Tallinn University

School of Digital Technologies

The “Interactive Carpet” – E-Textile based Interface for Children on Autism Spectrum Disorder for Social Interactions.

Master’s thesis

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Author’s Declaration

I declare that, apart from work whose authors are clearly acknowledged, this document is the result of my own and original work. This has not and is not being submitted for any other comparable academic degree.

Thesis has been supervised by PhD David Lamas. The secondary supervisors were PhD Kristi Kuusk and PhD Mari-Liis Kaldoja.

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Abstract

Autism Spectrum Disorder (ASD) is a lifelong neurodevelopmental disorder characterized by repetitive behaviors and impairment in verbal communication and social interactions. In the past, significant work has been conducted on TUIs and sensory integration therapy to improve life quality and general outcomes for individuals with ASD.

The master thesis proposes to investigate how e-textile-based interface can be designed to enhance the socializing potential of children with ASD. To this end the author introduced and investigated a new design and prototype of an “Interactive Carpet”, a physical artifact with carefully-chosen soft tactile properties and multi-sensory interface inputs. The “Interactive Carpet” has been built in cooperation with ASD specialists, incorporating research through design methodology, contextual inquiry and observational study methods.

Two observational studies have been conducted to observe the potential impact of integrating the “Interactive Carpet” in regular occupational sessions. The qualitative data has been gathered to analyze in what ways the prototype may promote social skills, and attention of children with Low-Functioning Autism. The conclusions and recommendations have been provided as well.

Summary in Estonian

Autismispektri häire (ASH) on püsiv närvisüsteemi arenguhäire, mida iseloomustavad korduvad käitumismustrid, verbaalse kommunikatsiooni kahjustus ja sotsiaalse tegevuse häired. On tehtud märkimisväärselt palju uuringuid erinevate interaktiivsete meetodite ja sensoorse integratsiooni ravi osas, eesmärgiga parandada ASH-ga isikute elukvaliteeti ning saavutamaks positiivseid muutusi.

Käesoleva magistritöö eesmärgiks on uurida e-tekstiili-põhise kontaktpinna potensiaalset positiivset mõju ASH-ga laste sotsialiseerumisele. Sellised kontaktpinnad võivad arendada tähelepanuvõimet ja sotsiaalseid oskuseid ning soodustada lapse-hooldaja vahelist suhtlust.

Magistritöö autor töötas välja “interaktiivse vaiba” prototüübi – nn “vaiba”, mis on spetsiaalsete pehmete puuteomaduste ning multisensoorsepinnaga. “Interaktiivne vaip” on loodud koostöös ASH spetsialistidega, ning ühendab endas disaini metoodikat, vaatlusuuringute tulemusi ja väliuuringud.

Autor viis läbi kaks vaatlusuuringut, et välja selgitada “interaktiivse vaiba” kaasamise mõju tavapärastes teraapiasessioonides. Uuringu jooksul kogutud kvalitatiivsed andmed võimaldasid analüüsida erinevaid viise kuidas prototüüp võiks arendada madalfunktsioneerivate autistlike laste sotsiaalseid oskuseid ning tähelepanuvõimet. Magistritöö sisaldab uuringute lõppjäreldust ning soovitusi.

Acknowledgments

The author thanks the supervisors of this master's thesis without whom this study would not be possible: professor David Lamas for his continuous support in shaping this study from research process perspective and supporting the author in establishing partnerships for making this study possible; Professor Kristi Kuusk for her willingness to collaborate, her inspiration about e-textile technologies and continuous support during the active stage of prototyping process. Special thank you goes to professor Mar-Liis Kaldoja for sharing her wealth of a knowledge about autism spectrum disorder and her effort and time spent for evaluating the videos and securing another evaluator, Helen Saareoja. Thank you, Helen, for your contribution.

Another thank you goes to Argo Ilves who was very kind to share his experience and connect the author with the daycares and autism specialists in Tallinn. Without his help it would be hard to initiate contacts with the daycares and conduct the studies. The author would like to express gratitude to Kati Kiver, Laura Feldbach, Katrin Lipso and all other therapists who made it possible to evaluate the prototype with children at the Kaokeskus daycare. Finally, special thank you goes to the author's grandmother, Nina Andreevna, who spent hours helping with knitting and stitching of the final elements of the "Interactive Carpet".

Table of Contents

1. Introduction

This master study aims at describing the research and rationale behind the design of the "Interactive Carpet" physical prototype for promoting socializing potential of children on low-functioning autism spectrum disorder.

Autism Spectrum Disorder (ASD) is a lifelong neurodevelopmental disorder (NDD) characterized by repetitive behaviors and impairment in verbal and social communication (American Psychiatric Association (APA), 2013). According to the World Health Organization (WHO, 2017), 1 in 160 children has autism spectrum disorder. Children on the spectrum have highly diverse range of symptoms, including cognitive level, speech development and multi-sensory perceptions. This master thesis is motivated by the idea that by providing appropriate environment and intervention, children even on the low-functioning spectrum can have improved quality of life.

Even though the ASD has highly heterogeneous nature, it shares some main features: deficits in social communication and restricted, repetitive patterns of behavior, manifested in highly restricted interests and hypo- or hyperactivity to sensory input or unusual interests in sensory aspects of the environment (Carpenter, 2013).

Multi-sensory integration therapy (MSI) is among the most common interventions practiced with children with autism and is based on the hypothesis that the nervous system's ability to process sensory stimuli can be improved by means of sensory stimulation (Baraneck, 2002; Lane, 2010; Schaaf, Miller, 2005). The multi-sensory integration therapy employs various objects with tactile, light and sound feedbacks (lamps, sensory walls, heavy blankets, etc.). According to Ornitz (Ornitz 1974) the atypical reactions to sensory inputs in children with autism is their primary symptom and the main cause of impairments in social, communication and language domains.

The background research revealed a number of studies on how the technology may assist with intervention practices of children with ASD. A prevailing number of studies investigate various digital applications and how these solutions may help with recognizing emotions, organizing daily routines, and developing empathy (Chen, 2016; Garzotto, 2017; Sampath, 2013; Simm, 2014). Another body of research investigates how robotic toys may enhance social skills of kids with autism (Gelsomini, 2017). Other studies are concerned with research of the natural-user interfaces (NUI) and how the whole-body interaction systems may augment sensory-integration therapies

and creativity (Ringland, 2014). More so, integrating Tangible User Interfaces (TUIs) into occupational therapies has proven its efficacy in children with ASD (Farr, 2010; Hornecker, 2006; Sitdhisanguan, 2012; Villafuerte, 2012). Overall research on integrating TUIs into ASD occupational therapies has shown positive effects for stimulating attention, shortening duration of solitary activities, lowering arousal (Farr, 2010; LeGoff, 2007). That said, to our best of knowledge, there was no thorough study done on the soft tangible interfaces incorporating smart textile technology for autistic children and how the interaction with soft physical objects with multi-sensory feedback may promote attention and enhance socializing potential of children on low-functioning ASD.

The goal of this master study is an attempt to explore different properties of the interactive, textile based prototype and how they may stimulate attention and promote child - care giver interaction. Considering the plethora of research on TUIs and sensory integration therapy, we **hypothesize**, that soft properties of the interface with multi-sensory feedback and detachable objects may promote attention and enhance socializing.

The design of the “Interactive Carpet” prototype is using **e-textile** technique which allows to embed circuitry inside of the interface seamlessly, using conductive threads and fabric. Soft circuitry allows greater intuitiveness in using an interface. The prototype proposes a novel fully soft interface that serves as a storytelling platform with detachable interactive objects for stimulating attention and senses. Moreover, we wanted to create a joyful experience for children and built an interface in the shape of a carpet to provide feeling of home and coziness for greater comfort to unlock socializing potential.

Therefore, the **research questions** are the following:

Q.1. To what extent can “Interactive Carpet” promote attention and enhance interaction between a child and a caregiver during playtime?

Q.2. In what ways can therapists and caregivers utilize the “Interactive Carpet” in their occupational therapy practices and for playful experiences?

The observational study in nature, it uses mixed methods within the umbrella of User - Centered Design and Research through Design approaches. Children with low-functioning autism are the

target population and the “Interactive Carpet” prototype serves as the intervention and the artifact for assessing the hypothesis.

The research process includes:

Figure 1. Research process

- **Background research** on autism spectrum disorder and further on the existing HCI solutions to gain profound understanding of needs and challenges children on low-functioning autism have and how they could be addressed;
- **Contextual inquiry** conducted in the Kaokeskus specialized daycare by means of unstructured interviews with the therapists during their daily occupational therapies sessions with children;
- **Prototyping** the artifact by means of which the assumption of the study was assessed. The prototype was iterated twice and each iteration was followed by an observational study;
- **Observational study** was conducted twice after each iteration of the prototype. During the observational studies the experience of six children was observed and recorded with an obtained consent form. The gathered qualitative data helped shed the light on the research problem and answer the research questions.
- **Results** from the studies were analyzed by the author and two Special Education specialists and conclusions were drawn.

Author’s participation at the LUDI Training school “Play & Toys for All” developed within the COST Action, provided an additional value in understanding experiences of children with disabilities, their needs and desires for “play for the sake of play” and how their caregivers are trying to address these needs.

Based on the study conducted within this thesis a conference paper was written and accepted for publication in the proceeding of TEI’18 the Twelfth International Conference on Tangible, Embedded, and Embodied Interaction conference (Zhiglova, 2018). The submission was evaluated

by three reviewers and the expertise level of the paper was evaluated as “Knowledgeable”. The paper was described as “well grounded”, “interesting and thoughtful” and “functionally complete”.

1.1. The rationale for selecting the topic

The initial interest for this topic evolved during the first semester HCI Foundations and Master Thesis Seminar classes with professor David Lamas. During the HCI Foundations class the author became acquainted with the existing e-textile based technologies and tangible interfaces that use soft circuitry for wellbeing and healthcare applications. Considering personal interest of the author in the topics of playful learning and development for children, the author saw a potentially beneficial avenue for research at the intersection of the e-textile based tangible interfaces and how they can benefit children’s development process. Further, during the Master Thesis seminar, the topic was narrowed down to a specific research problem of autism spectrum disorder, based on the knowledge of the essential importance of multi-sensory stimulation that tangible interfaces may provide to these children.

1.2. Thesis structure

This thesis consists of 4 main chapters.

The first chapter, **background research**, provides overview of the autism spectrum disorder and underlying theoretical knowledge and existing therapies and interventions. The second part of background research talks about the existing HCI solutions for children with autism spectrum disorder with special emphasis on tangible user interfaces. The second chapter is dedicated to **research process**, including contextual inquiry, prototyping and accessibility considerations. The third chapter talks about the **study design**, **participants**, **measures**, developed for evaluating the experience of children during the testing, and the actual **study procedure**. The final chapter discusses the **analysis and results** of the study. The main body of the thesis is accompanied by a number of appendices.

2. Background research

The background research consists of the overview of the Autism Spectrum Disorder, existing challenges children on the spectrum encounter and various interventions and occupational therapies for addressing these challenges. Then the author will talk about the solutions in the broader field of HCI existing to help kids on autism with skills development. After the broader overview of the solutions, the author will narrow down the focus on the solutions developed specifically for promoting the socializing potential using tangible user interfaces.

2.1. Autism spectrum disorder

Autism Spectrum Disorder (ASD) is a group of related conditions that share many similarities and underlying social-communicative impairments. The spectrum is an umbrella term that includes Autistic Disorder (or "autism"), Asperger's Disorder, and Pervasive Developmental Disorder. People with ASD are generally characterized as either high-functioning autism (HFA) or low-functioning autism (LFA). ASD symptoms develop before age three and are prevalent in males than females (Brock, Silva, Riffey & Ludena, 2013).

ASD is a highly heterogeneous disorder but such symptoms as persistent deficits in social communication and social interaction and restricted, repetitive patterns of behavior, manifested by stereotyped or repetitive speech, excessive adherence to routines, fixated interests or/and hyper-or hypo-reactivity to sensory input or unusual interest in sensory aspects of environment is common among most of children with ASD (Carpenter, 2013). Children with ASD tend to engage in solitary activities and have hard time sharing interests and enjoyment with others. The impairment in social domain also include inability for reciprocity, where a child is giving or taking something in a social interaction. Children with autism tend to communicate primarily with the purpose to express needs, desires but they have difficulties in expressing their interest in others and have mutual activities (Koegel, 1987).

Another defining characteristic of children with ASD is restricted and repetitive behavior (Carpenter, 2013; American Psychiatric Association, 2013). Such behavior manifests in having limited interests, rigid routines, repetitive movements and vocalizations. For example, during playtime a child may continuously interact with only one toy, or restricted to only one specific

action, spinning a wheel of a car. In addition, many children with autism tend to have atypical perceptions and reactions to different textures, smells, and tastes. They tend to explore objects sensory by touching, smelling, tasting and have fascination with subtle physical characteristics of toys, its texture, color and shades (Carpenter, 2013). There is a number of interventions techniques and therapies developed to help such children in their development process, including Applied Behavior Analysis (ABA), Pivotal Response Treatment approaches, Social Skills Training, Occupational therapies, and Multi-Sensory Integration techniques among others.

2.1.1. Existing intervention techniques

The main goals of the intervention techniques are to address core challenges of the ASD: social communication (join attention and social reciprocity) and language and related cognitive skills.

Applied behavior analysis (ABA)

The most widely used intervention technique is Applied Behavior Analysis (ABA). ABA aims at addressing challenging behaviors and learning essential skills. The intervention is based on positive reinforcement principles. Most ABA programs are highly-structured and follow an established curriculum. Each skill is broken down into small steps, and taught using prompts in various settings. A child has an opportunity to learn skill multiple times until he/she masters it. Every time a child achieves a desired result, he/she receives positive reinforcement in a form of verbal praise or something else that is very motivating for that child. Such intervention technique has been effective in teaching skills and coping with challenging behaviors (Baer, Wolf, Risley, 1968).

Pivotal response treatment (PRT)

A major problem, encountered in the field of autism, is the lack of motivation. Pivotal response treatment (PRT) is an evidence-based behavioral intervention. The goal of this intervention is to improve social communication skills in individuals with ASD. PRT is very effective in teaching social and communication skills because it builds upon interests and preferences of a child and positively reinforces not only successful completion of tasks by a child but all attempts to complete

the tasks. Positive reinforcement of all valid attempts increases the motivation of a child to stay engaged and focused on the activity (Lei, 2017).

Social skills training

Socializing is a complex construct consisted of joint attention, shared joy, reciprocity and eye gaze among other indicators. Joint attention, pretend play and shared joy are integral elements for successful social communication between people (Lei & Ventola, 2017). One of the examples of joint attention and shared joy is when during a play a child looks at the toy (or another object of interest), then looks at the caregiver (or a person involved in a playtime with a child), smiles at a caregiver and looks back at a toy. Thus, a child invites another person to share the joy and amusement about the object of interest. Children with autism usually have difficulty to engage in joint attention and share joy with others during play. Overall, there are several types of play which differ depending on the child's level of social engagement during playtime: solitary independent play, parallel play, associative play, and cooperative play. Children with autism are predominantly engaged in a solitary independent play and sometimes in parallel play (Koegel, 1987; Zager, 2005).

According to the National Professional Development Center for Autism Spectrum Disorders (NPDC, 2010), the social narratives are one of the evidence-based practices that are effectively teaching social skills to children with autism. In addition to teaching the social skills, social narratives are effective in addressing challenging behaviors such as aggression, anxiety as well as teaching hygiene and other daily routines. Social narratives are usually short stories and include pictures. They are highly individualized to the needs of a child and provide objective statements about various social situations (Ganz, Cook, Earles-Vollrath, 2006; NPDC, 2010).

Image 1. Social narrative example (TouchAutism, 2015)

Many children with autism, especially on low-functioning spectrum may not have ability for verbal language. For this population a number of Augmentative and Alternative Communication (AAC) devices and tools are developed. Among them, sign language, picture systems and a variety of technology based assistive communication devices.

Picture exchange communication system (PECS) is a widely used communication tool for individuals with deficits in verbal expressions. The principle of PECS is that individuals exchange cards with visuals in exchange for a desired item or to describe their emotional state. One of the goals of PECS is to initiate social contact. It is an evidence-based tool and has shown a number of positive outcomes in a communication domain for children with ASD (American Journal of Occupational Therapy, 1999).

Image 2. Example of PECS (Davies, 2007)

Occupational therapies

Occupational therapy is one of the integral parts of the overall treatment program and is widely used to promote the well-being of children with ASD. The main goal of the occupational therapy is to teach a child daily skills, social skills, fine motor skills with special emphasis on sensory processing and removing the barriers to learning and helping children become calmer and focused (Sherman, 2007; William, 2007). In occupational therapy these skills are taught through various play-like and role playing activities (Beth, 1999; Stagnitti, 2000).

Multi-sensory integration therapy

A number of studies demonstrated that sensory integration is essential for a child to be able to engage in play and have sustained interaction (Hoehn, 1994; Lang, 2012; Marco, 2012; May-Benson, 2010; Stephenson, 2005; Wieder, 1996; Williamson, Anzalone, 1997).

Multi-Sensory Integration therapy (MSI) is among the most common interventions because majority of children with ASD are having sensory dysfunction (Lang, 2012). Thus, they usually fall into one of the two groups: hyper- or hyposensitive. The hypersensitivity manifests in overreactions to sensory inputs and hyposensitivity is an under reaction to sensory inputs. For instance, children can be sensitive to noise, light, textures of the surfaces and smells. Their atypical sensory perceptions may trigger aggression, self- hurting, and disengagement.

According to a number of studies, one of the hypothesis of sensory abnormality is the defect in nervous system which does not process and integrates sensory stimuli correctly (Ayres, 1972; Ayres, Tickle, 1980; Schaaf, Miller, 2005). MSI is based on this hypothesis, assuming that the nervous system's ability to process sensory stimuli, can be improved by means of sensory stimulation. This means that by providing multi-sensory stimulation activities, a child with ASD may improve his sensory perception and as a result have better quality interactions with the environment around (Baraneck, 2002; Lane, 2010; Schaaf&Miller, 2005).

2.1.2. Multi-sensory integration and attention

The socio-cognitive integration of abilities model (SOCIAL) is a framework which defines the core dimensions for development of social skills (*Figure 2*). The development of social function is moderated by the external/internal factors, brain development and integrity which are then connected and influence the attention and cognitive skills.

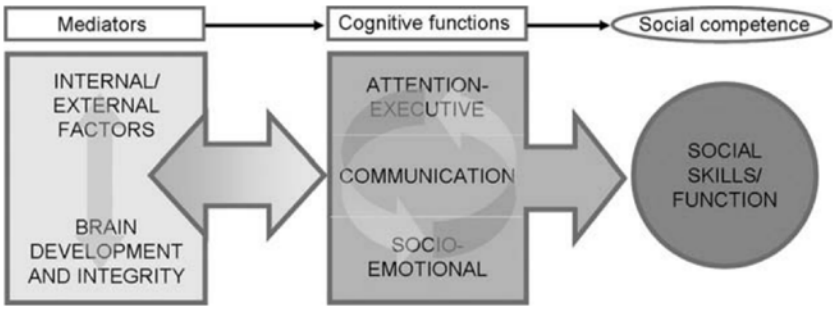

Figure 2. An integrative framework for the development of social skills

According to the SOCIAL model, one of the principal mediators of the social skills is brain development and integrity, which refers to how fast the neural paths process the information and react to external changes. The brain development then impacts the attention which is essential for acquiring social skills. Specifically, one of the building blocks of social communication is joint attention. Joint attention refers to the sharing of attention between a child and an adult in reference to some third event, person, or object. Individuals with ASD have atypical brain activity in virtually all regions associated with social cognition and generally experience difficulties with joint attention. Moreover there is evidence that deficits in the perceptual integration of sensory experiences (due to a range of abnormalities in the brain functions) may contribute to social difficulties in autism. The multisensory stimulation is known to influence the speed of neural paths processing. Consequently, speed of processing, often linked with attention, is associated with social outcomes (Beauchamp, 2010). To sum up, based on the SOCIAL model we may assume that multi-sensory stimulation may serve as a facilitator of joint attention which is a building block for social interaction.

2.1.3. Play for the sake of play

Very often, during the occupational practices, therapists and/or care givers are concentrating solely on the intervention outcomes and procedures, forgetting about an overall experience a child may have in the process. It is essential to keep in mind that children with ASD also would like to have a "fun" time and simply enjoy the things they like to do. It is important to foster playfulness, humor and friendship, at the same time keeping in mind the therapeutic objectives of the activity (Zager, 2005). In terms of ASD, the lack of shared enjoyment might be one of the hardest things for

caregiver/therapist to cope with. That said, all the tools expanding the possibilities of more shared joy are always welcomed by parents/caregivers/therapists of children with ASD. The fulfilling feeling from enjoyment of shared play by therapist and child could be seen as a thriving motivational force that benefits crucially to the overall developmental outcome (Putnam, 2008). Moreover, play is regarded as increasing developmental potential and providing a medium for development of other skills, most relating to social interaction and communication. When children pretend play, they are involved in the communicative process of sharing objects with others. Teaching social play offers an opportunity to prevent many secondary consequences of autism. Therefore, play should be regarded as a serious intervention goal as well as a means of intervention for children with autism (Tsao, 2008).

2.1.4. Theory of triadic interactions and transitional objects

This concept comes from D.W. Winnicott, a pediatrician and psychoanalyst who belongs to the British object relations school of psychoanalysis. According to Winnicott (Winnicott, 1953), a transitional object is an inanimate possession, usually a toy or a blanket. Such object may become a facilitator of interaction between child and a caregiver and motivate the child to explore the external environment. The move towards exploration comes with so called “triadic interactions”. In cognitive science, triadic interactions involves shared attention between two people and another object or a third person. This interaction implies joint attention and intentionality. Typically developing children can transition to triadic interactions using simple non-interactive objects, whereas kids with autism may need additional interactivity to transition to triadic interaction. The technology enhanced solutions, such as robots provide such possibility (Elias, 2011; Winnicott, 1953).

2.1.5. Summary

For the purpose of this study it is important to remember that autism is a spectrum with highly diverse symptoms, ranging in cognitive and speech abilities. At the same time, the challenges that are typical across the entire spectrum are within the social and communication domains and abnormal perception of multi-sensory stimuli.

Some of the most effective therapies and interventions are based on the positive reinforcement and motivation. Multi-sensory integration is an integral part of the occupational therapy practices. This therapy expose children to various tactile, audio, visual stimulations during the activities and by means of various objects (lamps, tactile walls, heavy blankets, etc.). Such activities help these kids to perceive the environment in a calmer and more focused way, self-regulate and have more engaged and positive interactions with the environment. Moreover, children with autism have a special relationship with objects, often exploring them through touch, smell, and taste.

Other techniques like storytelling, role-playing and using visuals for communication are highly effective and widely used with kids with autism.

Lastly, it is important to remember that for children with ASD, like for any child, the activities should be playful and promote shared joy between child and a caregiver/therapist.

2.2. Existing HCI solutions for ASD

Technology is very popular with children with ASD because it provides structured and controlled environment. Technological solutions are beneficial for these kids because they remove unpredictability and stress, related to interacting with other people. Many technologies were designed for enhancing socializing potential through providing predictability and capitalizing on the interests of this population (Farr, 2010).

According to the survey conducted by Putnam (Putnam, 2008), the three most desirable areas that people with autism (or their caregivers) want to be addressed through technology are social skills, academic skills and organizational skills. Social and communication skills were the most desirable and were expressed by 32% of the responders. Additionally, 19% requested software to be designed with “fun” in mind. For example, one of the respondents requested, “games to teach him that he enjoys” (Putnam, 2008).

Generally, computer applications, designed for the ASD, can be grouped in two major types: assistive technologies and technologies designed for learning interventions. Assistive technologies aim at helping with daily activities and routines, such as digital planners and scheduling systems. The second group of applications try to help with acquiring social skills, emotion recognition, and provide alternative communication channels (e.g. visuals).

Overall, a prevailing number of studies investigate various types of technological solutions. Many of them are digital applications (Chen 2016, Garzotto 2017; Sampath 2013; Simm 2014) and how these solutions may help kids with ASD with recognizing emotions, organizing daily routines, and developing empathy. Another body of research investigates how robotic toys may enhance social skills of kids with autism (Gelsomini, 2017). Other studies are concerned with research of the natural-user interfaces (NUI) and how the whole-body interaction systems may augment sensory-integration therapies and creativity (Ringland, 2014).

Further, the author will provide an overview of the selected studies mainly from ACM Digital Library of various HCI solutions for addressing challenges of kids with autism, with special attention on enhancing socializing potential. The goal of the overview was to understand how these solutions can be grouped by the objectives they serve and by the type of technology/interaction is used to achieve the objective. The mapping does not provide a comprehensive list of all solutions but rather provides an overview that demonstrates main existing directions in the existing field of HCI in the domain of autism spectrum disorder.

2.2.1. Apps and avatars

A prevailing number of assistive phone and tablet applications try to address communication and social challenges as well as support children with autism in planning their daily routines and addressing restricted and repetitive behaviors. Majority of commercially available apps are not evidence-based products (Autism Speaks, 2018).

Image 3. Example of scheduling app (ChoiceWorks, 2018)

Guided play system

This system, in the form of a plug-in, evaluates the behavior of a child during playtime with the goal of minimizing repetitive behavior by prompting new activities on the screen. The system is using ABA intervention principles in its design. Specifically, it includes building response repertoires, prompting variety of tasks, and reinforcing variability. The system is still in the evaluation process, therefore the effect of the application on restrictive and repetitive behavior (RRB) mitigation is yet to be tested (Chen, 2016).

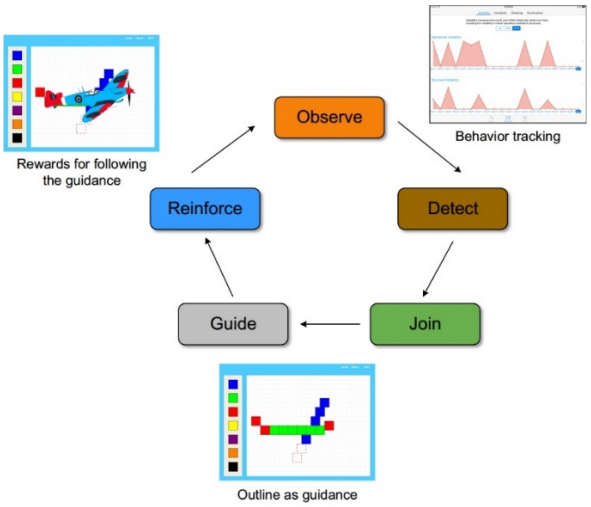

Image 4. Illustration of the Guided Play system (Chen, 2016)

Speech generating devices (SGD)

Speech Generating Devices (SGDs) provide speech output in terms of pre-recorded digitized speech. Many of these devices are based on pictures, and are designed so that a child selects a picture on the display of the device to play back an appropriate speech message. One of the benefits of these devices is that there is no limit on the number of pictures a child can carry in a SGD. Also, navigating and accessing a picture is much easier. Van Der Meer (2010) provided a review of SGD intervention with children with autism that covers 23 studies and 51 children. Most of these studies reported a positive outcome indicating that children with autism can learn how to use a SGD, and use it as an effective communication aid (Sampath, 2013).

Image 5. Example of the Speech Generating Device (Monroe Speech Designs, 2016)

FaceSay app for social skills

FaceSay produces games that can help children and adults with ASD with social skills by teaching them to recognize emotions and improving joint attention. FaceSay uses an interactive approach with computer animated avatars of humans and animals to teach emotion recognition skills. In the first of the three games a child should solve a problem by focusing on tracking the eyes of the avatar and then to respond to avatar's request. The study results suggests that providing children with opportunities to practice eye gaze, expression matching and face recognition in FaceSay's interactive environment improved their social skill. The children with Low Functioning Autism demonstrated improvement in two areas of the intervention: emotion recognition and social interactions (Hopkins, 2011).

Image 6. FaceSay App interface (FaceSay, 2018)

Baldi - avatar

Baldi is a virtual talking head, aimed at teaching language skills to children with autism. It is an avatar and a much more affordable alternative to physical social robots. Results from the evaluation of this system show significant improvement in vocabulary acquisition. It provides realistic visible speech that is almost as accurate as a natural speaker. (Bosseler and Massaro 2003).

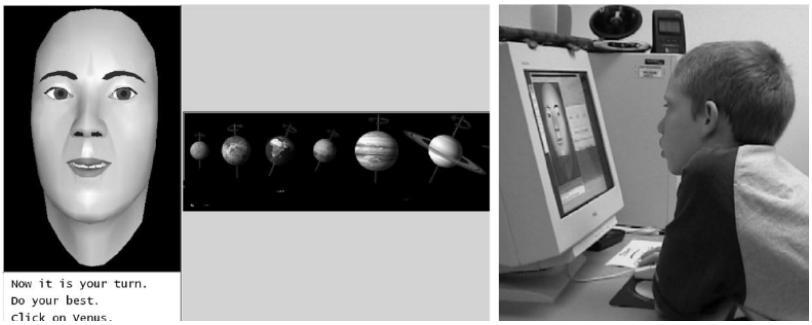

Image 7. Baldi-Avatar interface (Cole, 2003)

2.2.2. Social robots

Previous research with social robots (Kozima 2005, Gelsomini 2017) shows that children with autism effectively engage in social actions such as sharing attention, making eye contact and imitation with these robots. Social robots may provide a structured, predictable environment in which kids with ASD can perform social actions without anxiety in a close to reality interactions (Sampath, 2013). At the same time, social robots are costly and are not easily available for purchasing by many parents. Below are two examples of the robots aiming at enhancing social skills in children with autism.

Auti

The objective of the Auti robot is to encourage positive play behaviors and discourage problematic behaviors. Auti employs ABA positive reinforcement principles. For example, when a child exhibits positive actions like talking, patting or initiating play with a robot, Auti starts moving. And, contrary, when a child shows challenging behavior like screaming, hitting or throwing, Auti stops moving. Moreover, Auti has contrasting textures – fluffy soft fur and smooth legs for encouraging sensory exploration.

During the study an Active Auti (that would produce actions on its own) and Interactive Auti (adapting actions according to the child's behavior) were compared for the behavioral style of kids. Thus, the children with Interactive Auti displayed significantly more targeted positive behaviors than with Active Auti. It was noticed, that children with different levels of functioning appeared to play with the toys differently. For instance, low functioning children explored the toys sensory (touching it to their faces, feeling the vibration and holding the smooth legs while they moved). They would not respond to the action-response interaction (Andreae, 2014).

Image 8. Auti – social robot (Medgadget, 2011)

Puffy – inflatable interactive companion

Puffy is a social robot and meant to support educational and therapeutic interventions of kids, particularly for those with perceptual and sensory processing impairments. Puffy is programmed in a way that it can spot movements, emotions, and facial expressions of children. It provides feedback through lights, movements, voice, and video projections on its body. The visual appearance of the robot, with its affordances and multisensory stimulations, is meant to attract attention, to promote trust and engagement. The Puffy has been designed in cooperation with therapists and informed by previous research. It is in process of being studied with children (Gelsomini, 2017).

Image 9. Puffy-social robot (Gelsomini, 2017)

2.2.3. Natural user interfaces

Natural user interface (NUI) and gesture based natural interaction (NI) offer a new exciting interaction medium for children with autism.

Sensory paint

Sensory Paint is a natural user interface that uses Microsoft Kinect technology to superimpose the reflection of a user's body on the projected surface. Once the reflection is imposed, a user can "paint" it, manipulating tangible balls in his/her hands. This solution provides a combination of a whole-body movement and tangible interaction and is aimed at augmenting sensory integration therapies. The study results indicated novel ways to engage kids with ASD that can promote the development of social skills and multi-sensory abilities. (Ringland, 2014).

Mediate

Mediate is an interactive environment designed for kids on low-functioning autism to stimulate creativity and have fun time playing without any directed guidance from caregivers. Mediate generates multi-sensory stimuli in real time such as vibrotactile, auditory and visual. It is an adaptive interactive system which changes the stimuli depending on a child's body movements. The study showed promising results, indicating engagement from children with ASD even during the initial introductory stage. All participated kids expressed curiosity and explored system independently (Gumtau, 2005).

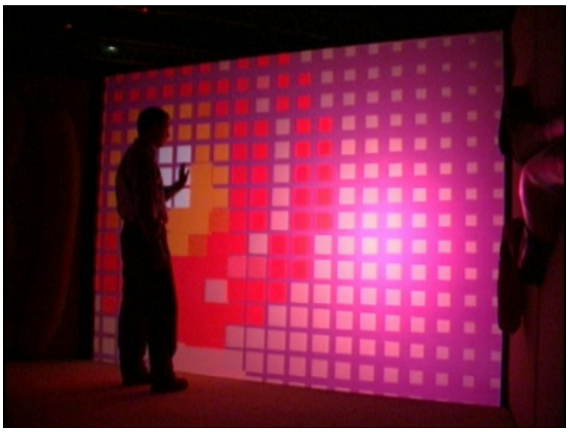

Image 10. Example of the interaction with the Mediate (UPF, 2015)

2.2.4. Tangible user interfaces

Tangible user interfaces (TUIs) are a branch of the field of Human-Computer Interaction (HCI) that embed digital technology into graspable forms, allowing users to access computer technology in novel ways (Ishii, Ullmer,1997) Further, according to Ulemr and Ishi (2000) "tangible interfaces give physical form to digital information, employing physical artifacts both as representations and controls for computational media." Tangible interfaces require designing both digital and physical form. Interconnectedness of both forms allows creating new forms of interactions. Such interactions are characterized as haptic, full body and spatial (Hornecker, 2006).

Haptics, a term that originates from a Greek word "haptesthai" meaning "of or relating to the sense of touch". Nowadays, **Haptic** is "the science of applying tactile, kinesthetic, or both sensations to human– computer interactions. It refers to the ability of sensing and/or manipulating objects in a natural or synthetic environment using a haptic interface" (ElSaddik, 2011). **Haptic interface** "consists of a haptic device and software-based computer control mechanisms. It enables human–machine communication through the sense of touch. By using a haptic interface, someone can not only feed the information to the computer but can also receive information or feedback from the computer in the form of a physical sensation on some parts of the body" (ElSaddik, 2011). **Haptic feedback** in most of the interfaces refer to vibration. In more complex environments like video games, haptic feedback may include force (movement) and non-contact feedback like air. In this study when we talk about haptic feedback we refer to vibration.

Even though many digital applications are aimed at addressing social challenges in kids with autism, they are often criticized for their addictiveness and isolation from human to human interaction. Children prefer to interact with the computer more than with a human, minimizing their social interactions in real environment.

Tangible objects are an example of the alternative technology and have an advantage over digital interfaces in that they can be shared and passed between multiple users while providing a desirable predictability and social interactivity at the same time. Tangible user interfaces may provide a fruitful avenue for supporting social interaction in children with ASD (Farr, 2010).

TUIs are offering a number of advantages over the digital interfaces. First, they are more accessible and intuitive from usability perspective, compared to other technologies. Second, TUI are successful in facilitating learning process because they are more entertaining and facilitate collaborative work. For instance, the collaboration is enhanced by allowing to share common space between users and observing other players' activity, and promoting imitation games. (Marshall, 2007).

A number of previous studies suggest that tangibles encourage social interaction in kids with autism as they allow for a broad range of interaction styles. Moreover, the studies on tangibles, enhanced with technology, show even better results with positive effects on social skills development. For instance, a notable study by LeGoff (2004) found that LEGO TM play reduced behavior typical of autism and improved social responses over an eight-week period. The author turns LEGO sets into tools for group work in children with Asperger's syndrome and highly functional ASD children. In this study, social responses were measured in terms of motivation to interact with peers, manner in which interactions were sustained, and whether aloof and rigid behaviors were overcome. The results of the intervention were positive, showing an improvement in social skills for all children (LeGoff, 2007). The study gives evidence that interventions related to play, collaborative work and objects can generate an improvement in long-life acquisition of social skills. Further, W. Farr (2010) tested and compared two types of interventions: LEGO therapy and the use of a tangible and programmable toy, called Topobo. The results of the study showed that playing with Topobo were effective in reducing solitary play activities, facilitating collaborative and associative play in comparison to the non-interactive tangible objects (Lego) (Farr, 2010).

Further, previous research on integrating TUIs into sensory integration occupational therapies with children with autism has demonstrated positive effect for enhancing attention, shortening duration of solitary activities, and lowering arousal (Farr, 2010; Hornecker, 2006; Sitdhisanguan, 2012; Villafuerte, 2012).

An occupational therapy method that supports sensory integration is believed to help stimulate brain activity in children with autism, and thus enhancing learning (Caldwell, 2008). Sensory integration is especially important therapy for Low-Functioning Autism children who often do not develop speech and rely on objects for interaction and communication. Therefore learning by manipulating objects is simpler for these children and more useful because tangibles serve as sensory stimulation in addition to its main learning objective. Therefore, TUIs by providing both interactivity and multiple senses stimulation should enhance learning process (Sitdhisanguan, 2012).

Further, the author will provide an overview of some of the existing TUI based solutions and how they intended to address the socializing potential of kids with ASD.

Topobo

Topobo is a 3D constructor with kinetic memory and ability to record and playback physical motion. A user can combine together static and motorized parts of the constructor and create shapes of animals and skeletons that are dynamic. For example, a dog can be constructed and then taught to walk by twisting its body. The dog will then repeat those movements and walk repeatedly. The Topobo was developed primarily for kids of 5-13 years old of normal development. Further Farr (2010) conducted a study where he observed the social behavior and cooperative play in six boys with autism during their play with both Topobo and Lego building blocks. The study results demonstrated that Topobo produced more cooperative play than LEGO. This demonstrates that toys enhanced with technology are more advantageous in unlocking the socializing potential of children with autism. (Raffle, 2004; Farr 2010).

Image 11. Example of Topobo constructor (Freezcha's blog, 2017)

Augmented knights castle

Farr (2010) in his other study compared the effects on social behavior of kids playing with a configurable tangible interface versus non configurable. Both TUIs were in the form of a castle with different physical elements. In a configurable castle a child could program his/her own voice for each element (physical figures) on the castle. In non-configurable castle figures had pre-programmed voices depending on the location they were placed by the child (achieved via RFID tags). The study showed that twelve participating children with mild autism demonstrated more cooperative play with the configurable castle versus non-configurable one. The process of making new sounds produced more excitement than having already pre-programmed sound. At the same time, children were engaged in more symbolic and imaginative play with figures in a non-configurable castle. A question still remains whether the demonstrated effect will remain with time. For that a longitudinal study is required.

Reactable – musical TUI

Another study assessed the potential of a musical tangible user interface for promoting social interaction abilities. The Reactable is a circular tabletop and a musical instrument that allows creating of complex musical pieces in a group. Users can interact, both through direct contact with the table, and through objects which are grouped in four categories: generators, sound effect, controllers and global objects.

During the study nine children with ASD participated in the research. The sample of the study served as a control group. The type of the study was basic withdrawal, as well as qualitative tools were used. In a statistically significant study the results showed an increase in social interaction during the sessions, including non-verbal children. The study findings showed that tangible objects with musical triggers are constantly reminding children of presence of other players and their role during playtime. The musical triggers and sharing objects were capturing children attention and promoted more cooperation. (Villafuerte, 2012).

2.2.4.1. Soft tangible interfaces

Stuffed toys, weighted blanket, pillows, or weighted vests have been used for various purposes such as promoting engagement, sustaining attention, and relaxation for children with ASD.

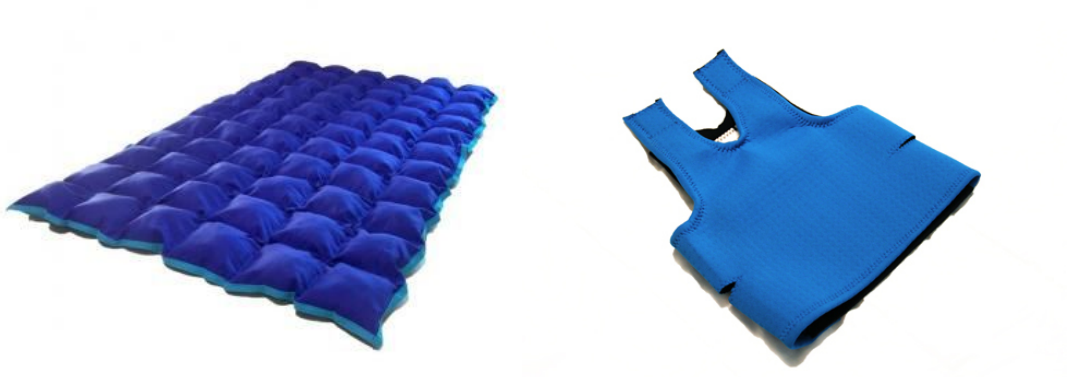

Image 12. Example of a weighted blanket and a weighted vest (LovetoKnow, 2018)

Wearable computing and **soft tangible interfaces** with haptic feedback is another area of HCI solutions being explored recently. **Wearable computing** is "the study or practice of inventing, designing, building, or using miniature body-borne computational and sensory devices. Wearable computers may be worn under, over, or in clothing, or may also be themselves clothes" (IDF, 2nd Ed.).

An example of **Soft tangible interface** could be soft toys, pillows and other soft objects with embedded electronics. Some of those soft tangible interface solutions employ **electronic textiles (e-textile)** as part of the design process.

E-textile, also known as **smart garments**, **smart clothing**, **smart textiles**, or **smart fabrics**, are fabrics that enable digital components such as a battery and a light, and electronics to be embedded in them. Smart textiles are fabrics that have been developed with new technologies that provide added value such as they can conduct electricity, or serve as body sensors (Kuusk, 2007; Hartman, 2014).

In this study term **E-textile** will mainly refer to the fabric and threads that conduct electricity, allowing seamless integration of circuitry inside of an interface. The benefit of using e-textiles is that they allow enhanced intuitiveness of manipulation with the objects. A selected number of existing prototypes are provided below.

+Me - transitional wearable companions

Transitional Wearable Companions are interactive devices, aimed at promoting engagement and emotional attachment in children with ASD. These types of devices are soft and look like animals. The devices are reacting based on a child's actions by outputting light, sound and vibration and providing reassuring physical contact. An important aspect is that a child can carry the object and thus develop an attachment to it without guidance from a caregiver. In addition, the caregiver has a possibility to reprogram the device in regards to its input/output rules and it has biosensors to gather information on physiological and emotional state of a child. This feature provides an additional value of on-line monitoring of the child's state and ability to alter the interaction with the device accordingly and even remotely. In a pilot study it was noticed that soft structure of the object and light effect were especially popular with kids with ASD (Quek, 2016).

Image 13. +Me transitional toy (Ozcan, 2016)

Soft haptic toys

Exploratory design and workshops where kids with autism would be actively involved in creating soft toys were explored with positive outcomes. This workshop session was a continuation of the Master thesis research by Aravindan where she designed and evaluated several prototypes. (Quek, 2016). The goal of the prototypes was to provide relaxation to children through manipulation of the soft objects with various vibration patterns. The results of the study showed that children especially enjoyed the softest textures for chosen fabrics and liked animal figures for toys, specifically cat shape. The vibration patterns were not distinguished precisely and were mainly perceived as strong, weak, or non-existent.

Image 14. Soft interactive toys (Quek, 2016)

2.2.5. Background research findings

The mapping of the existing HCI solutions available for children with ASD demonstrated a variety of objectives that these solutions are trying to address as well as the types of technology and interaction employed for achieving these objectives. Thus, digital applications' main objectives are to help children with autism to manage everyday life activities. Digital applications are very popular with children with ASD but they are often criticized for their addictiveness and impeding social interactions in real life.

Natural User interfaces are offering a whole body interaction with a system for promoting socializing and collaborative skills. Research shows positive effect on collaborative and social skills after using NUI solutions. At the same time, NUIs are requiring special equipment (e.g. Microsoft Kinect) and quite large spaces and therefore are not easily affordable by daycares and families.

Evidence based research on robots offer a promising way to teach children social skills in a more relaxed and controlled environment but unfortunately they are still very inaccessible for many parents due to their high cost.

Tangible User Interfaces provide an alternative technology offering important advantages over digital interfaces. Thus TUIs are more intuitive in use because they are physical objects. Also, they are successful in facilitating learning process and encouraging collaboration and socializing (Farr, 2010). More importantly, they provide an essential multi-sensory stimulation which is necessary for children with autism. We also see that soft tangible interfaces are especially exciting for children on low-functioning spectrum. From the overview of some of the existing TUI solutions, we see that they demonstrated promising results for promoting socializing potential in children with autism. At the same time, all the reviewed studies on TUIs designed for children on ASD have several weaknesses and challenges. First challenge is the heterogeneity of the autism spectrum disorder. Designing for this population is extremely challenging task because every child on spectrum is highly unique with his/her own needs, preferences, cognitive level, speech abilities and sensory perceptions. A solution designed for one child may not be suitable for another. In this case each solution should be carefully designed with a very specific characteristics of a target population in mind: same level of spectrum, similar cognitive level and speech abilities, similar sensory deficiencies, etc. Most of the studies reviewed had highly diverse groups of children in terms of spectrum, cognitive level and other characteristics which resulted in variability of the outcomes. For example, some children on low-functioning spectrum would behave in very different way from other children or they would interact with objects in a more intimate tactile way (biting, licking, exploring in a very close proximity) or would prefer the softest materials (Villafuerte, 2012; Quek, 2016).

In addition to that, all the studies thus far had very small population size (<10) which does not allow generalization. Lastly, to our best of knowledge, there was no thorough study done on the

soft interface incorporating smart textile technology for autistic children and how the interaction with soft physical objects with multi-sensory feedback may stimulate attention and enhance socializing of children on low-functioning ASD.

To sum up, the overview of the existing solutions and their limitations provided us with a foundation for designing the prototype of the “Interactive Carpet” and informed the study design for evaluating the prototype with children.

3. Research process

The **goal** of this master study is an attempt to explore different properties of the interactive, e-textile based prototype and how they may stimulate attention and promote better child - caregiver interaction. Considering the plethora of research on TUIs and sensory integration therapy, we **hypothesize**, that soft properties of the interface with various sensory feedback and detachable interactive objects should promote attention and enhance socializing. Therefore, the **research questions** are the following:

Q.1. To what extent can “Interactive Carpet” promote attention and enhance interaction between a child and a caregiver during playtime?

Q.2. In what ways can therapists and caregivers utilize the “Interactive carpet” in their occupational therapy practices and for playful experiences?

To achieve the goal of the study the author used mixed methods under the greater **User-Centered Design** (*Image 15*) and **Research through Design** approaches.

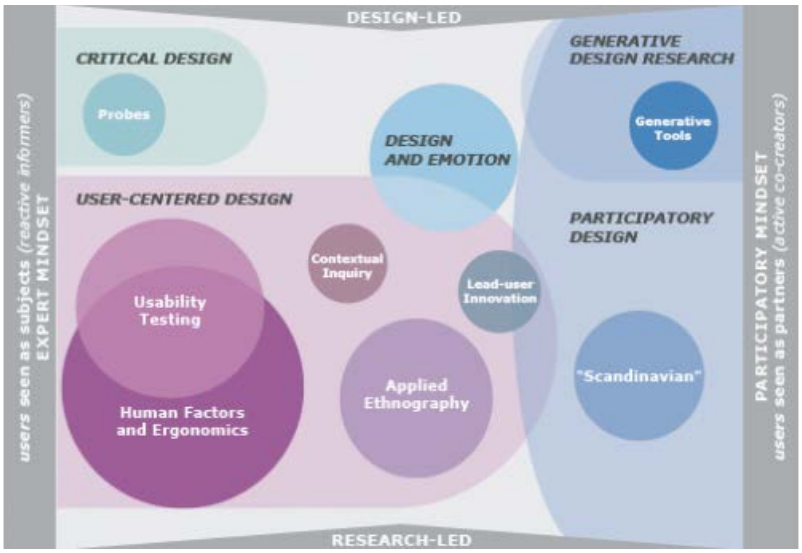

Image 15. Emerging trend in design research. The image is based on (Sanders, 2007)

Creating effective and useful products from a **user-centered** perspective begins with a focus on user goals, attitudes and behaviors (Cooper, 2003). 'You are not the user', can be heard from people who are skeptical about the effectiveness of user-centered methods. Keeping this in mind is even more important when designing products for audiences with special needs (Fischer, 2002).

Within the greater user-centered approach we employed the contextual inquiry approach to inform our first prototype iteration. **Contextual inquiry** is finding out about people's work where they are doing that work, while they are doing it, and finding out what doing that work means to them (Dekker, 2002).

During the contextual inquiry the author has met with therapists at Kaokeskus daycare in Tallinn and was able to observe the daily therapies and activities which therapists are practising with children. During the activities at the daycare the author was able to conduct unstructured interviews, take rich notes and photos.

Research through Design (RtD) is an approach to conducting scholarly research that employs the methods, practices, and processes of design practice with the intention of generating new knowledge (Olson, 2014). It is a concept where "designed artifacts, would become established as the chief elements in the process of generating and communicating knowledge" (Human-Interaction Design Foundation, 2018).

The RtD in the case of this study consisted of two iterations of prototyping, each of them followed by an observational study with children. Each observational study would inform the design of the next prototype. The conclusions and recommendations were gathered, analyzed and presented in the study results. The research process is demonstrated in the *Figure 3*.

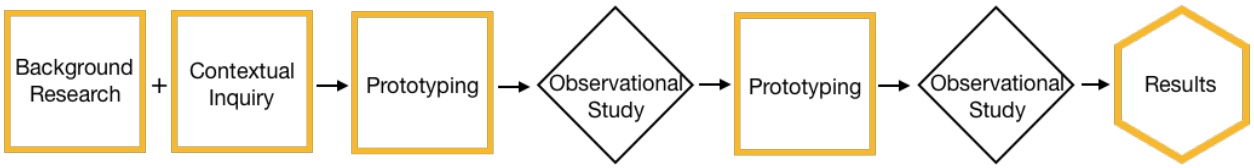

Figure 3. Research process

3.1. Contextual inquiry

In addition to background research on the existing interventions, occupational therapies and the existing HCI solutions for addressing the challenges of children with ASD in a social domain, the author met with practicing therapists from Kaokeskus day care (Käo Tugikeskus) in Tallinn. The daycare is working with children of various disabilities. Children with autism who go to this daycare regularly are mainly on low-functioning autism spectrum. During the meeting the author conducted an informal interview during which she took rich notes and took photos of the existing toys and tools, as well as observed some therapies which are actively practiced with children with autism. The author was also able to observe children participating in the activities and physical therapies. One of the therapists, Ms. Kati Kiiver, kindly showed various rooms they have at the daycare, such as sensory room, physical therapy room, playroom, kitchen as well as toys, games and techniques they practice with children.

In addition to meetings with therapists, the author had interviewed a parent who has a child with autism spectrum and who was able to gather feedback from other parents and share with an author. Thus, parents emphasized the importance of cause – effect learning interactions with special emphasis on “success and positive emotions”.

The gathered information from meeting at the daycare and with the parent represented in the *Table 1* and in the *Images 16-20*.

Topic of Inquiry	Gathered Information
Types of interventions, therapies practiced	Therapies: learning, behavioral, sensory integration; tactile, visual, smells, physiotherapy, music therapy, audio therapy. The center has developed its own communication system for kids following the Pragmatic Organized Dynamic Display system.
Principle of assigning interventions to children	The techniques varies according to the spectrum and cognitive level of kids. A sensory profiling test is used to determine whether a child is hyper or hypo sensitive
The most popular effective tools/toys/activities	Sorting, matching, simple domino, puzzles, memory games; sensory room (heavy blanket), sensory soft wall made by a parent; playing with objects of different texture, softness, color; associative activities (wind associates with a blowing air, winter = snow, object-related sound); Cause and effect games; Preferences greatly vary depending on the spectrum and cognitive level
Most effective types of TUIs, tangible objects used	Different objects of different shapes, surfaces, hardness, color. Kids like to squeeze, stroke objects, look at them very closely; vibrating objects are very attractive
Most desirable characteristics of games, toys with children	Children like to feel different surfaces, temperature change, smell, light (fiberglass) but not flashing bright light. Sound is very important
Spectrum of autism and age of children	Severe, low-functioning spectrum (most of the kids do not speak or walk), age 7 – 17 years old but cognitively equal to 2-3 years old
Most pressing challenges to be addressed	Children have difficulties with finding activities to do, to occupy themselves

Interaction style	A game/activity should allow a child and a caregiver to play together, share the same interactions for shared experience.

Table1. Gathered information from Kaokeskus daycare center

Using simple thematic analysis technique by means of most frequent words generating application, we constructed a sentence using the most frequent words from our contextual inquary investigation (*Figure 4*): “Different sensory objects/games with cause – effect, sound, color, surface.” “Different objects” are emphisized, inferring a need for variety to address highly diverse needs of kids with autiism.

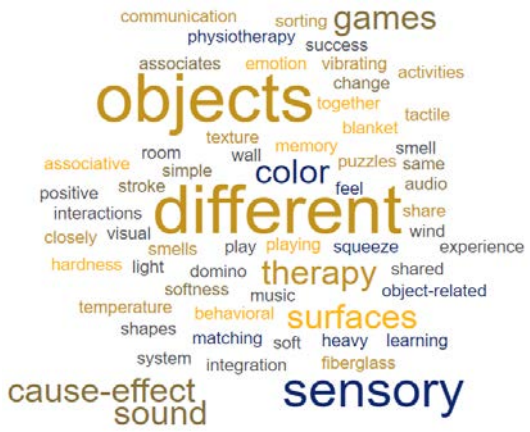

Figure 4. Most frequent words from the contextual inquiry

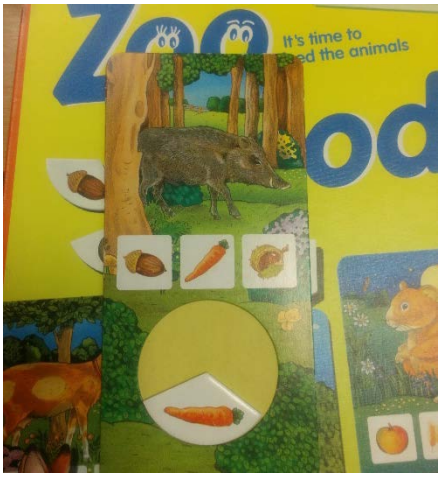

Image16. Matching game

Image 17. Puzzle game

Image 18. Sensory room

Image 19. Visual communication system

Image 20. Soft sensory wall made by a parent

Further, the author participated in the LUDI Training School “Play & Toys for All” where she immersed in a four days training on the importance of play and playfulness for children with disabilities, including with autism spectrum disorder. During this time she was able to receive not only theoretical knowledge but practically engage into experiences of children and their parents, observe the playtime, explore the existing toys and tools. In the end of the training, collaboratively she built a prototype of a toy for one of the participated children. This training has greatly informed further the design of the future prototype for this master thesis from the perspective of playfulness and importance of creating not only educational and assistive solutions but also those that would spark joy and “play for the sake of play”. “Play for the sake of play” is often an overlooked concept but we as designers and researchers should pay special attention to the concept of play because during playtime children learn essential life-long skills and the more enjoyable the process the

more engaged children are. The more engaged they are in the process, the more effective the results of the learning objectives become.

Moreover, the author was consulted throughout the duration of the study by clinical neuropsychologist and Associate Prof. of Paediatric Neuropsychology at Tallinn University, Dr. Mari-Liis Kaldoja. She advised on the autism spectrum disorder and each iteration of the prototype design was discussed with her.

3.1.1. Summary

Thus, after summing up all the findings from the background research and contextual inquiry at the Kaokeskus daycare, the following points were collected to inform the prototyping process and design concept of the "Interactive Carpet".

1. Autism spectrum disorder is highly heterogeneous in nature; therefore design of the prototype has to be highly customized for a very specific group of children in terms of their spectrum, cognitive development, multi-sensory dysfunction level and speech abilities;
2. In spite of high diversity of symptoms, impairments in social understanding, emotion perception and communication are present across all the spectrum;
3. Majority of children with ASD are having sensory dysfunction and multi-sensory integration therapy (MSI) is among the most common interventions (Lang, 2012).
4. It is essential to foster playfulness, humor and friendship, at the same time keeping in mind the therapeutic objectives of the activity (Zager, 2005);
5. According to the theory of triadic interactions and transitional objects, inanimate object (which can be carried, moved) may become a facilitator of interaction between child and a caregiver and motivate the child to explore the external environment (Winnicott, 1953). A TUI in a form of a carpet may serve as such transitional object;
6. Tangible User Interfaces provide an alternative technology offering important advantages over digital interfaces, especially for children on low-functioning spectrum. Thus, TUIs are more intuitive in use because they are physical objects. Second they are successful in facilitating learning process and encouraging collaboration and socializing (Farr, 2010); they provide an essential multi-sensory stimulation which is integral for children with autism;

7. E-textiles technology provides seamless integration of the electronics for enhanced intuitiveness of manipulation with the objects, providing greater comfort;
8. Some of the most popular and effective games and activities are sorting, matching, simple domino, puzzles, memory games; sensory room (heavy blanket), sensory soft wall; playing with objects of different texture, softness, color; associative activities and cause and effect games;
9. Children like to feel different surfaces, temperature change, smell, light but not flashing bright light. Sound is very important for many kids;
10. One of the most pressing challenges is that children have difficulties with finding activities to do, to occupy themselves for a sustained time;
11. The associative interactions with cause-effect that can teach about the world around (nature, animals, and emotions) are highly recommended;
12. A game/activity should allow a child and a caregiver to play together simultaneously, share the same interactions for shared experience and joy.

3.2. Prototyping

The prototyping process took a long time (two semesters) and was evolving throughout the whole research process. The prototyping included concept development, paper prototyping, experimenting with smaller versions of each future interaction on the main prototype and continuous experimentation with e-textile techniques.

The initial concept development of the future interactions was based on the background research and heavily influenced by the recommendations from the therapists and author's explorations of the existing techniques and tools at Kao Daycare. It was also customized for a specific group of children with whom the future prototype would be evaluated with during later stages of its development.

3.2.1. Target population

The Kaokeskus daycare expressed willingness to evaluate the prototype with children, therefore, the design concept was developed, keeping in mind children who attend this daycare regularly. We did not know who exactly would play with the prototype when it was ready but we knew that

most of the children with autism in Kaokeskus were on low-functioning autism spectrum disorder (LFA).

Children with LFA typically have restricted language (Preissler, 2008), behavioral and emotional issues, severe memory impairment (Boucher, Bigham, & Mayes, 2012), poor adaptive behaviors, sensory-related issues (Hall, Graff, 2011), and limited social skills (Holt, Yuill, 2014).

At the Kaokeskus daycare the most widely used interventions and therapies are communication system using visuals, music therapy and multi-sensory stimulation. Usually LFA kids at this daycare are playing on their own or with guidance of a caregiver. They often use objects as communication tools, explore things through tactile and visual senses by touching, squeezing, stroking, biting, tasting on a mouth. They have very short attention span and it is challenging for them to get accustomed to new things, activities, and environment. The age of children vary from age 7 – 17 years old but cognitively it is equal to 2-3 years old of normal cognitive development.

3.2.2. Initial design inspiration

Keeping the target population in mind, the initial concept envisioned some kind of "transitional object" that can be easily manipulated and moved by a child and/or caregiver and that can be easily integrated within a play space at the daycare. The object should provide multi-sensory stimulation and be highly intuitive and familiar for children. For example, at the Kaokeskus, one of the parents created a tangible sensory board (*Image 20.)* using felt and other soft materials. Some of the elements of the board were detachable by means of Velcro. The board would tell the story around the children' daily routine of commuting to the daycare. Therapists use this board regularly and children enjoy interacting with the board by manipulating the elements and attaching them to the wall. It gave an inspiration to the author for creating a similar sensory artifact but with cause-effect interactions and detachable objects, enhanced with technology. From the theoretical background research we learned that children with autism may benefit additional degrees of "animacy and interactivity" to elicit their engagement. The cause-effect regular nature of such type of interaction would give a child a higher sense of control and hence mitigate fearful and avoidance reactions (Elias, 2011).

Author: "What if a future prototype could be some sort of magic carpet, a storytelling platform, with different objects that could be mixed, detached and new created, and would teach about

environment around, at the same time providing multi-sensory stimulation and enjoyable experience to children?"

The author started looking if such carpet was already designed for children with autism but did not find anything like this. At the same time there were some products that shared certain similarities and served as an inspiration for the future design.

Image 21. Inspiration for prototype design (Amazon, 2018)

The inspirations from the contextual inquiry and other existing products lead to the creation of the paper prototype of the future "Interactive Carpet".

3.2.3. Paper prototype

The main goal of the paper prototype was to map out visually the future interactions on the carpet and what purpose they could serve: learning, therapeutic and playful.

Image 22. Paper prototype

The primary goal of the future prototype is to explore in what ways it can promote interaction between child and a caregiver, at the same time providing sensory stimulation and teach simple things about the world. For that, the game should provide various interactions which will require both collaborative and independent activities that can be shared. The play process should be supervised and directed by a caregiver who should explain and demonstrate different elements of the game (especially in the beginning) and engage in an interaction with a child through the elements of the game. Different elements of the game will require different inputs and will produce different outputs and serve different goals as described below.

Interaction 1. – Family. This is a cause-effect element representing a family which was envisioned to demonstrate two emotional states (happy and unhappy) based on the manipulation with the game. For example, if a player places balloons to the hand of a doll, a face of the child character doll would demonstrate a smile (the smile will light up with LED lights). If a player touches a fish element, a male character will "smile" because he is happy to catch a fish. In these interactions a caregiver should play an important role of explaining the meaning of interactions and storytelling.

Interaction 2. – Rainbow. This is a collaborative element. Two players at the same time should place the elements of the sun and the element of the rain cloud in order to get a rainbow. When both elements are pressed the rainbow will be light up.

Interaction 3. – Grass. This element requires stroking of the grass. When stroked, a player will receive light-on feedback.

Interaction 4. – Musical Caterpillar. This element will represent a musical game. The caterpillar is envisioned to play a simple melody and each colored circle will correspond with a distinct color according to each sound. The task of a player is to repeat the melody.

Interaction 5. – Puzzle House. This element will require a player to move the blocks in a way so that they match the shape of the house. When blocks are matched correctly a player will receive a vibration feedback.

Interaction 6. – Fish. This is a cause-effect interaction. After a gentle pressure onto a fish object, a player will receive a vibration feedback under his/her palm.

The paper prototype envisioned the most desirable (by caregivers and parents) types of interactions: cause-effect and associative, as well as it provides haptic feedback (vibration), sound and light for multi-sensory stimulation and attention promotion.

Initially, it was thought (mainly due to technology knowledge limitation) that some elements of the game would be permanently attached to the carpet and some would be independent detachable elements. The detachable elements would add more creativity and freedom of play and novelty through time. Other elements can be added as well but it is important to keep the game simple and not overwhelm a child with too many elements. The neuropsychologist, Dr. Mari-Liis Kaldoja, has advised to minimize the initial interactions because it can make a child nervous. The detachable elements can be added as the play progresses.

After the paper prototype was created and discussed with Dr. Kaldoja it was time to experiment with technology and start building first interactive elements.

3.2.4. E-Textiles

Previous work on how to promote acceptance in the context of sensitive service determined that by promoting a state of confidence it is possible to increase the final acceptance. Trust is ensured through the use of intuitive elements which are easy to understand and be in control while using those. The ability to integrate soft circuitry with everyday objects (clothes, toys, etc.) leverages the familiarity and intuitiveness of the objects in which they are integrated. (Vega-Barbas, 2015). The use of e-textiles presents an interesting option for the development of the prototype for children on low-functioning autism. The soft circuit or e-textile technique provides great potential for people with difficulties to explore touch-based interaction (Heimdal, 2010).

The rationale behind using only soft circuits by means of conductive thread and conductive fabric was to enhance the intuitiveness of the prototype and provide greater comfort and "coziness" during playtime. As it has been established, for children with LFA it is especially difficult to get accustomed to new objects and environment. We thought that fully soft object in a form of a "foldable" and "squeezable" carpet can provide additional comfort and make the process of familiarization easier for kids.

3.2.5. Making process

The process of experimenting with circuits and coding took long time because the author did not have previous experience neither with electronics nor with programming. Nonetheless, it was an exciting and rewarding experience.

First, all separate interactions were tried out in a mini versions of little prototypes to understand what was possible, what was not and how to make it possible. Before starting with electronics the author conducted a thorough research on the existing e-textile materials, their properties (conductivity, resistance), learned from the tutorials and blogs (Instructables, 2018; Hartman, 2014).

The main materials and tools used during small and big prototyping are the following:

Soft circuitry: conductive thread, conductive fabric, conductive Velcro;

Microprocessor: Lilypad, an Arduino based and designed for e-textile technique specifically;

Sound: Lilypad Mp3 player;

Actuators: LEDs of various form, size and color; vibrating motors;

Sensors: Do it yourself (DIY) pressure sensors;

Switches: DIY momentary switch, soft buttons;

Power: Lipo (Lithium ion polymer) battery 3.7 V, 2000 mAh

Materials: felt, cotton, regular threads, mesh, Velostat.

The very first interaction the author began experimenting with was rainbow. It is meant to be a collaborative interaction that needs two people at the same time to activate the output. For the input a user needs to place a sun and a cloud on the conductive Velcro in order to receive a rainbow as an output. The embedded LEDs on the rainbow would light up.

Image 23. Mini prototype of a Rainbow interaction

The initial challenge for all the interactions was to figure out how to make the elements detachable, ideally, all of the elements. After some probing and consultations with one of my supervisors, Dr. Kristi Kuusk the author realized that the conductive Velcro can be used for these purposes. Basically, all the objects had Velcro on the back of their surfaces which had to be attached to the corresponding conductive Velcro on the body of the interface. After the first interaction was

completed, the author moved to experimenting with the figures of dolls to achieve the effects of the emotion through cause-effect interaction. In a brain-storming session with Dr. Mari-Liis Kaldoja we thought about the way of how an emotion could be demonstrated through interaction with dolls. It had to be an easy to understand cause-effect element that would instantly be triggered by certain action. Of course we understood that emotion was a complex construct and may be not clear to children on low-functioning spectrum. Yet it was important to include it because understanding emotions is one of the most prominent challenges for children with ASD within social domain. In the end, it was decided to show positive emotion by lighting up LEDs on the mouth of each doll. The LEDs would light up if a certain input was performed with dolls: placing a flower or balloon on the hand of a doll; placing a hand of a doll onto another doll's hand, etc. All these were achieved by means of conductive Velcro. The next set of interactions was the underwater world with fish elements. The fish elements' input was a pressure sensor, and output-haptic feedback (vibration). To achieve this interaction the author had to create a pressure sensor. It was a handcrafted pressure sensor, implemented in a "sandwich" like way with velostat (resistive material). By creating certain threshold the author determined at what resistivity the output (vibrating motor) would be triggered. The vibration strength was also programmed to change its level based on the pressure force.

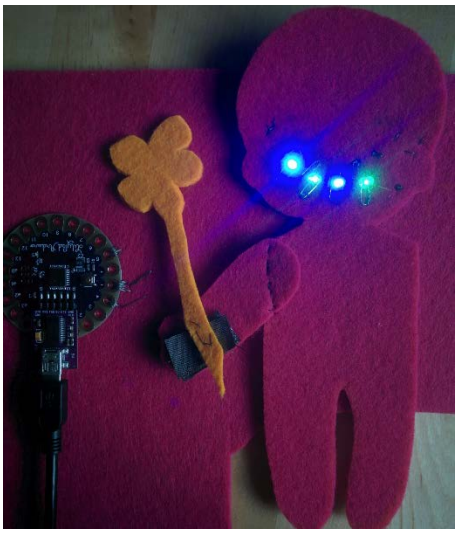

Image 24. Mini interaction with a doll

Image 25. Experiments with switches and sensors

After experimenting with interaction with the dolls' elements, the author moved to figuring out how to integrate sound seamlessly to the element of the rain cloud. The idea behind this, was to

provide an audio stimulation to a child. Thus, by pressing the cloud a sound of a thunderstorm with rain would play. To do that some sort of player had to be integrated into the circuitry. The Lilypad Mp3 player served this role. The principle was that by grounding through a momentary switch a certain pin on the Mp3 player microprocessor, a music uploaded to sd card (sd slot is integrated into the Mp3 player) would start playing. In addition to customizing the Mp3 code, the soft momentary switch had to be created to trigger music on the Mp3 player. After all the desired interactions were implemented in the form of mini-prototypes, the author moved to building the first iteration of the main prototype with all desired interactions and elements on it.

3.2.6. Iteration 1

First, the author found a suitable mesh, the body of the interface (*Image 26*) where the circuitry would be seamlessly integrated. Two pieces of natural thick felt (40 cm * 20 cm each) were combined (sewed together) into one big piece (80cm * 40 cm).

Image 26. Paper elements on the interface felt body

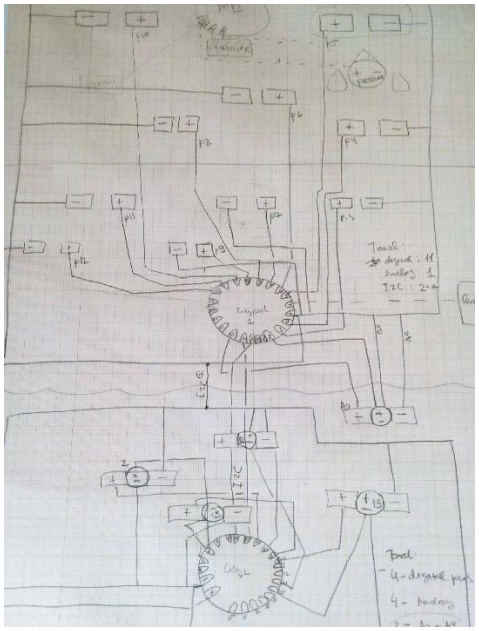

Image 27. Circuitry schema

Second, the circuitry schema was drawn (*Image 27*) which included two Lilypad microprocessors to accommodate all necessary pins, both digital and analog. Third, the interaction of the rainbow (*Images 28, 29*) was created following the principal of the mini prototype built before. The actual element was carefully crafted to resemble the real rainbow will all required colors in the right

order. The LED's were sewed and connected in series to save on digital pins. At the same time, it was important to figure out how many LED's can one pin light up finely. In this case it was 5 LEDs per one digital pin.

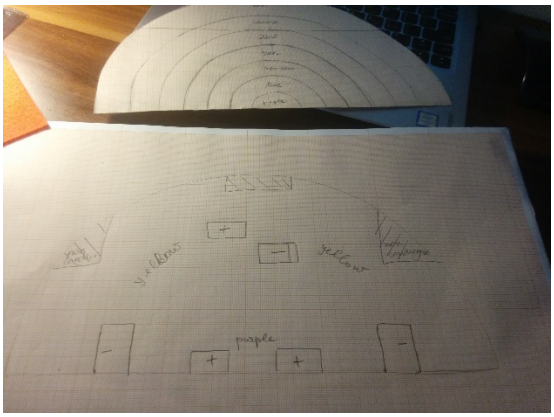

Image 28. Circuitry schema of the rainbow

Image 29.Rainbow element with LED's on

Next, the figures of dolls (*Image 30*) were crafted so that each figure could be a detachable object. It was a tricky element because the conductive velcros have to be integrated into the rest of the soft circuitry so that one pair of them would be responsible for the LED's output, another pair would be responsible for grounding the trigger for the actuator to start (LED's on the mouth of a doll).

Image 30. The elemnts dolls

Image 31. Soft circuitry

Then, the elements of fish with pressure sensor and the Mp3 player were integrated into the circuitry. The last element was the grasss (*Image 32*) but in the first iteration it was not interactive

yet. At the same time it was figured out how to create it in terms of physical design. It was essential to create a grass looking element, which can be stroked so that each stroke would serve as an input to an output (LED's in this case).

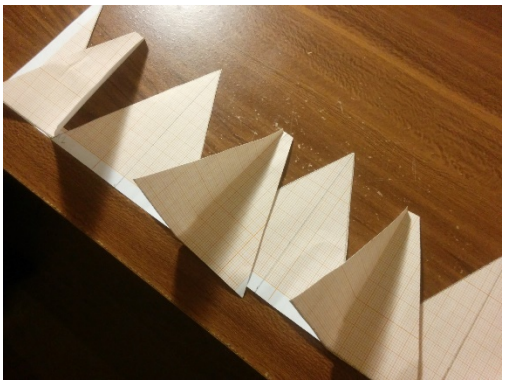

Image 32. Pattern of the grass element

Image 33. Fish elements

Fabric for the detachable elements was selected based on the children's preferences as well as variability, durability and softness. Felt provides a variability of thicknesses and colors that are comfortably integrated into circuits. At the same time the material is strong and can serve for a long time. More importantly, the thrapists from daycare showed many objects, including sensory board made of felt. Felt is popular with children with autism but so as a variety of other tactile surfaces. Considering the limited timing, the author integrated some other materials as well (limited). For example, the elemnts of fish (*Image 33*) were knitted with various patterns, shapes and colors. The clothes of doll was crafted with cotton of different colors. The final version of the iteration 1 prototype can be seen below (Images 34 - 36).


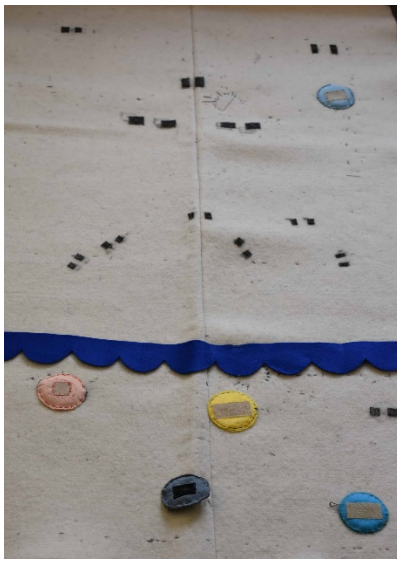
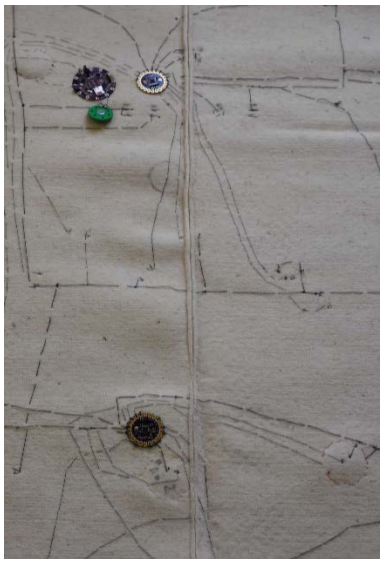

Image 34. Prototype faceside **Image 35.** Faceside w/o elements **Image 36.** Prototype backside

The *Image 34* demonstrates the faceside of the prototype, the interface with which target population will interact with. The faceside of the protoype is devided in three main parts (water, earth, air) to teach children simple things about the world around them. The *Image 35* deminstrates the prototype when all the elements are detached. The round elements (pink, yelllow, blue, gray) in the "underwater section" are the handmade pressure sensors and the indicaters of the placeholdres for detachable figures of fish. Under each pressure there is a vibrating motor embedded, making it a multi level circuitry.

3.2.7. Iteration 2

The second iteration was built based on the recommendations from the therapists and observations of children playing with the "Interactive Carpet" together with their teachers. The changes made to the second version of the prototype are the following:

1. Many more elements were added to the game as well as various tactile surfaces; variety of hardness, color, shape; extended set of clothing for dolls; in addition to felt, a variety of fabrics was added (satin, fur, yarn, cotton);
2. Clear division of air, earth, water sections, made of different materials (neoprene, polyester, felt);

3. Signifiers to the placeholders were added; thus, each element shape was outlined by thread on the body of the carpet.
4. Interactive grass element was added with the LEDs embedded inside the grass “leaves”.
5. Haptic feedback was updated so that each pressure sensor for fish would have its own distinct vibration pattern.

The Images demonstrates the finished version of the Iteration two prototype of the “Interactive Carpet”.



Image 37. Prototype faceside **Image 38.** Faceside w/o elements **Image 39**. “Grass” circuit

3.2.8. Accessibility considerations

During the Accessible Computing class with Prof. Dr. Vladimir Tomberg the author learned about the universal design principles and importance of practicing accessibility in any design process. Since the “Interactive Carpet” was designed for a special group of children, testing the game against the universal design principles was essential (*Table 2*). According to the Center for Universal Design at North Carolina State University (2017), **Universal Design** (also known as Accessible Computing, etc.) is "the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design".

Keeping user informed	Each interaction provides haptic, visual or sound output to provide immediate feedback to a child of what is happening	Yes
Adaptability to users	The detachable elements provide flexibility to adjust the play according to the needs and interests of each child	Yes
Error prevention	The face side of the carpet has signifiers, outlining the shapes of the main elements.	Yes
Helping users recognize and recover from error	There is no error possible that would break the game (only physically destroying it) but if the element is not placed correctly the interaction will not provide any output.	partially
User control & freedom	A child has freedom of placing the elements, mix & match those but in case the desired output is not happening a child can be confused.	partially

Table 2. Evaluation of the "Interactive Carpet" prototype versus Universal Design- based tool.

The evaluation was based on the Universal Design Evaluation tool which was shared with us by Prof. Tomberg at the Accessible Computing class. The evaluation was slightly adapted according to the relevancy of this particular prototype design. The original tool was designed for evaluating websites and other digital platforms. The tool evaluates against four main aspects: Flexibility & Efficiency of Use (Keeping User Informed; Adaptability to users), Error Prevention, Helping users recognize and recover from error, and User control & freedom.

From the *Table 2* we can see that the game is designed to keep user informed by means of haptic, visual, and sound feedback. It helps a child to get immediate understanding of what is happening, keeping him/her focused and incentivized to continue. The design is also adaptable to different needs, interests of a child due to the fact that the detachable elements can be added or removed depending on the situation. Another positive aspect from the Universal Design perspective is that the prototype is designed in a way to prevent error of placing an element incorrectly resulting in absence of feedback from an interaction. This is addressed by means of signifiers, outlining the

shapes of the main elements. The evaluation also revealed weak aspects such as recovering from an error of placing the element incorrectly is not addressed fully. The signifiers help to prevent the error but if the error happened a child may not realize what to do next. Also the necessity of precisely placing the objects on top of the conductive Velcro may invite frequent errors of incorrect placing the elements. In terms of user control & freedom a child has freedom in selecting elements but he/she does not have much freedom in placing them as wished.

3.2.9. Prototype intended value

Thus far the last version of the "Interactive Carpet" prototype was designed based on the background research, contextual inquiry and study results and recommendations from therapists. The intended value that this interface may bring is illustrated in the *Figure 5*.

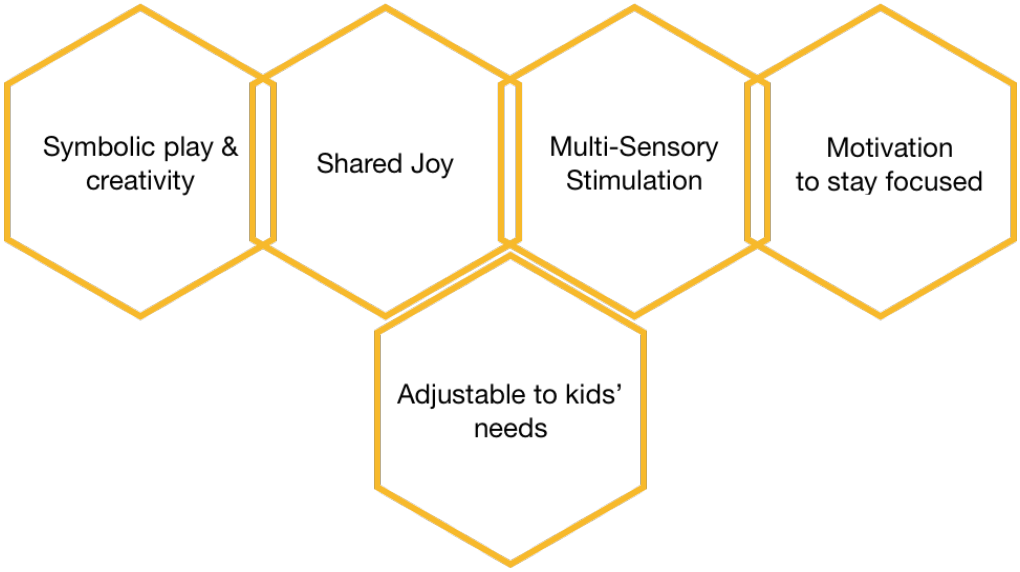

Figure 5. Intended benefits of the "Interactive Carpet" prototype

Considering highly heterogeneous nature of the autism spectrum we wanted to make sure that every child within low-functioning spectrum may find something they enjoy or interested to play with. Attwood (1998) and Greenspan and Wieder (1998) have recommended utilizing a child's stereotyped interests or behaviors, and finding ways to adapt these to promote the development of social, communication and play skills. Thus, by providing something of interest to a child we anticipated to spark interest in other things as well. It is intended to be achieved by the **adjustability to children's needs** and providing variety depending on the situation. For example,

if a child becomes focused on one particular element of the game, a teacher can try different scenarios: demonstrating new element/interaction, triggering attention redistribution; next time when child plays with the game remove the objects of restricted interest.

Motivation to stay focused can be achieved by engaging a child in different interactions and creating new objects for the game based on the child's interest. The "Interactive Carpet" is a **multi-sensory stimulation** technique in itself as it is providing variety of tactile, visual and audio stimulation. Moreover, the detachable elements of the game allow adding new tactile experiences easily.

Shared joy and **symbolic play** and **creativity** is the ultimate goal of the game because shared joy and symbolic play are the essential aspects of the social behavior. The prototype may serve as a **storytelling platform**, inviting a child and a caregiver engage in exploring the elements symbolically and share them at the same time. The caregiver in this case play a role of a storyteller, engaging child in a shared interaction by exchanging figures on the carpet, mixing them and manipulating objects simultaneously. Therapies associated with play, facilitate the acquisition of social competence through the creative use of objects (Hendrix, 2009).

Moreover, **shared joy** and playfulness can be facilitated by creating a relaxed cozy atmosphere for a child. Thus, "Interactive Carpet" may serve as a "micro cosmos" for a child offering an "island" of coziness, hominess and joy. The affordances of the game allow a child to lay down and play in a relaxed comfortable position. The colors of the game are warm and soothing, providing additional value for relaxation and having a "fun" playtime. Such game can be part of the home interior or remind home to a child if placed in a daycare.

4. Method

This research proposes to explore different properties of the interactive, textile based, carpet prototype and how they may stimulate attention and enhance social skills and promote better child-care giver interaction. Considering the plethora of research on TUIs and sensory integration therapy, we hypothesize, that interactive properties of the prototype with multi-sensory feedback and detachable elements may promote attention and enhance socializing. Two observational studies are meant to validate our assumption as well as inform the design process. The

observational studies, conducted in a structured environment, use both qualitative and quantitative tools for analysis. In addition to two structured observational studies, the "Interactive Carpet" was left in a daycare for a week in an attempt to integrate it in daily activities from time to time. The written feedback from a therapist who facilitated and observed the playtime, was obtained and included in this study (*Appendix 5*).

4.1. Participants

Participants for both studies were recruited from Kaokeskus daycare that offers various welfare and care services for children and adults with severe cognitive and developmental disabilities, including low-functioning autism disorder. The total number of observed children was 6, where 3 of them participated in both studies and 3 children participated in one study only.

Study 1 participants

Child 1 (M) – male, with low-functioning autism and severe mental disability (cognitive development is equivalent to 1.5 – 2 y.o. of normal development). The child does not have spoken language abilities. The most challenging aspects of his behavior are aggressive behavior, emotional instability, inability to communicate verbally. The child has sensitivity to touch and smell. He is physically active and his favorite activities are to smell different aromas and listen to music.

Child 2 (O) – male, with low-functioning autism and severe mental disability (cognitive development is equivalent to 2 y.o. of normal development). The child understands few words from a familiar person and uses few English words himself (e.g. "No"). The most challenging aspects of his behavior are aggressive behavior, restricted and stereotyped behaviors, inability to communicate verbally, resistance to change and emotional instability. The child has sensitivity to sound. He enjoys imitating things (animals, voices), cause-effect toys, cooking classes, dressing/undressing himself. He prefers one on one activities.

Child 3 (K) – male, with low-functioning autism and severe mental disability (cognitive development is equivalent to 2– 3 y.o. of normal development). The child understands spoken language and when motivated can speak whole sentence. The most challenges he encounters are emotional instability and resistance to change. The child has sensitivity to taste. His favorite

activities are drawing, looking at the color books, visual effects. He needs to know when exactly lesson starts and ends.

Child 4 (L) – female, with low-functioning autism and severe mental and hearing disability (cognitive development is equivalent to 1.5 – 2 y.o. of normal development). The child does not have spoken language abilities and cannot hear. The most challenges are restricted interests, low attention span, and fine motor skills. The child has sensitivity to taste, sound (wears hearing aid) and touch. She likes tangible objects, rough surfaces, textiles, water bubbles and other visual effects.

Study 2 participants

During the second study children 1 – 3 from the first study were participating, in addition to two new children below.

Child 5 (J) – male, with low-functioning autism and severe mental disability (cognitive development is equivalent to 2 y.o. of normal development). The child understands spoken language and can repeat some words and can speak short sentences. The most challenging aspects of his behavior are restricted and stereotyped behavior, low attention span, fine motor skills, and emotional instability. The child has sensitivity to touch and sound. He prefers to play on his own and his favorite tools are Lego, cartoons, color books.

Child 6 (A) – female, with low-functioning autism and severe mental disability (cognitive development is equivalent to 2 y.o. of normal development). A child understands few words of spoken language and when motivated can speak whole sentence or repeat words. The most challenges are restricted interests and social interaction. The child has sensitivity to touch, visual and audio. Her favorite activities are playing with bubble maker, i-pod, music instruments and cold toys. She dislikes noisy and crowded places.

4.2. Measures and indicators

To validate the assumption of the study, a composite variable was observed - social interaction. The social interaction variable was formed by a group of target behaviors. For the purposes of this study the Autism Diagnostic Observation Schedule (ADOS – 2) has been consulted to develop

indicators for observing the social interaction during the prototype testing. Specifically, frequency of indicators will be coded as indicated in *Table 3*. In addition to that, the attention was measured to understand total duration (t) spent with the game and per each interaction versus whole study time per each child.

The social interaction is a complex construct which consists of multiple variables – behaviors and reactions of an observed child. To code each variable an ADOS – 2 classification and coding algorithm was adopted.

ADOS – 2 is the gold standard observational instrument for use in the diagnosis and for classification of autism and ASDs. It involves direct observation and engagement of children and adults for whom an ASD is suspected. The ADOS – 2 consists of Observation and Coding sections. The Observation section contains details of the activities to be carried out. The Coding section provides specific behaviors to be coded according to pre-set operationalized criteria (Lord, 2012).

The coding algorithm is based on 4 Modules. Different Modules assess behaviors based on the age group and language abilities of children. In this study the observations and coding will be based on Module 2 as it assess children of any age group with few speech abilities. This is the most appropriate group as it includes the type of children we would observe in the daycare.

The table (*Table 3*.) was constructed which will be used to observe and code the behaviors and reactions to the "Interactive Carpet" prototype play activities. The table reflects the goal of the prototype – observe children's attention and socializing during playtime with the carpet. It was developed in consultation with the neuropsychologist, Dr. Mari-Liis Kaldoja.

Focus of Observation	**Indicators**
Child's response to introduction of a game and his/her initiative and response to the activities with the game	Child's response to the introduction of the game
	Child initiates a play with the game
Observation of affect, initiation of joint attention, shared enjoyment	Child notices the feedback from the game (blinking light, sound or vibration) without pointing at them
	Child vocalizes, gestures, looks at a caregiver's face while the game is on (light is blinking, sound on, vibration)

	Observation of having fun, expression of enjoyment or displeasure; motor sensor behavior
Child's reaction to an unusual social press in which some elements of the game do not work	Child looks at a caregiver
	Child reaches out to the element of the game
	Child vocalizes, moves hand of a caregiver
Observe Joint Attention	Child looks in the direction of the game's element when a caregiver says "Look at that!"
	Eye contact
	Expression of enjoyment
Observe child's imitation of the game activities	Child initiates the action on the game (demonstrated by a caregiver)
Observe child's interactive behavior during a structured task	Child indicates need for more elements on the carpet
	Reaching over for the elements
	Vocalization, gestures, eye-contact
Observe creative use of objects	Child selects elements of the game to create a story
	Exploring materials of the game symbolically
	Exploring materials of the game functionally
Positive display of attention	Child stays with the activity (duration to be recorded)
Negative display of attention	Child flits from object to object
Child's response to an unusual social situation in which you interfere with the child's access to a game	Use of eye contact to infer your intent
	Using vocalization to indicate an awareness of the unusual situation
	Child uses your hand in communicative response
	Uses hand as a tool (no eye contact/vocalization)
	Direct facial expressions
Observation of a child's response to a caregiver's withdrawal	Child is playing with a carpet
	Observe overall behavior

Table 3. Indicators of Social behavior

Some of the indicators in the *Table 3*. observe the overall engagement and attention in the play process as well as creative use of objects and imitation of the game activities. These variables are integral elements and indicators of social skills.

In addition to social interaction variable, the attention was measured to understand total duration of time (t) spent with the game and per each interaction versus whole study time per each child. This quantitative measure allowed us to see how focused a child was on the game and with which interactions he was engaged the most. From that we could infer what child liked the most and the overall level of engagement.

4.3. Apparatus

To collect the observed information each play session was videotaped with the obtained consent form (*Appendix 4*). In addition to videos, the author took rich notes, conducted unstructured interviews and used pre and post study survey with therapists (*Appendices 1-2*). For the analysis of the observational studies, in addition to qualitative tools mentioned above, the quantitative tools were used as well (frequency of social behavior indicators and duration of time (minutes)).

4.4. Procedure

Before testing the prototype with children, the level of cognitive development and autism spectrum of each child was identified as well as preferences for activities and sensitivities. Also, the post study survey with the caregivers about each child's experience with the prototype and how they see the "Interactive Carpet" to be used in occupational therapy was conducted.

In the beginning of the first study the author conducted a 30-minutes training session with therapists at the Kao Center and demonstrated the prototype and how to use it.

In addition to the usability aspects, the author discussed possible scenarios of play with each child and the duration of play. Since the participating children are all on low-functioning autism, they all need guidance and direction during activities, especially with new things; therefore, it was decided that during the first study the therapists will take the leading role and will be guiding the child through the playtime, by prompting the interactions with objects. The author also talked about the storytelling aspect of the prototype and encouraged the therapists to try and create stories during the playtime. We also agreed that there will be about 20 minutes given to each child to play. It was also agreed that if children are interested they may engage in a free play and should be

encouraged to do so, by giving them some independency in exploring the game. Basically, even though in a somewhat structured session, we wanted to make this experience as informal and as natural as possible for participating children.

Image 40. Session with therapists and sessions with children

Image 41. Sessions with children

After the training session, the author and four therapists went to another room where the actual play sessions were conducted. This was a smaller room which is normally used for a therapist-child one on one sessions. It was decided to dim the light in the room to make the atmosphere more intimate and avoid additional irritating triggers for children (such as bright daylight). The "Interactive Carpet" was placed on the floor on top of the mat. During the actual session there were the author and four more therapists inside the room, observing the playtime.

After everything was set up and connected, the first child was brought to the room by his/her therapist and would engage in a playtime. After the session would be over (either because the child showed a need to leave or a therapist would instruct to leave to attend to another activity), the next child would enter the room. During the actual playtime the therapist was free to choose what

elements and interactions to show first and was in charge of the whole playtime session, basing her judgement on the current behavior and mood of a child. During the first study the game was placed in a way that the underwater section was the closest to the child when he/she entered the room. As a result, it was the first interaction all the children would engage with. During the second study it was decided to change the position of the game so that the first interaction the kids would encounter would be “rainbow”. This decision was made because during the first study the therapists noticed that if a child was introduced to the game, starting from fish elements, he/she would expect a press input cause-effect interaction for all other elements. We wanted to see whether it would affect the interaction style in any way or form if the initial interaction would be other than fish. Also, during the second study it was agreed to give more freedom of play with less guidance, especially for children that would participate for the second time. The therapists would lead the playtime by showing the elements to a child with phrases like “Look at this” and then explaining what it was and why, engaging in a storytelling play.

5. Results

The results of this study are observational in nature and are not statistically significant. The gathered data (using qualitative and quantitative tools) can only show an observed behavior of children through which we can make certain assumptions regarding our hypothesis.

5.1. Study 1

In this section we will describe the experience of children who participated in the Study 1.

Child 1 – (M)

Since this child is highly sensitive and often expresses aggressive behaviors, the caregiver removed all other interactions, except fish and rainbow. Nonetheless, the child interacted only with the vibrating fish. He noticed different patterns of vibration and enjoyed it, by smiling and looking at the caregiver. He would seat, lay down with his ear on the fish element or touch the fish elements with hand. The two reviewers of the videos provided the following commentary: “*He enjoys the vibration, calms down and smiles*”. Child initiates the play through “mainly sensory

manipulations", demonstrates "lots of repetitive and stereotypic behaviors". The therapist noted that the child was surprisingly calm during the play time.

Child 3 – (K)

Both evaluators agreed that the child expressed interest when the prototype was introduced and initiated the play himself: "Child is engaged immediately", "vocalizes, and uses gestures (joint attention)", "child looks very attentive, seeks sensory stimuli", "there are clear signs of curiosity and he is really focused, so he clearly enjoys the activity". During the playtime Child 3 was especially interested in playing with fish elements by exploring it with hands and placing the cheek to the fish. Also he paid special attention to the blinking rainbow and was looking at it in very close proximity. The child also tried to place objects on the hand of the dolls but had difficulty of taking the object off from the Velcro – it was hard for him. The child did not express a lot of interest in playing with dolls and spent few time on them.

Child 2 – (O)

After the initial introduction of the game the child "seems to understand instructions better" and is "quite proactive". During the playtime the child expresses "occasional mutual laughs" and "enjoys interaction, seems interested". Also, he "was quite well directed and cooperative" but also "shows some repetitive behaviors e.g. pushing". The evaluator also noticed that the child stays with the activity "quite long time". In the beginning he paid attention at the vibrating fish and was exploring the vibrations and after that tried to press on other objects in the similar way (e.g. the dolls), probably expecting the same vibrating effect. After the vibration did not happen from dolls, he became interested in the dolls themselves and they became his favorite interaction. He spent the rest of his playtime with them, undressing them and mixing different hairstyles. He also became curious about the lighted smiles and explored the LEDs under the lips of the doll.

Child 4 – (L)

The girl had hearing impairment and was very distracted but nonetheless followed the instructions from the caregiver. She was interested in vibrating fish and put her face near the sensor and tried to feel it with her face. The child was repeatedly returning to the fish section of the game, and was

putting her ear on top of the pressure sensors. Also, she got interested in the blinking rainbow, attentively looking at it and then putting her head closer to the rainbow. She also got distracted easily and had too many objects to look at. It made her excited but she did not concentrate her attention for too long time. According to the reviewer evaluation: “Child shows some initiative, but therapist seems directional and does not let child freely explore the carpet”. During the playtime the child “mostly flits” from one interaction to another. The child shows “some positive emotion, not definitely defined as fun”, “behavior mainly manipulative and repetitive; no symbolic play; few attempts can be coded as functional”.

Attention results

The attention was calculated in duration of time spent engaging with the prototype directly in minutes. Thus from the calculated time we can infer two main things: the popularity of the interactions and how much time was spent on playing with the prototype versus the total time being in the room.

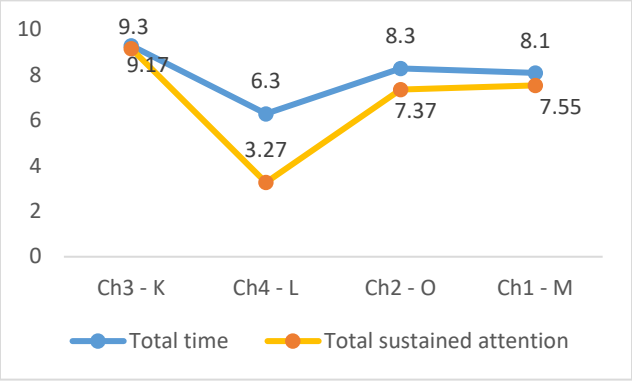

Table 4. Total playtime vs total sustained attention - S1

Table 4 demonstrates the total duration of sustained attention (direct focus on the interactions of the game in minutes) for all participating kids in study 1. We can see that children 1, 2 and 3 were attentive to the interactions of the game for about 90% of total playtime. For child 4 the sustained attention lasted only about 50 % of the time.

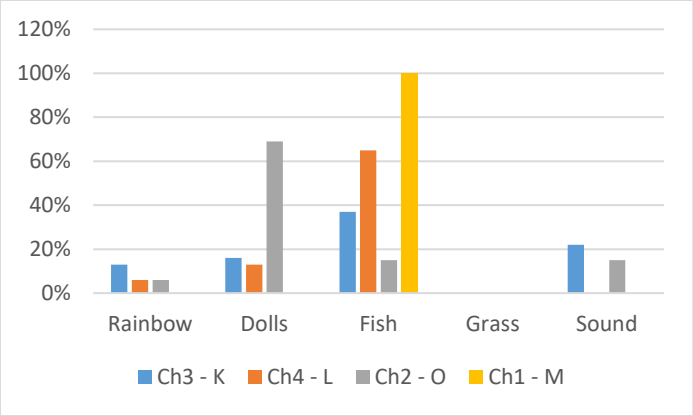

Table 5. Total sustained attention per interaction - S1

Table 5 demonstrates how popular each interaction was for all participated children during first study. Thus, we can clearly see, based on the duration of time spent per interaction, that the fish with haptic feedback was the most favorite interaction for most of the children, except child 2 who preferred dolls interaction more. The second most favorite interaction was dolls, followed by the rainbow and all other interactions.

Feedback from the therapists

After the first study, in addition to the observed experiences of the children, we received valuable feedback from the therapists on how we could improve the second iteration of the prototype. The recommendations were taken under consideration and many of the suggestions (taken time and technology limitations) were included in the design of the second iteration.

The recommendations were the following:

- Add more tangible properties to the elements of the game: more fabric variety, colors; different hardness and even temperature of the objects;
- Add olfactory to the elements;
- Add clear separation of the sections of the game to distinguish the water, earth and sky sections by placing a background material of the corresponding colors. In that way a child can associate the elements better;
- The materials should be sturdy as autistic children cannot control the force they exert and can break things easily;

- The dolls figures should have detachable clothes and hair so a child can mix and match. In the first version of the prototype the hair and clothes were mostly attached to the dolls.

In general, the caregivers gave a positive review to the session. They noted that kids liked most of all the vibration and sound. Also, children are familiar with the Velcro sound (when put on/off) and the actual material of the Velcro surface.

5.2. Study 2

Child 1 – (M)

This child participated the second time.

During the second study Child 1 expressed some interest to the rainbow as well but when he wanted to bite the sun element and caregiver did not let him, the child became upset and frustrated. He still tried to play with the “rainbow” and still made the attempts to bite the “sun” again. After some time the caregiver lead him towards the fish interactions and after some hesitation he started playing with “fish”. The vibrating patterns seem to calm him down because he was nervous and frustrated before interacting with “fish” but after he engaged in feeling various vibrations and holding “fish” he became relaxed and calm. He also tried to match the shapes of the fish to the corresponding signifiers (outline of the shapes) on the prototype.

Child 3 – (K)

This child participated the second time.

During the second study the child interacted very similar to the first study but we could clearly see that he recognized the game and already knew what to do without additional help or guidance from the therapist. He remembered the inputs necessary for fish and rainbow and was engaged in more free play.

Child 5 – (J)

According to the reviewers, for this child it was “hard to get started; needs help in focusing”. At the same time, “feedback from the game helps child to sustain attention”. The child shows “some examples of fun (mainly through simple sensory manipulations)”. Also, one of the evaluators noticed that the “play is modeled; plays after directions are given” and that “quality of the interaction with the carpet gets better in the end of the session”. When the child was introduced to the carpet he was not focused. Right after the therapist showed him the rainbow interaction and he saw blinking light he immediately became quiet and focused on the interaction, by touching the rainbow. He explored all other interactions but in a guided manner, following the directions from the therapist.

Child 6 – (A)

The girl was quite engaged throughout the whole playtime but as with the Child 5 it was hard for her to concentrate on the game initially until she saw the first feedback from the rainbow interaction. She started exploring together with the therapist by following her prompts. This child can also understand the speech and say few words. Therefore the therapist tried to practice words with the girl by showing the elements on the game and naming them. The reviewers also noticed that for this child “it is hard for her to start interacting, hard to focus, but after getting more acquainted, it's easier for her to sustain the attention”. When it comes to the interaction with a caregiver “definite looks, waits for feedback”. “Child is cooperative, interested, follows directions well”, “behavior is modeled”.

Attention results

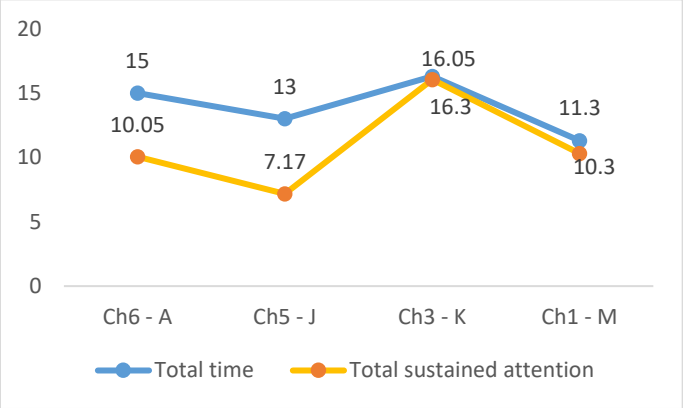

Table 6. Total playtime vs total sustained attention – S2

The *Table 6* demonstrates the total duration of sustained attention (direct focus on the interactions of the game in minutes) for all kids, participated in Study 2. We can see that children 1 and 3 were attentive to the interactions of the game for more than 90% of total time. For the child 5 the sustained attention lasted only about 50 % of the time and for the child 6 – about 66% of total playtime.

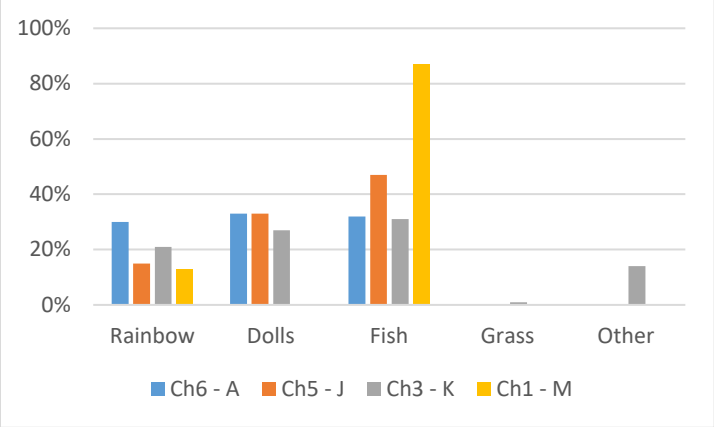

Table 7. Total sustained attention per interaction – S2

The *Table 7* demonstrates how popular each interaction was for all participated children during Study 2. Thus, we can see that the fish element again is the most favorite interaction for most of the children. At the same time we see that for children 6 and 3 the rainbow and dolls interactions are equally interesting. You can notice that in the *Table 5* there was sound interaction but during the second study it was called “other”. During the second study there was no sound as it stopped

working right in the beginning of the study. “Other” includes interactions with tangible objects, not enhanced with technology.

Feedback from the therapists

The therapists after the second study noticed that children who participated second time remembered the game and knew what to do. Also the clear separation of the sections (water, earth, sky) and additional elements allow them to create more play scenarios with children. Moreover, the signifiers of the elements’ shapes were interesting for children because some of them tried to match the elements to the outlines.

The author also received additional feedback on how to improve the game from design perspective: adding more profound sound effects, stronger vibration, adding sad emotion in addition to the smile. In addition to that, one of the therapists proposed an interesting idea “the three different topics – sky, earth, water – would be great if they were separate so that a kid could choose a part he wants to play with”. Also, therapists repeatedly mentioned that it was very hard for kids to manipulate with Velcro and place the elements very precisely. It was suggested to use magnets instead of conductive Velcro.

5.3. Discussion

Analyzing the findings from both studies, we can discuss about engagement with the game, social behaviour during the playtime, overall experience of children and caregivers and talk more indepth about experiences of two chidren who participated in both studies.

Based on the attention graphs (*Tables 4-7*) we see that 4 children out of total 6 were concentrated on the game for about 90 % of all time for both studies. The other kids had between 50 – 60 % of sustained attention. We can also see that children who participated in both studies showed similar attention pattern for both studies. The attention graphs also demonstrate that in both studies for all children the fish interaction with haptic feedback was the most interesting to play with. At the same time, we see that some of the children payed equal attention to dolls and rainbow interactions. And, for another child who participated in both studies and played additional time (when the game

was left at the daycare for a week) the dolls interaction was the most preferable one for all play times.

This observation proves the heterogeneous nature of the spectrum and overall high range of interests and sensitivities of this group of children. Moreover, the pre-study survey about the children's history, symptoms and interests, showed that their individual preferences on daily basis manifested in the game as well (preference for blinking lights, or special sensitivity to touch, vibration etc.).

Another importnat observation that applies to all participated children is that the variety of feedback from interactions (blinking light, vibration, sound) helps a child to be focused, switch focus and continue interacting with a caregiver while playing. Also, therapists noted that detachable elements bring flexibility to the play process. Thus, therapists can remove or introduce the element depending on the situation and behaviour of the child. Moreover, the therapists were practising teaching words, using the elments of the carpet. They noticed that children with some speech abilities were willingfully repeating the words, playing with the elments of the game simultaneously.

Comparing interactions in Study 1 to Study 2, we can see that the duration of playtime in the second study has been increased for about 40 -50 %. One reason to this could be the agreement with therapists to let children engage in more free play during the second study without exxessive guidance. Additional reason could be the fact that the game was improved based on the feedback from study 1 and had many more new elements to play with, including interactive grass. According to therapists, clear sepration of the water, earth and air sections were helpful for children to understand the interactions better. The additional detachable elements also allowed therapists to have more scenraious for storytelling.

To understand the quality of social interactions, while coding the videos, the reviewrs were focusd on very specific behaviors: eye gaze, reciprocity, joint attention, functional play, creative use of objects, expressions of joy, etc. Thus, from this perspective we can say that most children were highly directed by the therapists in their playtime and followed the guidances well, expressing joint attention, functional play, eye gaze and some elements of joy. At the same time, most of children were attempting to fleet from one interaction to another. When this would happen, the therapist would guide them to another interaction to bring their focus back. If children were let

playing on their own, they either would engage in the interaction they enjoyed the most or would lose focus.

There was another interesting aspect, revealed in terms of interaction with the carpet as a whole tangible element. Thus, since the carpet was placed on the floor and its soft properties and circuitry allowed to lay down on it, very often children would interact in a position most comfortable for them. It seems that the properties of the carpet would promote playfulness in a relaxed way: children would lay down or seat on the carpet or even walk sometimes. Moreover, the soft properties and shape of the carpet would allow sharing the same space between child and a caregiver promoting more intimate interaction, sharing objects and joy of play together.

The cases of the Child 1 and Child 3 who participated in both studies can provide more detailed information on the children' experience with the carpet and quality of social interactions.

By summing up all the instances of social behavior (*Table 8.*), we were able to see differences in behavior during Study 1 versus Study 2 for Child 1.

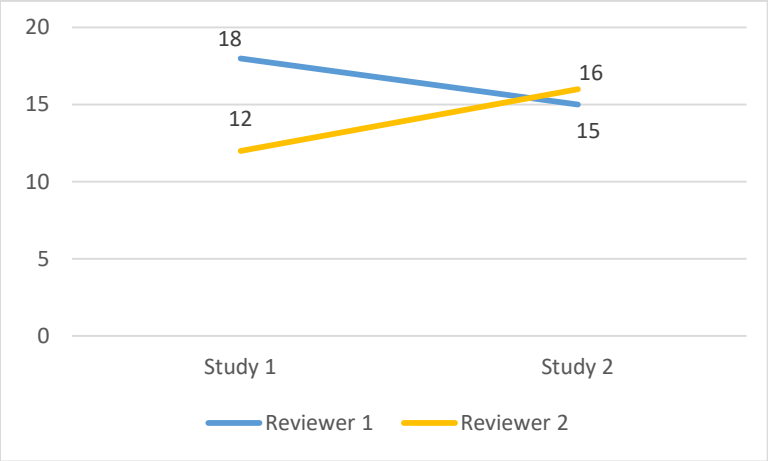

Table 8. Total number of social behavior instances – Child 1(M)

The graph in the *Table 8* demonstrates the total number of instances (indicators of social behavior in *Table 3.*) for each study per each reviewer. Thus, during the first study the reviewer 1 indicated 18 instances of social behavior, whereas during Study 2 the number of indicators was 15, showing 16% decrease. In contrast to reviewer 1, the evaluation from the second reviewer showed 12 instances during first study and 16 instances during the second study, demonstrating 33 % of increase. The contradicting evaluations, looking at the comments and nature of indicators, may be

explained by the fact that the evaluators perceived certain behavior as absence of social indicator where they thought the situation was not applicable in that moment. Also, the evaluators have contrasting opinions about whether this child had fun or joy.

Analysis of the independent evaluations revealed some disagreements that prevail in both studies. Thus, the only persistent indicator which has varying opinions is "Observation of having fun, expression of enjoyment or displeasure". Other contradicting indicators were whether the child uses object functionally or uses vocalization to indicate an awareness of the unusual situation but these are very minor disagreements and relate to very specific situation which could be perceived differently by each evaluator. The agreements were more consistent throughout all main indicators directly related to socializing. Thus there was the same evaluation across both studies for both reviews for such indicators as "child's positive response to introduction of the game", "observation of affect, joint attention", "eye contact", "reaching over for the elements", as well as "positive display of attention". Some selected comments from the reviewers for both studies: "*I believe he would have played, but he was upset because the caregiver did not let to play him with the elements he selected at the beginning of the session*". One of the evaluators also mentioned: "*The difference was really evident while comparing the two videos of Markus. He was clearly much more relaxed and showed more skills and interest in the first video, when he had more freedom to explore the carpet*." And another evaluator mentioned about the situation when the child was given more freedom to interact with the prototype, he would demonstrate "better qualitative manipulations, uses different sensory ways to explore the carpet".

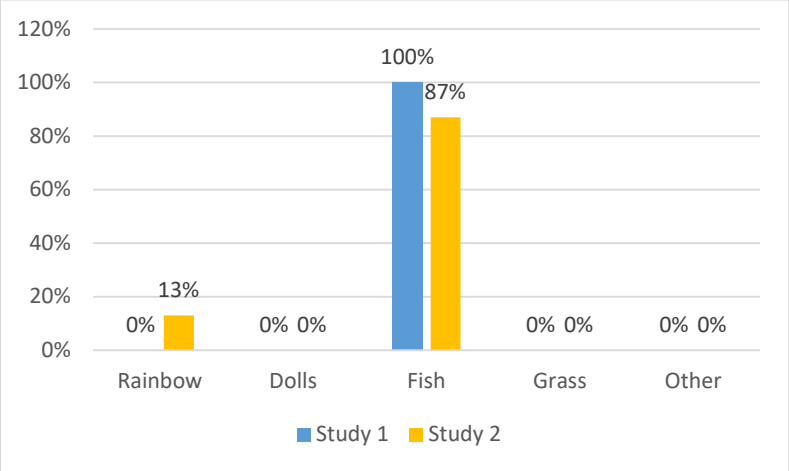

Table 9. Total sustained attention per interaction for both studies – Child 1(M)

The *Table 9* demonstrates the preferences of the Child-1 for each interaction. We clearly see that during the first study he only played with fish. During the second study the child also tried to interact with the rainbow but was stopped by a caregiver when he attempted to bite the element of the sun. As reviewers mentioned, there is an assumption that this child could have more quality interactions if he would have more opportunities for free play.

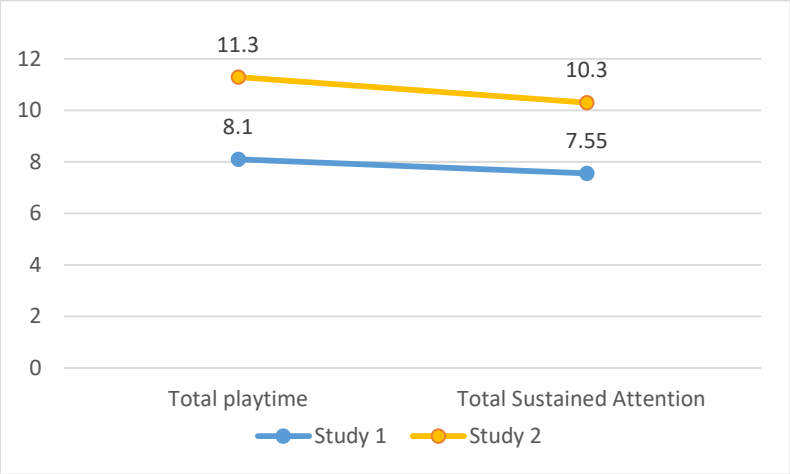

Table 10. Total sustained attention vs total playtime for both studies – Child 1(M)

From the *Table 10* we can see that 93% of the total playtime was dedicated to the interactions with the elements. During the Study 2 the child spent slightly less time on the interactions – 91% versus total playtime. At the same time it is important to note that duration of the total time has been for 37 % longer than during the first study (8 minutes vs 11 minutes).

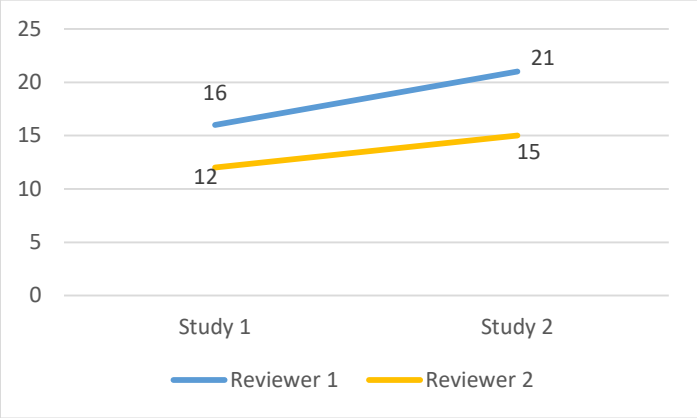

Table 11. Total number of social behavior instances – Child 3 (K)

In the case of Child-3, the reviewers were in agreement. The evaluation from the first reviewer indicated 31 % increase and the second reviewer - 25 % increase in social indicators. Child 3 in general showed more activity during the playtime and it was probably clearer to understand his intentions. As in the case with Child 1, the main inconsistency in evaluations is related to evaluating whether the child expresses the emotions of joy and having fun. Other inconsistencies are related to the situations which were perceived by one of the evaluators as non-applicable (e.g. caregiver withdrawal).

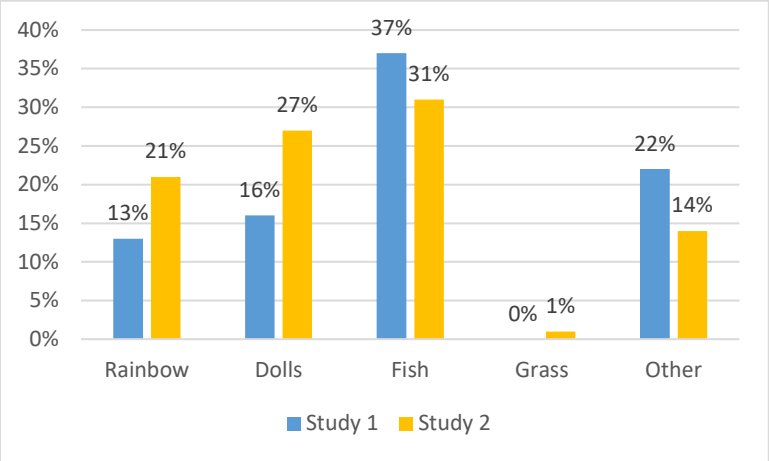

Table 12. Total sustained attention per interaction vs total playtime - Child-3 (K)

Table 12 demonstrates that the most popular interaction for Child-3 was fish for both studies, then dolls and then he spent almost equal time with rainbow and other interactions. The grass element did not hold attention almost at all during both studies. There was an expectation that the grass element will have more popularity among kids during the second study because the interactivity (light feedback upon stroking) was added.

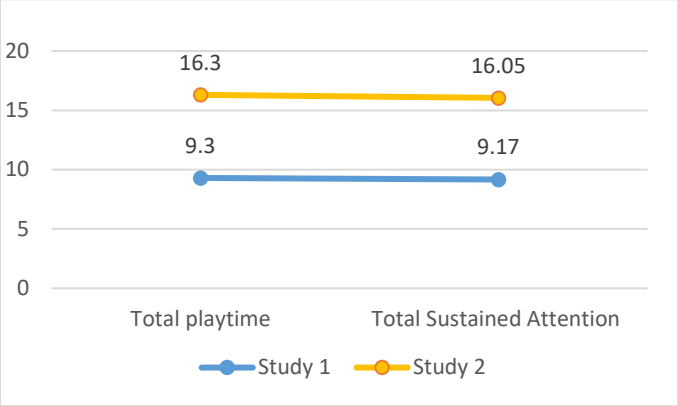

Table 13. Total sustained attention vs total playtime for both studies – Child 3 (K)

As we can see from the *Table 13*, Child-3 spent almost 100% of his total playtime interacting with the prototype. The same can be observed for both studies. At the same time, based on the commentary from the reviewers, the child has been fleeting from one interaction to another without spending a prolonged time on something one.

Summing up the experiences of Child-1 and Child-3, we can see that their preferences and engagement level with the carpet are quite consistent for both playtimes. At the same time we see that children spent almost double time with the carpet in the second study and expressed more variety in using the elements. For example, Child 1 has tried new interaction in the second study and Child 3 dedicated more time on rainbow and dolls interactions. We may assume that the reason for that could be that the second version of the carpet has offered many more elements to play with. Moreover, giving a child more opportunities for free ply may reveal more variety in interactions.

Feedback from Therapists

After the second study the therapists were asked to complete the post-study reflections questionnaire. The questionnaire reveled valuable information on how this type of prototype could potentially be used as part of the occupational therapy and how it can be beneficial to children. The original answers can be seen in the *Appendix 2.* In summary, for some children "it could be a part of the daily routine – socializing" with the therapist or a caregiver. Several therapists mentioned that "in a longer perspective kids can learn cause-effect tasks" and that the game "would probably be a way to provide sensory stimulation and tactile experiences". On the other side one of the therapists noted that "for our children the electric connections seem to be fragile and some materials as well so all activities with the carpet should definitely be assisted."

And addition, feedback from one of the therapists is nicely summarizing the gathered information: "*In our case we can use that kind of game mostly one on one situations, therapist and child. Activities that therapist will do with this smart carpet will develop different abilities that autistic persons have difficulty with, for example: how to take part in interaction with another person, enjoying being with another person, learning to do sequences of activity with a person, taking turns, sharing personal space, using and understanding eye contacts, using and understanding*

facial expressions etc. Therapist can do the storytelling about the theme of the carpet and at the same time child can listen and deal with the tools that are on the carpet. Therapist can tell the different stories in different sessions for example" (*Appendix 5.)*

6. Conclusions

To reiterate, the **goal** of this master study was an attempt to explore different properties of the interactive, e-textile based prototype and how they may stimulate attention and promote social interactions between child and a caregiver during playtime.

Based on the background research on autism spectrum disorder and existing HCI solutions, we **hypothesized**, that properties of the interface with various sensory feedback and detachable objects should promote attention and enhance socializing.

Specifically, the author wanted to find out:

Q.1. To what extent can "Interactive Carpet" promote attention and enhance interaction between a child and a caregiver during playtime?

Q.2. In what ways can therapists and caregivers utilize the "Interactive Carpet" in their occupational therapy practices and for playful experiences?

Thus during the iterative process and the feedback from the observational studies revealed rich insights and some answers to the research questions.

Answers to Q1:

The "Interactive Carpet" during both studies brings the most value in terms of socializing potential when the playtime is guided by the therapist. The therapist would be the main facilitator, prompting new interactions by showing new elements of the game and demonstrating their interactivity. The intended ultimate value of the "Interactive Carpet" was an attempt to enhance social interaction between child and a caregiver. Within social interaction construct we wanted to see whether the prototype could promote symbolic play and creativity, shared joy, and joint attention. Since the study was of a qualitative type we can only infer certain things related to socializing. For example, the studies showed that most of children would follow the guidance of the caregiver and would repeat the task. Children would look at the element and then at the caregiver, indicating **joint**

attention and **even joy** (through occasional smile). It seems that detachable objects are also helpful in keeping children interested and focused. Caregivers were introducing the new objects every time a child would lose focus or engage in a repetitive behavior. The ability to introduce new elements as the play goes allowed a child **to sustain attention**, **switch focus** and **engage in joint attention**.

It is not clear whether this type of interactive carpet may promote **symbolic play and creativity**, at least not in this group of kids. Most of children during both studies would engage mostly in functional play only, imitating the actions of the therapists. It can be explained by the fact that for children on low-functioning spectrum it is hard to engage in creative use of objects in general and it takes longer time to develop these skills. A longitudinal study would be needed to investigate more on this.

The studies also revealed that the game can provide a **multi-sensory stimulation** to some children that could serve as addition stimulator for sustaining social interaction. At the same time, it was noted that the game does not provide strong stimulation and will not be beneficial for kids who seek enhanced tactile stimulations (e.g. very hard objects).

Moreover, the soft properties and shape of the carpet promoted sharing the same space between child and a caregiver, inviting for more intimate interaction, sharing objects and joy of play together in a relaxed position.

Answers to Q2:

Based on the feedback from the therapists the "Interactive Carpet" could potentially be part of daily occupational therapy practices, specifically for teaching cause-effect tasks, teaching words through storytelling, and for multi-sensory stimulation.

Repeatedly, therapists would note that this type of game could serve as **a tool to teach kids words** through the **stories**, meanwhile being engaged in an interaction. Another value that this prototype could bring is teaching children **cause –effect interactions through storytelling**. Thus, therapists noted that different detachable elements can serve as a **base for creating stories** and showing **cause-effect** of these stories. The interactive-cause effect tasks would keep the child attention and amusement. The fact that the objects are detachable and new elements could be added may serve as a continuous novelty for new stories. Such variety of detachable objects and multi-sensory

stimulation (tactile, visual, audio) allows **adapting the playtime to different preferences and needs**. During both studies all 6 children found something to play with. At the same time, this has to be investigated further to understand whether this interest is sustained or just a cause of novelty.

To summarize, the study has achieved the goal of exploring how the properties of "Interactive Carpet" may promote social interaction between child and a caregiver and qualitatively tested our hypothesis.

Thus, the study revealed that this type of prototype offers potential for enhancing social interactions between child and a caregiver in a guided manner. The shape of the carpet, serving as a shared space and providing ability to play in an intimate and relaxed way, promotes closer interaction with a caregiver. The detachable objects and cause-effect interactions with multi-sensory stimulation provide opportunity for storytelling, thus, promoting sharing of objects, sustaining attention and facilitating social interaction.

6.1. Limitations of the study

The findings of the study are not statistically significant and therefore cannot be generalized for bigger population. It is limited by the fact that the population size was very small. Moreover, certain aspects, such as sutainability of the interest for the game or general affect on socializing can only be tested in longitudinal studies with control groups.

During the actual study process very often the faces of children were not captured on camera. It caused confusion in the evaluation process and the inconsistency in interpreting the experinces of the children. In addition to that, one of the children participating in both studies was not recorded during the second study.

Most of the time, the playtime was highly directed by the therapists. It would be very useful to see how a child would behave if he/she would be given more independency during playtime. It may also reveal that this game is only suitable for a highly modeled play.

6.2. Future work

Many improvements could be done to reaffirm finding of this study. Moreover, rich qualitative data, gathered in this study, can serve as a good foundation for further research.

1. To find out whether there is an effect on the development of social skills a statistically significant longitudinal study with control groups would be needed.
2. More sessions with children playing with the “Interactive Carpet” could reveal how the interaction with it evolves with time. More sessions with children will be essential to understand whether kids find the carpet interesting after some time and whether the ability to create new objects and create new stories can serve as stimulation for sustainable interaction and interest.
3. It would be important in the future to model the sessions in a way that children would have more independency in interacting with the prototype and the caregiver would take more of a role of an observer.
4. It would also be useful to see whether two kids at the same time can play with the carpet. Since the carpet serves as a shared space between two players it could potentially be helpful in facilitating the interaction not only between a child and a familiar person to this child but also with less familiar people.
5. From design and usability perspective integrating magnets instead of conductive Velcro will be an important change to implement. It would be interesting to see whether the interaction with magnets could improve the overall experience and socializing potential of children.
6. It would be insightful to conduct observational studies in the context of home where a child could play with the “Interactive Carpet” in his natural environment together with the parents/caregivers. These studies could shed a light on whether this prototype could bring an additional value for enhancing interaction between a child and a parent.

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9. Appendices

9.1. Appendix 1. Pre-Study Questionnaire about the background history, symptoms and interests of participated children.

Pre-Study Questionnaire

1. Fist Name of a child MARKUS
2. Gender MALE
3. School and kindergarten (when he/she started and how long have been going) KAO BASIC SCHOOL (since sept. 2015)
4. Any other psycho-educational or rehabilitation activities (e.g. speech and language therapist, physiotherapy, psychotherapy); if applicable, how many time a week?
   once a week
5. Exact diagnosis of ASD according to the ICD-10 codes (and if possible, the level of cognitive/intellectual abilities: e.g. normal, borderline, mildly, moderately or severely impaired) ASD, severe mental disability
6. Any other psychiatric, neurological or genetic disorder (or medical diagnosis like diabetes, PCI, ADHD) epilepsy
7. The level of spoken language (no spoken language; few words understood by familiar persons; speech consisting of at least 3-word sentences, but used in limited situations; age appropriate expressive language).
   NO spoken language
8. Main problems parents perceive (rate from 0-5 how problematic these areas are for her child; 0 – not at all, 5 - absolutely).
   a. Verbal and nonverbal communication 0 1 2 3 (4) 5
   b. aggressive behaviour 0 1 2 3 (4) 5
   c. restricted interests 0 (1) 2 3 4 5
   d. stereotyped behaviours 0 1 (2) 3 4 5
   e. low attention span (focusing and switching attention) 0 (1) 2 3 4 5
   f. social inclusion 0 (1) 2 3 4 5
   g. social interaction 0 (1) 2 3 4 5
   h. general cognitive development 0 1 2 (3) 4 5
   i. emotional stability 0 1 2 (3) 4 5
   j. resistance to changes 0 (1) 2 3 4 5
   k. overall coordination/gross motor skills 0 (1) 2 3 4 5
   l. fine motor skills and hand-eye coordination 0 1 (2) 3 4 5
9. What are the child's areas of strength?
   social, emotional, active, physically active,

10. What type of sensitivity does a child have?

- Visual
- Auditory
- Smells
- Touch
- Taste
- Other (please describe) likes to listen certain type of music (has his own "playlist")

11. What types of things work best for a child in terms of rewards and motivation?

Likes to smell different aromas (has a special box with a lot of different aromas)
Can listen his own favourite music

12. Comments (please share your observation about playtime behaviour, favourite toys/activities, tactile elements, smells, touch, less favourite activities, socializing with others, etc.)

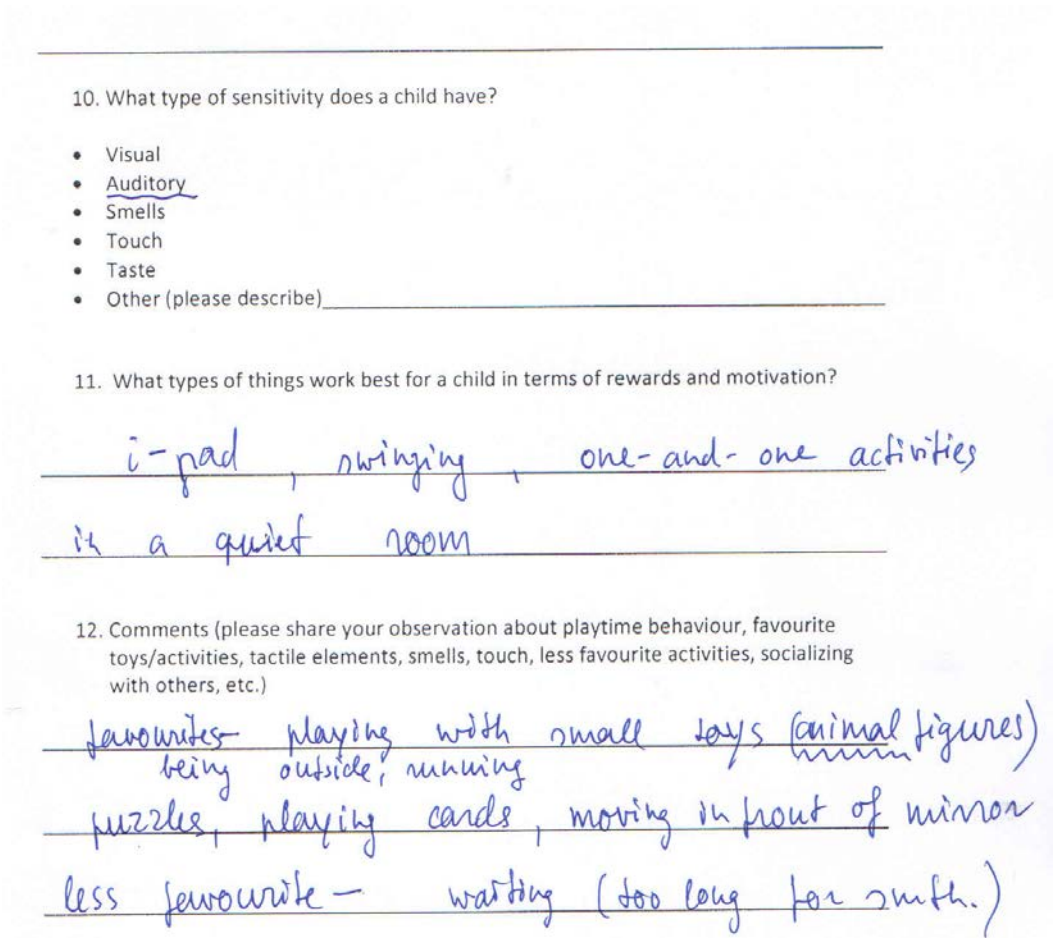
Favourite: being outside (on a playground), swinging, "aroma box", music

Less favourite: lessons that involve cooking, sometimes art lessons

Image 42. Pre-Study Questionnaire – Child (1)

Pre-Study Questionnaire

1. Fist Name of a child OLIVER
2. Gender MALE
3. School and kindergarten (when he/she started and how long have been going) KAO BASIC SCHOOL (since sept. 2016)
4. Any other psycho-educational or rehabilitation activities (e.g. speech and language therapist, physiotherapy, psychotherapy); if applicable, how many time a week?
   once a week
5. Exact diagnosis of ASD according to the ICD-10 codes (and if possible, the level of cognitive/intellectual abilities: e.g. normal, borderline, mildly, moderately or severely impaired) ASD severe intellectual disability, speech disability
6. Any other psychiatric, neurological or genetic disorder (or medical diagnosis like diabetes, PCI, ADHD)
7. The level of spoken language (no spoken language; few words understood by familiar persons; speech consisting of at least 3-word sentences, but used in limited situations; age appropriate expressive language).
   uses a few English words e.g. „NO"
8. Main problems parents perceive (rate from 0-5 how problematic these areas are for her child; 0 – not at all, 5 - absolutely).
   a. Verbal and nonverbal communication 0 1 2 (3) 4 5
   b. aggressive behaviour 0 1 2 (3) 4 5
   c. restricted interests 0 1 2 (3) 4 5
   d. stereotyped behaviours 0 1 2 3 (4) 5
   e. low attention span (focusing and switching attention) 0 1 2 (3) 4 5
   f. social inclusion 0 1 2 (3) 4 5
   g. social interaction 0 1 2 (3) 4 5
   h. general cognitive development 0 1 2 3 (4) 5
   i. emotional stability 0 1 2 3 (4) 5
   j. resistance to changes 0 1 2 3 (4) 5
   k. overall coordination/gross motor skills 0 1 2 (3) 4 5
   l. fine motor skills and hand-eye coordination 0 1 2 (3) 4 5
9. What are the child's areas of strength?
   copies, imitates things he likes e.g. animals, animals' voices, movements
   caus- effect toys, watching himself moving in front of mirror
   helps with cooking, dressing - undressing himself



10. What type of sensitivity does a child have?

- Visual
- Auditory
- Smells
- Touch
- Taste
- Other (please describe)_____

11. What types of things work best for a child in terms of rewards and motivation?

i-pad, swinging, one-and-one activities in a quiet room

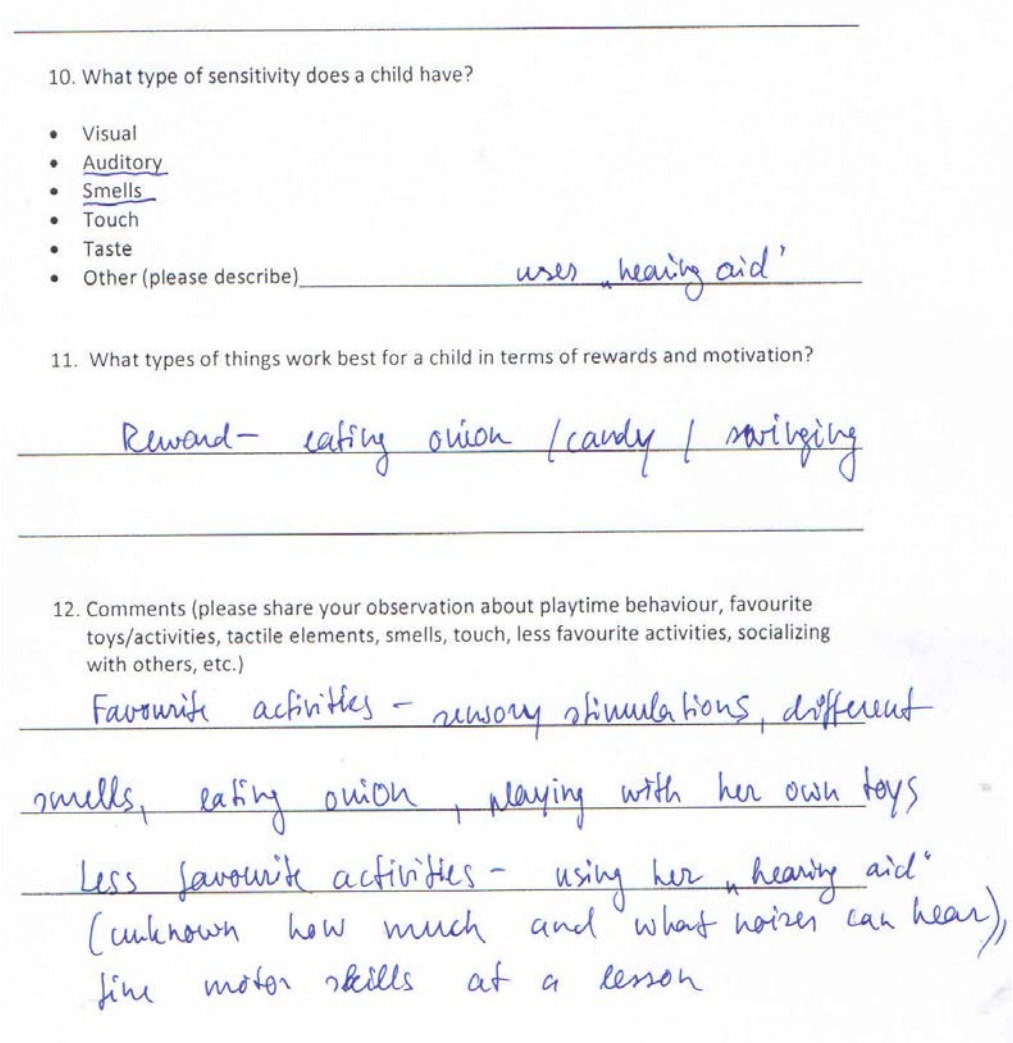
12. Comments (please share your observation about playtime behaviour, favourite toys/activities, tactile elements, smells, touch, less favourite activities, socializing with others, etc.)

favourites- playing with small toys (animal figures) being outside, running
puzzles, playing cards, moving in front of mirror
less favourite - waiting (too long for smth.)

Image 43. Pre-Study Questionnaire – Child (2)

Pre-Study Questionnaire

1. Fist Name of a child LISETE
2. Gender FEMALE
3. School and kindergarten (when he/she started and how long have been going) KAO BASIC SCHOOL (since sept. 2017a.)
4. Any other psycho-educational or rehabilitation activities (e.g. speech and language therapist, physiotherapy, psychotherapy); if applicable, how many time a week?
   hipotherapy once a week
5. Exact diagnosis of ASD according to the ICD-10 codes (and if possible, the level of cognitive/intellectual abilities: e.g. normal, borderline, mildly, moderately or severely impaired) ASD; severe intellectual disability; auditive disability
6. Any other psychiatric, neurological or genetic disorder (or medical diagnosis like diabetes, PCI, ADHD)
7. The level of spoken language (no spoken language; few words understood by familiar persons; speech consisting of at least 3-word sentences, but used in limited situations; age appropriate expressive language).
   no spoken language
8. Main problems parents perceive (rate from 0-5 how problematic these areas are for her child; 0 – not at all, 5 - absolutely).
   a. Verbal and nonverbal communication 0 1 2 (3) 4 5
   b. aggressive behaviour (0) 1 2 3 4 5
   c. restricted interests 0 1 2 3 (4) 5
   d. stereotyped behaviours 0 1 (2) 3 4 5
   e. low attention span (focusing and switching attention) 0 1 2 (3) 4 5
   f. social inclusion 0 1 (2) 3 4 5
   g. social interaction 0 1 (2) 3 4 5
   h. general cognitive development 0 1 (2) 3 4 5
   i. emotional stability 0 (1) 2 3 4 5
   j. resistance to changes 0 (1) 2 3 4 5
   k. overall coordination/gross motor skills 0 1 2 (3) 4 5
   l. fine motor skills and hand-eye coordination 0 1 2 (3) 4 5
9. What are the child's areas of strength?
   Physically active
   Likes - playing with water
   - visual effects
   - strong textiles
   - rough



10. What type of sensitivity does a child have?

- Visual
- Auditory
- Smells
- Touch
- Taste
- Other (please describe) uses „hearing aid'

11. What types of things work best for a child in terms of rewards and motivation?

Reward – eating onion / candy / swinging

12. Comments (please share your observation about playtime behaviour, favourite toys/activities, tactile elements, smells, touch, less favourite activities, socializing with others, etc.)

Favourite activities – sensory stimulations, different smells, eating onion, playing with her own toys

Less favourite activities – using her „hearing aid" (unknown how much and what noises can hear), fine motor skills at a lesson

Image 44. Pre-Study Questionnaire – Child (4)

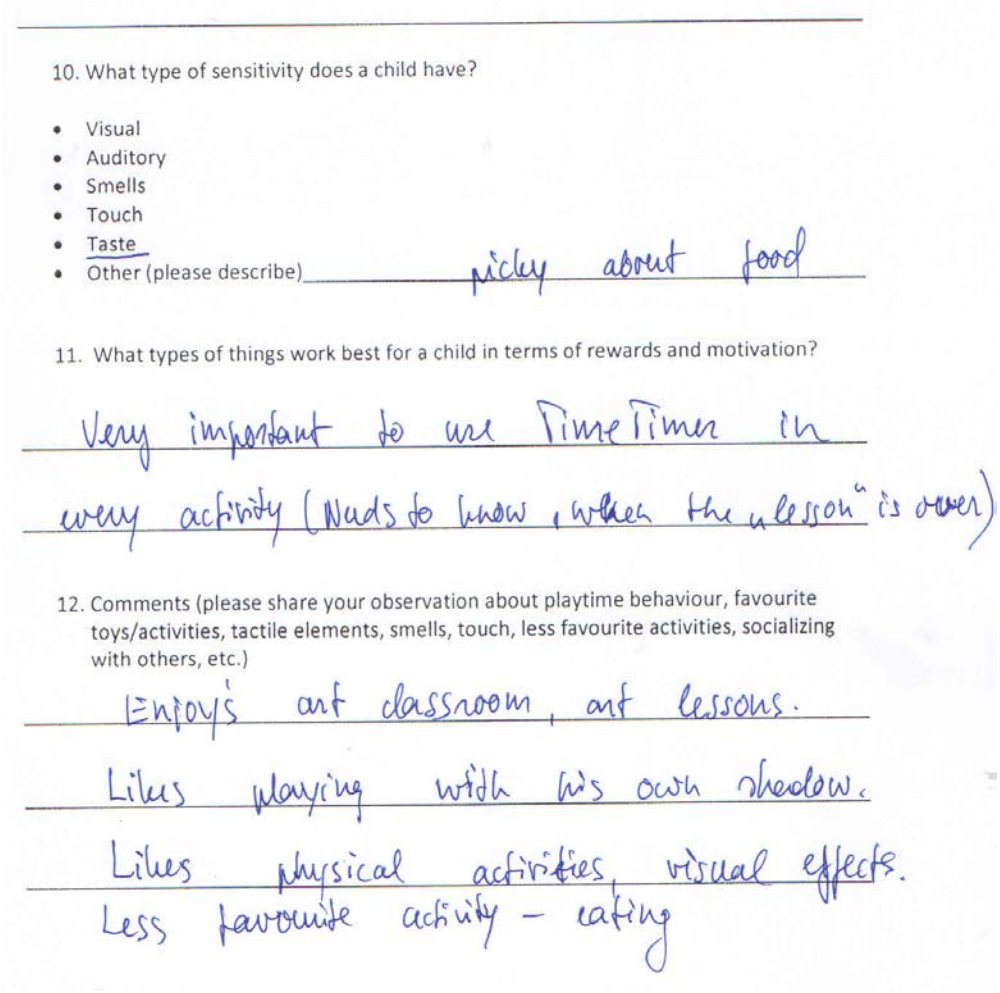
Pre-Study Questionnaire

1. Fist Name of a child KASPAR
2. Gender MALE
3. School and kindergarten (when he/she started and how long have been going) KAO BASIC SCHOOL (since sept. 2017)
4. Any other psycho-educational or rehabilitation activities (e.g. speech and language therapist, physiotherapy, psychotherapy); if applicable, how many time a week?
   once a week
5. Exact diagnosis of ASD according to the ICD-10 codes (and if possible, the level of cognitive/intellectual abilities: e.g. normal, borderline, mildly, moderately or severely impaired) ASD severe intellectual disability
6. Any other psychiatric, neurological or genetic disorder (or medical diagnosis like diabetes, PCI, ADHD)
7. The level of spoken language (no spoken language; few words understood by familiar persons; speech consisting of at least 3-word sentences, but used in limited situations; age appropriate expressive language).

   spoken words understandable, repeats phrases and sentences when motivated uses simple sentences

8. Main problems parents perceive (rate from 0-5 how problematic these areas are for her child; 0 – not at all, 5 - absolutely).
   a. Verbal and nonverbal communication 0 1 2 3 (4) 5
   b. aggressive behaviour 0 (1) 2 3 4 5
   c. restricted interests 0 (1) 2 3 4 5
   d. stereotyped behaviours 0 1 (2) 3 4 5
   e. low attention span (focusing and switching attention) 0 (1) 2 3 4 5
   f. social inclusion 0 (1) 2 3 4 5
   g. social interaction 0 (1) 2 3 4 5
   h. general cognitive development 0 (1) 2 3 4 5
   i. emotional stability 0 1 2 (3) 4 5
   j. resistance to changes 0 1 2 (3) 4 5
   k. overall coordination/gross motor skills 0 1 (2) 3 4 5
   l. fine motor skills and hand-eye coordination 0 (1) 2 3 4 5
9. What are the child's areas of strength?

   likes drawing, draws people, animals, birds
   likes „colors – books", likes „art & craft",
   knows numbers and colours
   can write his own name, letters



10. What type of sensitivity does a child have?

- Visual
- Auditory
- Smells
- Touch
- Taste
- Other (please describe) picky about food

11. What types of things work best for a child in terms of rewards and motivation?

Very important to use TimeTimer in every activity (Needs to know, when the „lesson" is over)

12. Comments (please share your observation about playtime behaviour, favourite toys/activities, tactile elements, smells, touch, less favourite activities, socializing with others, etc.)

Enjoys art classroom, art lessons.
Likes playing with his own shadow.
Likes physical activities, visual effects.
Less favourite activity – eating

Image 45. Pre-Study Questionnaire – Child (3)

Pre-Study Questionnaire

1. Fist Name of a child JAKOB
2. Gender MALE
3. School and kindergarten (when he/she started and how long have been going) KIO BASIC SCHOOL (SINCE 2016)
4. Any other psycho-educational or rehabilitation activities (e.g. speech and language therapist, physiotherapy, psychotherapy); if applicable, how many time a week?
   Physiotherapy, speech therapy, art therapy, occupational therapy once a week
5. Exact diagnosis of ASD according to the ICD-10 codes (and if possible, the level of cognitive/intellectual abilities: e.g. normal, borderline, mildly, moderately or severely impaired) ASD
6. Any other psychiatric, neurological or genetic disorder (or medical diagnosis like diabetes, PCI, ADHD)
7. The level of spoken language (no spoken language; few words understood by familiar persons; speech consisting of at least 3-word sentences, but used in limited situations; age appropriate expressive language).
   Repeats a few words, small sentences
8. Main problems parents perceive (rate from 0-5 how problematic these areas are for her child; 0 – not at all, 5 - absolutely).
   a. Verbal and nonverbal communication 0 1 2 3 4 (5)
   b. aggressive behaviour 0 (1) 2 3 4 5
   c. restricted interests 0 1 2 3 (4) 5
   d. stereotyped behaviours 0 1 2 3 (4) 5
   e. low attention span (focusing and switching attention) 0 1 2 3 (4) 5
   f. social inclusion 0 1 (2) 3 4 5
   g. social interaction 0 1 (2) 3 4 5
   h. general cognitive development 0 1 2 (3) 4 5
   i. emotional stability 0 1 2 (3) 4 5
   j. resistance to changes 0 1 (2) 3 4 5
   k. overall coordination/gross motor skills 0 1 (2) 3 4 5
   l. fine motor skills and hand-eye coordination 0 1 2 (3) 4 5
9. What are the child's areas of strength?
   Plays alone with toys

10. What type of sensitivity does a child have?

- Visual
- Auditory
- Smells
- Touch
- Taste
- Other (please describe)_____

11. What types of things work best for a child in terms of rewards and motivation?

popcorn, i-pad, playing with his own toys.

12. Comments (please share your observation about playtime behaviour, favourite toys/activities, tactile elements, smells, touch, less favourite activities, socializing with others, etc.)

Favourite: Teletubbies, lego-pieces, cartoons, kids books

Less favourite: school lessons, cooking, art

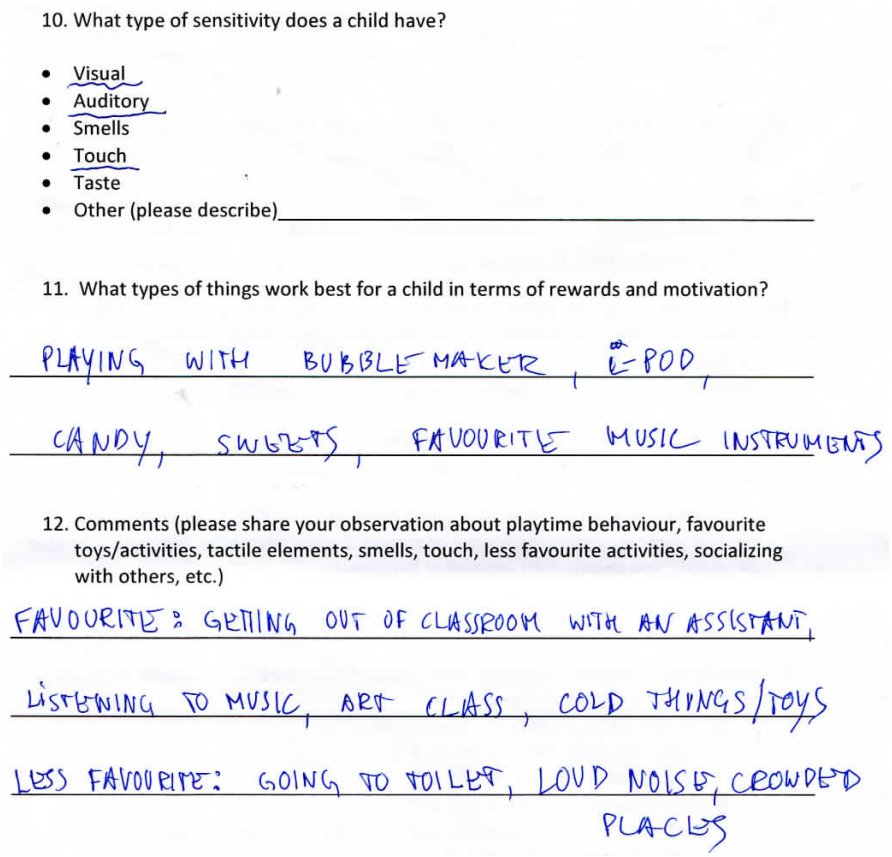
Image 46. Pre-Study Questionnaire – Child (5)

Pre-Study Questionnaire

1. Fist Name of a child ANNI
2. Gender FEMALE
3. School and kindergarten (when he/she started and how long have been going) KAO BASIC SCHOOL (SINCE 2015)
4. Any other psycho-educational or rehabilitation activities (e.g. speech and language therapist, physiotherapy, psychotherapy); if applicable, how many time a week? PHYSIOTHERAPY
5. Exact diagnosis of ASD according to the ICD-10 codes (and if possible, the level of cognitive/intellectual abilities: e.g. normal, borderline, mildly, moderately or severely impaired) ASD, severe mental disability
6. Any other psychiatric, neurological or genetic disorder (or medical diagnosis like diabetes, PCI, ADHD)
7. The level of spoken language (no spoken language; few words understood by familiar persons; speech consisting of at least 3-word sentences, but used in limited situations; age appropriate expressive language).

   WHEN MOTIVATED REPEATS WORDS, PHASES
8. Main problems parents perceive (rate from 0-5 how problematic these areas are for her child; 0 – not at all, 5 - absolutely).
   a. Verbal and nonverbal communication 0 1 2 (3) 4 5
   b. aggressive behaviour 0 (1) 2 3 4 5
   c. restricted interests 0 1 2 (3) 4 5
   d. stereotyped behaviours 0 1 2 3 (4) 5
   e. low attention span (focusing and switching attention) 0 1 (2) 3 4 5
   f. social inclusion 0 1 (2) 3 4 5
   g. social interaction 0 1 2 (3) 4 5
   h. general cognitive development 0 1 2 3 (4) 5
   i. emotional stability 0 1 (2) 3 4 5
   j. resistance to changes 0 1 (2) 3 4 5
   k. overall coordination/gross motor skills 0 (1) 2 3 4 5
   l. fine motor skills and hand-eye coordination 0 1 (2) 3 4 5
9. What are the child's areas of strength?

   FYSICALLY ACTIVE, PUZZLE PIECES, FINE MOTOR SKILL



10. What type of sensitivity does a child have?

- Visual
- Auditory
- Smells
- Touch
- Taste
- Other (please describe)_____

11. What types of things work best for a child in terms of rewards and motivation?

PLAYING WITH BUBBLE MAKER, iPOD,

CANDY, SWEETS, FAVOURITE MUSIC INSTRUMENTS

12. Comments (please share your observation about playtime behaviour, favourite toys/activities, tactile elements, smells, touch, less favourite activities, socializing with others, etc.)

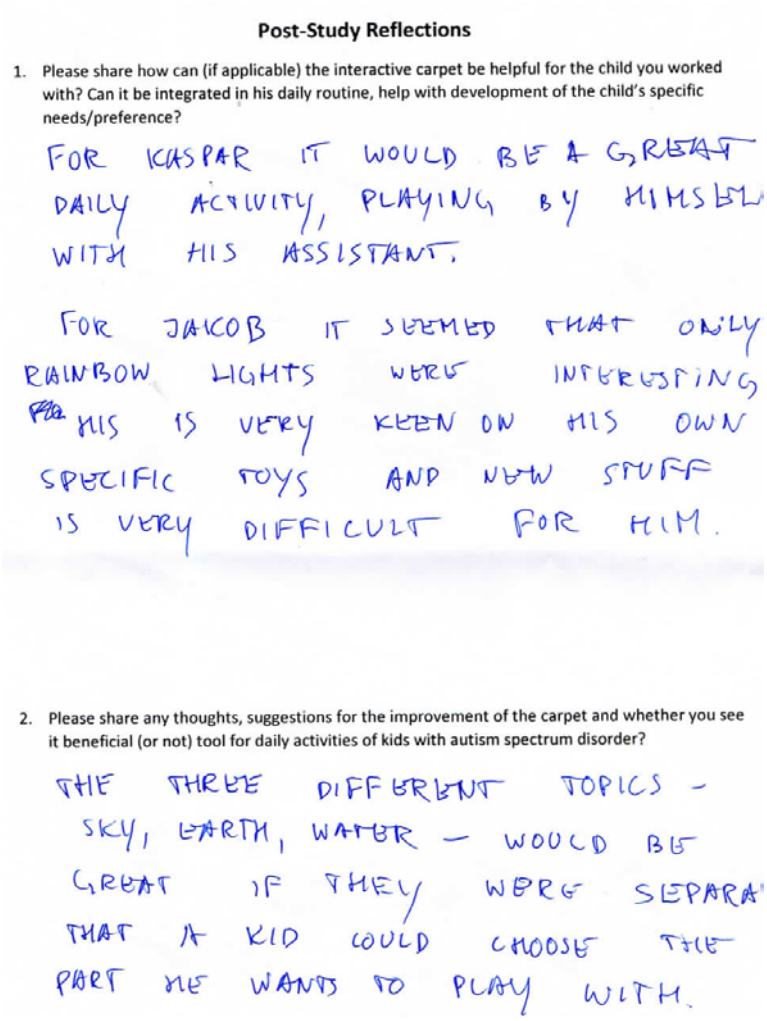
FAVOURITE: GETTING OUT OF CLASSROOM WITH AN ASSISTANT,

LISTENING TO MUSIC, ART CLASS, COLD THINGS/TOYS

LESS FAVOURITE: GOING TO TOILET, LOUD NOISE, CROWDED PLACES

Image 47. Pre-Study Questionnaire – Child (6)

9.2. Appendix 2. Post-Study Feedback from the therapists



Post-Study Reflections

1. Please share how can (if applicable) the interactive carpet be helpful for the child you worked with? Can it be integrated in his daily routine, help with development of the child's specific needs/preference?

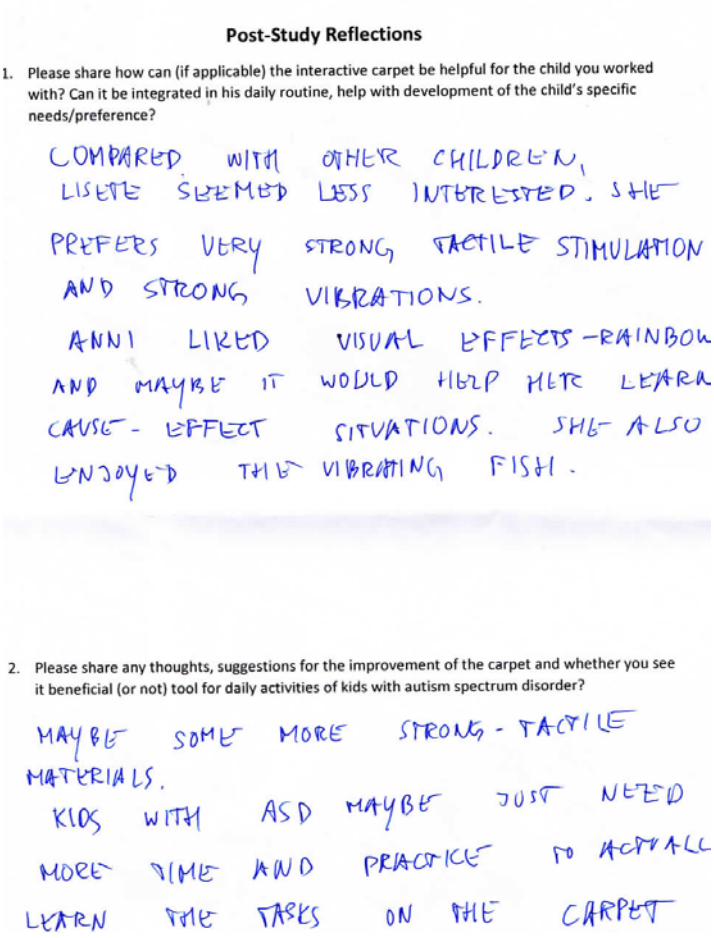
FOR KASPAR IT WOULD BE A GREAT DAILY ACTIVITY, PLAYING BY HIMSELF WITH HIS ASSISTANT.

FOR JAKOB IT SEEMED THAT ONLY RAINBOW LIGHTS WERE INTERESTING HIS IS VERY KEEN ON HIS OWN SPECIFIC TOYS AND NEW STUFF IS VERY DIFFICULT FOR HIM.

2. Please share any thoughts, suggestions for the improvement of the carpet and whether you see it beneficial (or not) tool for daily activities of kids with autism spectrum disorder?

THE THREE DIFFERENT TOPICS - SKY, EARTH, WATER — WOULD BE GREAT IF THEY WERE SEPARA THAT A KID COULD CHOOSE THE PART HE WANTS TO PLAY WITH.

Image 48. Post – Study Survey about Children 3 and 5



Post-Study Reflections

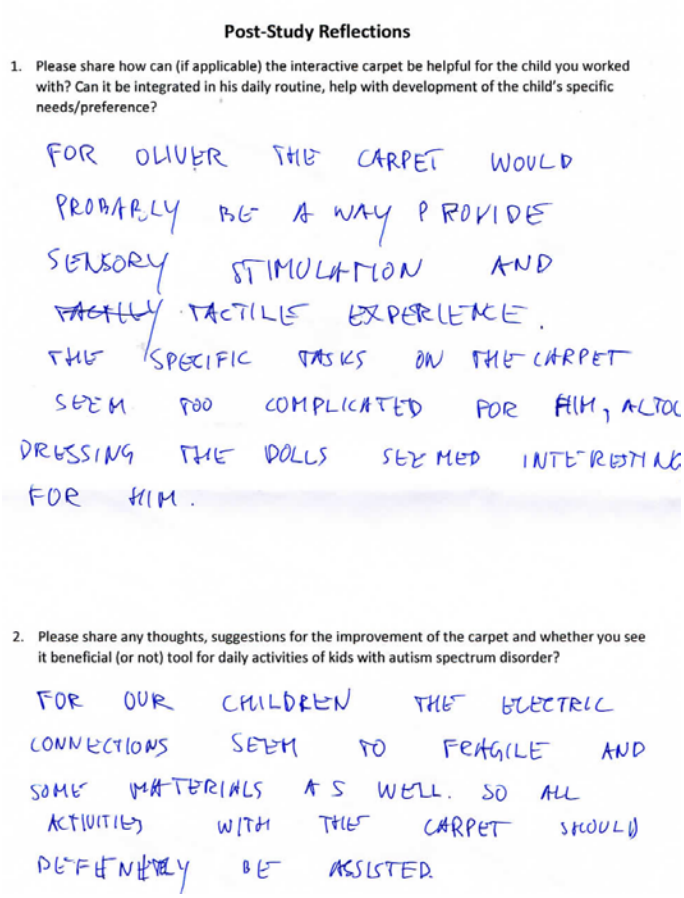
1. Please share how can (if applicable) the interactive carpet be helpful for the child you worked with? Can it be integrated in his daily routine, help with development of the child's specific needs/preference?

COMPARED WITH OTHER CHILDREN, LISETTE SEEMED LESS INTERESTED. SHE PREFERS VERY STRONG TACTILE STIMULATION AND STRONG VIBRATIONS.
ANNI LIKED VISUAL EFFECTS - RAINBOW AND MAYBE IT WOULD HELP HER LEARN CAUSE - EFFECT SITUATIONS. SHE ALSO ENJOYED THE VIBRATING FISH.

2. Please share any thoughts, suggestions for the improvement of the carpet and whether you see it beneficial (or not) tool for daily activities of kids with autism spectrum disorder?

MAYBE SOME MORE STRONG - TACTILE MATERIALS.
KIDS WITH ASD MAYBE JUST NEED MORE TIME AND PRACTICE TO ACTUALLY LEARN THE TASKS ON THE CARPET

Image 49. Post – Study Survey about Children 4 and 6



Post-Study Reflections

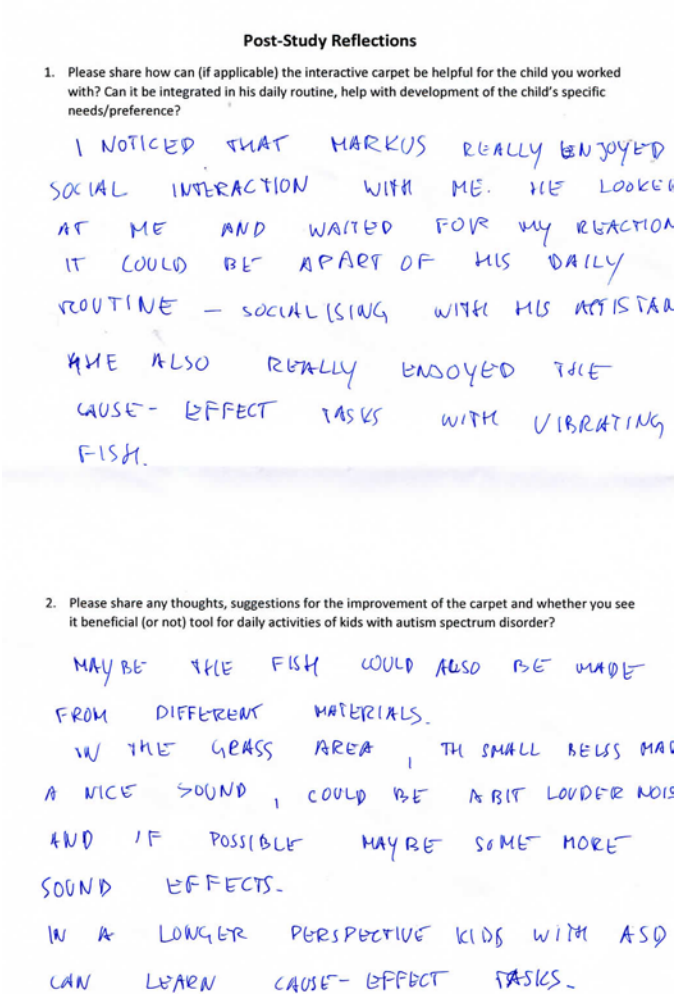
1. Please share how can (if applicable) the interactive carpet be helpful for the child you worked with? Can it be integrated in his daily routine, help with development of the child's specific needs/preference?

FOR OLIVER THE CARPET WOULD PROBABLY BE A WAY PROVIDE SENSORY STIMULATION AND ~~TACTILLY~~ TACTILE EXPERIENCE. THE SPECIFIC TASKS ON THE CARPET SEEM TOO COMPLICATED FOR HIM, ALTOG DRESSING THE DOLLS SEEMED INTERESTING FOR HIM.

2. Please share any thoughts, suggestions for the improvement of the carpet and whether you see it beneficial (or not) tool for daily activities of kids with autism spectrum disorder?

FOR OUR CHILDREN THE ELECTRIC CONNECTIONS SEEM TO FRAGILE AND SOME MATERIALS AS WELL. SO ALL ACTIVITIES WITH THE CARPET SHOULD DEFINITELY BE ASSISTED.

Image 50. Post – Study Survey about Child 2



Post-Study Reflections

1. Please share how can (if applicable) the interactive carpet be helpful for the child you worked with? Can it be integrated in his daily routine, help with development of the child's specific needs/preference?

I NOTICED THAT MARKUS REALLY ENJOYED SOCIAL INTERACTION WITH ME. HE LOOKED AT ME AND WAITED FOR MY REACTION IT COULD BE APART OF HIS DAILY ROUTINE – SOCIALISING WITH HIS ASSISTANT HE ALSO REALLY ENJOYED THE CAUSE- EFFECT TASKS WITH VIBRATING FISH.

2. Please share any thoughts, suggestions for the improvement of the carpet and whether you see it beneficial (or not) tool for daily activities of kids with autism spectrum disorder?

MAYBE THE FISH COULD ALSO BE MADE FROM DIFFERENT MATERIALS.
IN THE GRASS AREA, TH SMALL BELLS MAK A NICE SOUND, COULD BE A BIT LOUDER NOIS AND IF POSSIBLE MAYBE SOME MORE SOUND EFFECTS.
IN A LONGER PERSPECTIVE KIDS WITH ASD CAN LEARN CAUSE- EFFECT TASKS.

Image 51. Post – Study Survey about Child 1

9.3. Appendix 3. Feedback from 1 week prototype use

Summary

1 week – 3 autistic boys.

Each boy had had his own favourite things in the carpet. And they were interested in totally different things on the carpet.

1 boy always played with dolls (dressed them and changed hair colour) and when he was tired of playing with the dolls he started to put his fingers through the halls. And then I had to stop the process.

Second boy always toughed fishes to feel the vibration. This was the only thing he liked. And also he wanted to hear the sound of rain and was very surprised at the first time smelling the flower.

Third boy was watching me playing with the carpet and repeated the words I asked to him to repeat. He did not liked to thatch anything.

9.4. Appendix 4. Consent form

Consent Form for Participants

Study Description:	**A child and a caregiver will play using the interactive carpet prototype which includes a soft carpet, sensors and various soft elements. A caregiver will be the main facilitator of the play with a child. The prototype aims at enhancing socializing and attention skills of a child with ASD.**

Participant's Statement

I Kati Kiiver

agree that:

- the study purposes have been explained to me orally;
- had the opportunity to ask questions and discuss the process; and
- received satisfactory answers to all my questions
- Given this, I am glad to participate in the study as a facilitator of the play

For the following please circle "Yes" or "No" and initial each point.

V I agree for the videotape and photographs to be used by the researcher for publications and/or thesis work only. All private information will be kept confidential. YES / NO.

Signed:

Date: 21.02.2018

9.5. Appendix 5. Feedback from the therapist

Gmail by Google

Yulia Valerievna Zhiglova <yzhigl@tlu.ee>

Vs: Visit to the Kao Center with an Interactive Carpet Prototype

2 messages

Kati Kiiver <kati@kaokeskus.ee> Thu, Dec 14, 2017 at 5:48 AM
To: Yulia Valerievna Zhiglova <yzhigl@tlu.ee>

Hi Yulia,

In our case we can use that kind of game mostly one on one situations, therapist and child. Activities that therapist will do with this smart carpet will develop different abilities that autistic persons have difficulty with, for example: how to take part in interaction with another person, enjoying being with another person, learning to do sequences of activity with a person, taking turns, sharing personal space, using and understanding eye contacts, using and understanding facial expressions etc.

At first therapist will introduce to the child what is on the carpet and what can you do with them and later on, the same session or anohter, therapist can do the storytelling about the theme of the carpet and at the same time child can listen and deal with the tools that are on the carpet. Therapist can tell the different stories in different sessions for example.

Kati