as well as to anticipate the behavior patterns of "the other one" (Nadel & Umr, 2004). Future studies should investigate about the facility in learning sequences of turn-taking and the possible structuring of communication and understanding "the other one" in people with non-verbal ASC.

b) Communication Mediated by Tangible Interfaces

The use of technology as a mediator of communication between people with ASC and those with typical development reduces the stress caused by having to process implicit information commonly present in standard communication. These technologies facilitate the structuring of communication, making it predictable and making its rules of operation explicit. There is evidence about the special preference and ability of people with ASC in the use of technology, from learning complex mechanisms to the use of 2.0 technologies to remain unnoticed in their communication through the Internet (Simon Baron-Cohen, 2008; Burke et al., 2010). However, even though there are technologies that facilitate the learning of social skills through the use of technology, it is noteworthy that the biggest challenge in creating interventions related to the improvement of quality of life of a person with ASC must be focused on the possibility of these acquired skills to be replicated, understood and carried outside the context of the intervention.

From the results of the applied qualitative methodology (observation, fieldwork and interviews with the children's tutors), behaviors that repeated in several subjects in the sample were observed. For the purpose of this research it was decided to report and discuss these behaviors, given their importance for the development of new studies about the use of tangible technologies and communication of fully non-verbal individuals with ASC.

- The use of objects would reduce the stress of start communication with TD people and their peers.

Children with ASC have qualitative differences around the use of objects with respect to typically developing children. This includes everything from non-symbolic use of objects to a more intimate exploration, through oral examination for example. Is worth mentioning that the use of objects allows to display and to define the subject's relation to their environment, hence the importance of building theory around the possible use of objects as triggers in communication. During the recording and subsequent analysis of material collected through qualitative methodological tools used, 4 of the 10 subjects in the sample were found to use with musical objects (toys) to start non-verbal communication with peers, after the Reactable sessions. The subjects S2 (11 years old) and S1 (11 years old) initiated turn-taking sequences using a musical toy spontaneously after three days of work with the Reactable. In a later interview, the therapist recommended to continue working with the Reactable for a longer period of time, since S1 had never developed spontaneous game strategies with peers, and S2 had not got involved in turn-taking sequences with her peers before working with the Reactable. On the other hand, S6 (10 years old) established turn-taking sequences in response to the interaction of the therapist outside of the Reactable sessions, which included waiting for the interaction to mimic the behavior of his peer, without any given directions. In the material recorded before the use of the Reactable, the subject S7 (5 years old) exhibited use of musical toys to engage in turn-taking sequences with their peers, but it was after the use of the Reactable that the use of the toy to initiate interaction with his peers was detected. After that, S7 used the musical toy with a clear intention to provoke his peers through sound.

These recorded data demonstrate that the sound becomes a space invader, allowing to break the solitude of game. Any sound interaction breaks the confinement of a child with autism, calling his attention to the other's behavior. The sound presence of the therapist or a peer invades the sound space of the person with ASC, calling their attention and making them understand that the presence of another person has implications for their own space (Alvin & Warwick, 1992). The behaviors observed during the investigation, may give evidence of a limited learning about the presence and the calling to the "other", outside of a previously structured context. However, to validate this information, further studies with a larger sample of subjects with ASC, should focus their research on how sound, together with the shared or not shared use of the object can facilitate communication of non-verbal population.

- The children approached the objects to their body looking for a special behavior from pucks and after that share the object to their therapist.

By analyzing 100% of the recorded video during the sessions with the Reactable, a qualitatively different use of the pucks was detected. In addition to the conventional use of objects with the Reactable, the pucks can be rotated 360 degrees on the same side or switched to a different side; 3 of the 10 children included in the sample (S1, 11 years old, S7, 5 years old, Alexander, 11 years old), used objects to show interest in the following way: S1 and S7 repeatedly stroked their body when the puck objects

generated sound pleasant to them, and then shared the object with the therapist. S3 stroked the Reactable with his hands, and then shared the puck with the therapist. Such anecdotal behaviors repeated during the sessions with the Reactable for these children. Future research should explore these behaviors from two different perspectives. One, about the use of other materials with which objects are made to interact (smooth, soft, rough) to discover if there is a direct relationship between these materials and forms of sharing this object. The second perspective about this detected behavior may raise a theoretical question: are there implicit "emotional" elements about sharing objects that have previously been caressed by the child with ASC? If so, there may then be a qualitatively different interaction of non-verbal children with objects or perhaps this effect is related only to the fact that it is a musical object. Results that tip the balance toward music have been found in previous studies (Heaton, Hermelin, & Pring, 1999; Kim, Wigram, & Gold, 2009), however, future research should look further into these possibilities of communication with larger samples in the relationship with shared musical objects.

Finally, even if the sample (n = 9) is small to consider the results to be conclusive, and the randomly recruited sample implies a high diversity amongst children, the results of the present research give statistical significance in the social interaction composite variable. The outcome is encorouging for future studies around musical TUI and children with ASC, even for non-verbal subjects. To compensate for the lack of data that would help explain possible outliers, qualitative material was collected. The used metodological strategy showed noteworthy information on the most interesting behaviors at a theoretical level. For both reasons, it is recommended to future researchers in the Autism Spectrum condition, to include in their samples non-verbal individuals and to measure new variables related to new ways to learn social abilities trough low cost techonologies.

BIBLIOGRAPHY

Accordino, R., Comer, R., & Heller, W. (2007). Searching for music's potential: A critical examination of research on music therapy with individuals with autism. *Research in Autism Spectrum Disorders*, *1*(1), 101-115. doi:10.1016/j.rasd.2006.08.002

Alvin, J., & Warwick, A. (1992). *Music therapy for the autistic child*. (A. Warwick, Ed.) (2nd ed., p. 152). New York, New York, USA: Oxford University Press. Retrieved from http://bks2.books.google.je/books?id=Ux-Bu2A9IC8C

American Psychiatric Association. (2000). *American Psychiatric Association, Diagnostic and statistical manual of mental disorders*. American Psychiatric Association. Retrieved from http://books.google.co.uk/books?hl=ca&lr=&id=w_HajjMnjxwC&oi=fnd&pg=PP1&dq=Diagnostic+and+Statistical+Manual+of+Mental+Disorders,+Fourth+Edition&ots=i7LY5q9G5K&sig=O_-sfD5GGF7ehhCH0Dr0Jz1I9yI#v=onepage&q=Diagnostic and Statistical Manual of Ment?url_ver=Z39.88-2004&f=false

Amir, R. E., Van den Veyver, I. B., Wan, M., Tran, C. Q., Francke, U., & Zoghbi, H. Y. (1999). Rett syndrome is caused by mutations in X-linked MECP2, encoding methyl-CpG-binding protein 2. *Nature genetics*, *23*(2), 185-8. doi:10.1038/13810

Ashwin, E., Ashwin, C., Rhydderch, D., Howells, J., & Baron-Cohen, Simon. (2009). Eagle-eyed visual acuity: an experimental investigation of enhanced perception in autism. *Biological psychiatry*, *65*(1), 17-21. Society of Biological Psychiatry. doi:10.1016/j.biopsych.2008.06.012

Asperger, H. (1944/1991). "Autistic Psychopathy" in childhood. In U. Frith (Ed. & Trans.), Autism and Asperger syndrome (pp. 37–92). Cambridge: Cambridge University Press. (Original work published 1944).

Assessment, P., & Syndrome, A. (n.d.). Psychological Assessment of Asperger Syndrome. *Psychological Assessment*, 45-72.

Baron-Cohen, S. (1989). The autistic child's theory of mind: a case of specific developmental delay. *The Journal of Child Psychology and Psychiatry and Allied Disciplines*, *30*(2), 285-297. Wiley Online Library. Retrieved from http://doi.wiley.com/10.1111/j.1469-7610.1989.tb00241.x

Baron-Cohen, S, Allen, J., & Gillberg, C. (1992). Can autism be detected at 18 months? The needle, the haystack, and the CHAT. *The British journal of psychiatry: the journal of mental science*, *161*, 839-43. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/1483172

Baron-Cohen, Simon. (2009). Autism: the empathizing-systemizing (E-S) theory. *Annals of the New York Academy of Sciences*, *1156*, 68-80. doi:10.1111/j.1749-6632.2009.04467.x

Baron-Cohen, Simon, Leslie, A. M., & Frith, U. (1985). Does the autistic child have a "theory of mind"? *Cognition*, *21*(1), 37–46. Elsevier. Retrieved from http://linkinghub.elsevier.com/retrieve/pii/0010027785900228

Baron-Cohen, Simon. (2008). Autism, hypersystemizing, and truth. *Quarterly journal of experimental psychology (2006)*, *61*(1), 64-75. doi:10.1080/17470210701508749

Baron-Cohen, Simon, Ashwin, E., Ashwin, C., Tavassoli, T., & Chakrabarti, B. (2009). Talent in autism: hyper-systemizing, hyper-attention to detail and sensory hypersensitivity. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, *364*(1522), 1377-83. doi:10.1098/rstb.2008.0337

Baron-cohen, S. (2008). Theories of the autistic mind, *21*(2), 112-116.

Bass, J. D., & Mulick, J. A. (2007). SOCIAL PLAY SKILL ENHANCEMENT OF CHILDREN WITH. *Psychology*, *44*(7), 727-735. doi:10.1002/pits

Boussemart, B., & Giroux, S. (2007). Tangible User Interfaces for Cognitive Assistance. *AINAW'07 Proceedings of the 21st International Conference on Advanced Information Networking and Applications Workshops- Volume 2* (pp. 852-857).

Bowler, D. M. (1992). Theory of mind in Asperger's syndrome. *Journal Of Child Psychology And Psychiatry*, *33*(5), 877-893. Blackwell. Retrieved from http://cat.inist.fr/?aModele=afficheN&cpsidt=5372267

Bruscia, K. E. (1987). *Improvisational models of music therapy* (p. 590). Springfield: C.C. Thomas. Retrieved from http://books.google.com/books?id=Isw5AQAAIAAJ

Bruscia, K. E. (1998). *Defining music therapy* (2nd ed., p. 300). Barcelon: Barcelona Publishers. Retrieved from http://books.google.com/books?id=6Z99QgAACAAJ

Burke, M., Kraut, R., Williams, D., & Ave, F. (2010). Social Use of Computer-Mediated Communication by Adults on the Autism Spectrum. *CSCW '10 Proceedings of the 2010 ACM conference on Computer supported cooperative work* (pp. 425-434).

Cicchetti, D. V., & Rourke, B. P. (2004). *Methodological and biostatistical foundations of clinical neuropsychology and medical and health disciplines*. (Domenic V. Cicchetti & Byron Patrick Rourke, Eds.) (2nd ed., p. 778). Netherlands: Psychology Press. Retrieved from http://books.google.es/books?id=TqfgKIcLqiwC

Clark, T., Feehan, C., Tinline, C., & Vostanis, P. (1999). Autistic symptoms in children with attention deficit-hyperactivity disorder. *European Child & Adolescent Psychiatry*, *8*(1), 50-55. Springer Berlin / Heidelberg. Retrieved from http://dx.doi.org/10.1007/s007870050083

Crane, L., Pring, Linda, Ryder, N., & Hermelin, Beate. (2010). Executive functions in savant artists with autism. *Research in Autism Spectrum Disorders*, 6-13. Elsevier Ltd. doi:10.1016/j.rasd.2010.09.007

Ellis, P., & Leeuwen, L. V. (2000). Living Sound: human interaction and children with autism. *Music in Special Education, Music Therapy and Music Medicine* (pp. 1-23).

Farr, W., Yuill, N., & Raffle, H. (2010). Social benefits of a tangible user interface for children with Autistic Spectrum Conditions. *Autism: the international journal of research and practice*, *14*(3), 237-52. doi:10.1177/1362361310363280

Frith, Uta. (1989). *Autism: explaining the enigma Volumen 2 de Cognitive Development*. (Wiley-Blackwell, Ed.)*booksgooglecom* (2nd ed., Vol. 7, p. 249). Cornwall: Blackwell. Retrieved from http://www.amazon.com/dp/0631229019

Giusti, L., Zancanaro, M., Gal, E., & Weiss, P. L. T. (2011). Dimensions of Collaboration on a Tabletop Interface for Children with Autism Spectrum Disorder. *CHI 2011 Session:Tabletop & Wall Displays* (pp. 3295-3304).

Gold, C, Wigram, T, & Elefant, C. (2006). Music therapy for autistic spectrum disorder. *Cochrane database of systematic reviews (Online)*, (2), CD004381. doi:10.1002/14651858.CD004381.pub2

Hailpern, J., Karahalios, K., & Halle, Jim. (2009). Creating a Spoken Impact: Encouraging Vocalization through Audio Visual Feedback in Children with ASD. *CHI '09 Proceedings of the 27th international conference on Human factors in computing systems* (pp. 453-462).

Hailpern, J., Karahalios, K., Halle, James, Dethorne, L., & Coletto, M.-kelsey. (2009). A 3: HCI Coding Guideline for Research Using Video Annotation to Assess Behavior of Nonverbal Subjects with Computer-Based Intervention. *ACM Trans Access Comput (2009)*, *2*(2), 1-29. doi:10.1145/1530064.1530066.http

Happe, F. (2005). The Weak Central Coherence Account of Autism. In F. R. Volkmar, R. Paul, A. Klin, & D. Cohen (Eds.), *Handbook of Autism and Pervasive Developmental Disorders* (Vol. 1, pp. 640-649). John Wiley & Sons Inc.

Heaton, P, Hermelin, B, & Pring, L. (1999). Can children with autistic spectrum disorders perceive affect in music? An experimental investigation. *Psychological medicine*, *29*(6), 1405-10. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/10616946

Heaton, Pamela. (2003). Pitch memory, labelling and disembedding in autism. *Journal of child psychology and psychiatry, and allied disciplines*, *44*(4), 543-51. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12751846

Heaton, Pamela. (2009). Assessing musical skills in autistic children who are not savants. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, *364*(1522), 1443-7. doi:10.1098/rstb.2008.0327

Heaton, Pamela, Beate, H., & Pring, Linda. (1998). Autism and Pitch Processing: A Precursor for Savant Musical Ability? *Music Perception*, *15*(3), 291-305.

Hendrix, K., Herk, R. V., Verhaegh, J., & Markopoulos, P. (2009). Increasing Children ’ s Social Competence Through Games , an Exploratory Study. *Analysis*, 3-6.

Hornecker, E. (2011). The Role of Physicality in Tangible and Embodied Interactions. *interactions*, *18*(2), 19-23.

Ishii, H., & Ullmer, B. (1997). Tangible Bits: Towards Seamless Interfaces between People , Bits and Atoms. *CHI ’97 Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 1-7).

el Kaliouby, R., Picard, R., & Baron-Cohen, Simon. (2006). Affective computing and autism. *Annals of the New York Academy of Sciences*, *1093*, 228-48. doi:10.1196/annals.1382.016

Kanner, L. (1943). Autistic disturbance of affective contact. *Nerv Child*, *1*(2), 217-250.

Kim, J., Wigram, Tony, & Gold, Christian. (2008). The effects of improvisational music therapy on joint attention behaviors in autistic children: a randomized controlled study. *Journal of autism and developmental disorders*, *38*(9), 1758-66. doi:10.1007/s10803-008-0566-6

Kim, J., Wigram, Tony, & Gold, Christian. (2009). Emotional, motivational and interpersonal responsiveness of children with autism in improvisational music therapy. *Autism: the international journal of research and practice*, *13*(4), 389-409. doi:10.1177/1362361309105660

Klin, A., Jones, W., Schultz, R., & Volkmar, F. (2003). The enactive mind, or from actions to cognition: lessons from autism. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, *358*(1430), 345-60. doi:10.1098/rstb.2002.1202

Konstantinidis, E. I., Luneski, A., Nikolaidou, M. M., Hitoglou-antoniadou, M., & Bamidis, P. D. (2009). Using Affective Avatars and Rich Multimedia Content for Education of Children with Autism. *Work*, 9-13.

LeGoff, D. B. (2004a). Use of LEGO as a therapeutic medium for improving social competence. *Journal of autism and developmental disorders*, *34*(5), 557-71. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/15628609

LeGoff, D. B. (2004b). *Use of LEGO as a therapeutic medium for improving social competence. Journal of Autism and Developmental Disorders* (Vol. 34, pp. 557-571). Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/15628609

Leekam, S. R., Nieto, C., Libby, S. J., Wing, Lorna, & Gould, Judith. (2007). Describing the sensory abnormalities of children and adults with autism. *Journal of Autism and Developmental Disorders*, *37*(5), 894-910. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/17016677

Legoff, D. B., & Sherman, M. (2006). Long-term outcome of social skills intervention based on interactive LEGO play. *Autism: the international journal of research and practice*, *10*(4), 317-29. doi:10.1177/1362361306064403

Lopez, L. (2009). Music and child neurology: a developmental perspective. In R. Haas & V. Brandes (Eds.), *Music that works* (pp. 179-184). Springer Vienna. Retrieved from http://dx.doi.org/10.1007/978-3-211-75121-3_12

Marshall, P., Rogers, Y., & Hornecker, E. (2007). Are tangible interfaces really any better than other kinds of interfaces? Conference Item. *CHI'07 workshop on Tangible User Interfaces in Context & Theory* (p. 28).

Montes, G., & Halterman, J. S. (2007). Bullying among Children with Autism and the Influence of Comorbidity with ADHD: A Population-Based Study. *Ambulatory Pediatrics*, *7*(3), 253-257. doi:DOI: 10.1016/j.ambp.2007.02.003

Mottron, L., Peretz, I, & Ménard, E. (2000). Local and global processing of music in high-functioning persons with autism: beyond central coherence? *Journal of child psychology and psychiatry, and allied disciplines*, *41*(8), 1057-65. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11099122

Mundy, P., Delgado, C., Block, J., Venezia, M., Hogan, A., & Seibert, J. (2003). Early social communication scales (escs). *Communication*, (305).

Mundy, P., Sigman, M., Ungerer, J., & Sheran, T. (1986). Defining the social deficits of autism: the contribution of non-verbal communication measures. *Journal child Psychol.*, *27*(5), 657-669. J. Child Psychol.

Nadel, J., & Umr, C. (2004). Early imitation and the emergence of a sense of agency. *Proceedings of the 4th international workshop on epigenetic robots* (pp. 15-16).

Naoi, N., Tsuchiya, R., Yamamoto, J.-I., & Nakamura, K. (2008). Functional training for initiating joint attention in children with autism. *Research in developmental disabilities*, *29*(6), 595-609. doi:10.1016/j.ridd.2007.10.001

Owens, G., Granader, Y., Humphrey, A., & Baron-Cohen, Simon. (2008). LEGO therapy and the social use of language programme: an evaluation of two social skills interventions for children with high functioning autism and Asperger Syndrome. *Journal of autism and developmental disorders*, *38*(10), 1944-57. doi:10.1007/s10803-008-0590-6

Parsons, S., & Mitchell, P. (2002). The potential of virtual reality in social skills training for people with autistic spectrum disorders. *Journal of intellectual disability research: JIDR*, *46*(Pt 5), 430-43. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12031025

Parés, N., Soler, M., Sanjurjo, À., Carreras, A., Durany, J., Ferrer, J., Freixa, P., et al. (2005). Promotion of creative activity in children with severe autism through visuals in an interactive multisensory environment. *Proceeding of the 2005 conference on*

Interaction design and children - IDC '05 (pp. 110-116). New York, New York, USA: ACM Press. doi:10.1145/1109540.1109555

Peeters, T. (2008). *Autismo, de la comprensión teórica a la intervención educativa* (p. 248). Ávila: Autismo Ávila.

Peretz, Isabelle. (2002). Brain specialization for music. *The Neuroscientist: a review journal bringing neurobiology, neurology and psychiatry*, *8*(4), 372-80. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12194505

Peretz, Isabelle, & Zatorre, R. J. (2005). Brain organization for music processing. *Annual review of psychology*, *56*, 89-114. doi:10.1146/annurev.psych.56.091103.070225

Putnam, C., Hall, L., & Chong, L. (2008). Software and Technologies Designed for People with Autism: What do users want? Categories and Subject Descriptors. *ASSETS'08* (pp. 13-15).

Rigler, J., & Seldess, Z. (2007). The Music Cre8tor: an interactive system for musical exploration and education. *NIME '07 Proceedings of the 7th international conference on New interfaces for musical expression* (pp. 415 - 416). ACM New York, NY, USA ©2007.

Riviere, A. (2001). El autismo y los trastornos generalizados del desarrollo. In A. Marchesi, C. Coll, & J. Palacios (Eds.), *Desarrollo psicológico y educación III. Trastornos del desarrollo y necesidades educativas especiales*, (Alianza., pp. 329-360). Madrid.

Robins, B., & Dautenhahn, K. (2010). Developing Play Scenarios for Tactile Interaction with a Humanoid Robot: A Case Study Exploration with Children with Autism. *Autism*, 243-252.

Robins, B., Dickerson, P., Stribling, P., & Dautenhahn, K. (2004). Robot-mediated joint attention in children with autism: A case study in robot-human interaction. *Interaction Studies*, *5*(2), 161-198. doi:10.1075/is.5.2.02rob

Rowland, C. M., & Schweigert, P. D. (2009). Object lessons: How children with autism spectrum disorders use objects to interact with the physical and social environments. *Research in Autism Spectrum Disorders*, *3*(2), 517-527. doi:10.1016/j.rasd.2008.10.005

Rundblad, G., & Annaz, D. (2010). The atypical development of metaphor and metonymy comprehension in children with autism. *Autism : the international journal of research and practice*, *14*(1), 29-46. doi:10.1177/1362361309340667

Simpson, K., & Keen, D. (n.d.). Music Interventions for Children with Autism: Narrative Review of the Literature. *Journal of autism and developmental disorders*, 1-8. doi:10.1007/s10803-010-1172-y

Solos, H., Parkes, A. J., & Ishii, H. (2004). Topobo: A Constructive Assembly System with Kinetic Memory. *CHI '04 Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 647 - 654). New York, NY: ACM.

Stephens, C. E. (2008). Spontaneous imitation by children with autism during a repetitive musical play routine. *Autism: the international journal of research and practice*, *12*(6), 645-71. doi:10.1177/1362361308097117

Strauman, T. J. (1994). Introduction: social cognition, psychodynamic psychology, and the representation and processing of emotionally significant information. *Journal of personality*, *62*(4), 451-8. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/7861301

Tomasello, M., & Farrar, M. J. (1986). Joint attention and early language. *Child development*, *57*(6), 1454-63. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/3802971

Vanderbruggen, N., Van Geit, N., Bissay, V., Zeeuws, D., Santermans, L., & Baeken, C. (2010). Asperger syndrome, violent thoughts and clinically isolated syndrome. *Acta neurologica Belgica*, *110*(4), 334-6. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/21327833

Whalen, C., & Schreibman, L. (2003). Joint attention training for children with autism using behavior modi ¢ cation procedures. *Journal Of Child Psychology And Psychiatry*, *3*, 456-468.

Whalen, C., Schreibman, L., & Ingersoll, B. (2006). The collateral effects of joint attention training on social initiations, positive affect, imitation, and spontaneous speech for young children with autism. *Journal of autism and developmental disorders*, *36*(5), 655-64. doi:10.1007/s10803-006-0108-z

Wigram, T. (2004). *Improvisation: methods and techniques for music therapy clinicians, educators and students* (p. 237). J. Kingsley Publishers. Retrieved from http://books.google.com/books?id=n7rwZdVg98MC

Wigram, T, & Gold, C. (2006). Music therapy in the assessment and treatment of autistic spectrum disorder: clinical application and research evidence. *Child: care, health and development*, *32*(5), 535-42. doi:10.1111/j.1365-2214.2006.00615.x

Williams, E. (2003). A comparative review of early forms of object-directed play and parent-infant play in typical infants and young children with autism. *Autism: the international journal of research and practice*, *7*(4), 361-77. doi:10.1177/1362361303007004003

Wing, L, & Gould, J. (1979). Severe impairments of social interaction and associated abnormalities in children: epidemiology and classification. *Journal of autism and developmental disorders*, *9*(1), 11-29. Retrieved from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?db=pubmed&cmd=Retrieve&dopt=AbstractPlus&list_uids=155684