DESIGN OF SOFT TANGIBLE USER INTERFACE WITH HAPTIC FEEDBACK TO HELP CHILDREN WITH AUTISM

A Thesis

by

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ABSTRACT

Autism is a spectrum of neurodevelopmental disorders characterized by limited social skills. The Centers for Disease Control and Prevention (CDC) estimate that 1 of 68 children born in the United States has some degree of Autism Spectrum Disorder (ASD). While symptoms can vary widely between individuals, autism symptoms begin to manifest in very early childhood and can be an emotional challenge for parents, causing extreme difficulties in the development of communication. This paper explores a design process of interactive soft toys for children with High Functioning Autism (HFA). Participatory design methodology was used and based on the interaction with HFA children in local events and centers, soft toys were developed from observations made and questions asked. There is also an in depth user study done that helps confirm the results obtained from the preliminary user studies. A cat soft toy made with soft felt fabric and different vibration patterns was developed to help improve relaxation in children with Autism. This method proved very effective and we will discuss about it in detail in this paper.

DEDICATION

This thesis is dedicated to my younger brother who is diagnosed with Autism Spectrum Disorder and who is also one of the most caring and affectionate person. He inspires me and the most valuable thing he taught me is to always be happy no matter what.

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr. Hwaryoung Jinsil Seo for motivating me and for providing me with very rich resources, My committee members, Dr. Francis Quek and Dr. Mandy Rispoli, for their support and for helping me learn more about Embodied Interaction and Autism.

I would also like to thank my father Aravindan, mother Jayanti, sister Ankitha, Uncle Sukumar pattnaik, Aunt Shanti Pattnaik and friend Vignesh Arulvanan for always encouraging me and the constant support. Thanks to Dallas Museum of Art and Brazos Valley Rehabilitation center for letting me volunteer and giving very valuable input. Thanks to the department faculty and staff for making my time at Texas A&M University a very valuable experience.

I want to thank the members of the Soft Interaction Lab for giving me abundant feedback and helped improve the design and study. I also want to extend my gratitude to all the children and parents who participated in the user study.

NOMENCLATURE

ASD	Autism Spectrum Disorder
HFA	High Functioning Autism
LFA	Low Functioning Autism
DMA	Dallas Museum of Art
BVRC	Brazos Valley Rehabilitation center

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1. INTRODUCTION

1.1 Motivation

Children with Autism are present with severe communication deficits especially with social interaction and emotional control according to dsm5.org. People with ASD tend to have communication deficits, such as responding inappropriately in conversations, misreading nonverbal interactions, or having difficulty building friendships appropriate to their age. In addition, people with ASD may be overly dependent on routines, highly sensitive to changes in their environment, or intensely focused on inappropriate items. Again, the symptoms of people with ASD will fall on a continuum, with some individuals showing mild symptoms and others having much more severe symptoms. So, it is essential that children with Autism are given some form of relaxation to be able to be able to cope with such symptoms.

The soft circuit or eTextile techniques provide great potentials for people with difficulties to explore touch-based interaction (Giles, 2014; Heimdal, 2010). To aid in day-to-day life and to develop necessary skills, some are given aided augmentative and alternative communication technologies (AAC) according to Giles.. The relative popularity of these technologies has led to a proliferation of competing software. At the time of this publication, the authors observed over 250 AAC offerings within the Apple iTunes App Store©, alone, with a cost range of free to $250.

According to The Hindu, in a developing country such as India or even in a developed country such as United States, many or say about 80% of the people can't afford such expensive therapeutic products. And it is very crucial for a child with Autism or in fact any disability to have some form of relaxation to cultivate and ameliorate their senses as they grow.

1.2 Research Questions

It is important that there is some technology that helps Children with Autism relax. This study will focus on exploring this area by investigating the following questions:

1. How do children with Autism respond to interactive soft pillow with Haptic feedback in high-stress situations?

    a. Do the pillows relax them when they are tensed and how?

    b. Does only the feedback matter or does the material and the characteristic of the pillow matter too and how?

    c. Does the interactivity (touch sensor) of the pillow help?

2. LITERATURE REVIEW

Prior research proves that interactive systems inviting human touch help children with autism in various ways. In clinical research, it is known that therapeutic touch is beneficial to many populations including children with autism.

2.1 Autism Spectrum Disorder

Autism is a spectrum of neurodevelopmental disorders characterized by limited social skills. (Escalona, 2001) According to Center for Disease Control and prevention (CDC), It is estimated that 1 of 68 children born in the United States in 2008 has some degree of Autism Spectrum Disorder. While symptoms can vary widely between individuals, autism symptoms begin to manifest in very early childhood and can be an emotional challenge for parents, causing extreme difficulties not only in the development of communication but also memory impairment, epilepsy, impaired emotional control, and, relatedly, self-harm (Garzotto, 2014, Giles, 2014). In one case, sixty one percent of ASD children completely failed to develop speech (Grandin, 1992).

There is evidence to support the belief that early intervention, while unlikely to change the fundamental elements of autism itself, may ameliorate symptoms and improve communication skills, increasing overall quality of life (Heimdal, 2010; El, 2006).

As ASD children are frequently more apprehensive of, and slower to adapt to, new situations, the relative complexity of existing AAC solutions may be problematic. Limited emotional control is a major consideration; frustration provides a possibility of interventions backfiring. As such, engagement is of high concern for involved interfaces and there may be a great advantage in focus on interface simplicity and playfulness instead of simply expanding on features (Tware, 2014).

2.2 Therapy for ASD

To better address these limitations, we need to address how these children are modeled as users. While there is a temptation to suggest that these children simply need access to an applicable pictorial dictionary, this perspective does not consider the massive amount of development that occurs during childhood, ignoring the embodiment at work in childhood experience.

Behavior Analysis is the scientific study of behavior. Applied Behavior Analysis (ABA) is the application of the principles of learning and motivation from Behavior Analysis, and the procedures and technology derived from those principles, to the solution of problems of social significance. Many decades of research have validated treatments based on ABA. According to Center for Autism, ABA methods are used to support persons with autism in at least six ways:

1. To increase behaviors (eg reinforcement procedures increase on-task behavior, or social interactions);

2. To teach new skills (eg, systematic instruction and reinforcement procedures teach functional life skills, communication skills, or social skills);

3. To maintain behaviors (eg, teaching self control and self-monitoring procedures to maintain and generalize job-related social skills);

4. To generalize or to transfer behavior from one situation or response to another (eg, from completing assignments in the resource room to performing as well in the mainstream classroom);

5. To restrict or narrow conditions under which interfering behaviors occur (eg, modifying the learning environment); and

6. To reduce interfering behaviors (eg, self injury or stereotypy).

Javier mentions that a number of clinical trials and single-subject studies have been published measuring the effectiveness of long-term, comprehensive applied behavior analytic (ABA) intervention for young children with autism. Results suggested that long-term, comprehensive ABA intervention leads to (positive) medium to large effects in terms of intellectual functioning, language development, acquisition of daily living skills and social functioning in children with autism. (Javier, 2010)

Sensory room and Quiet room

There are many in-house therapies developed such as a sensory room, which is widely acknowledged in the Autism community. The sensory room has bright flickering lights, which change periodically, projectors showcasing calm places and sceneries,

relaxing and peaceful sounds, bubble tubes and bright colorful toys. This sensory room helps the children relax and unwind. Many families have this sensory room for their children, but the issue with this room is that the items used to make the sensory room are very expensive and they are not mobile.

The Quiet room is a method that is adopted in school and houses. The quiet room can be a corner in a school is usually a small space in the corner of a room with books, beanbags, soft toys and family photo albums. This room is meant to be silent with no digital technology. It is to help the child relax through getting close to their roots. This technique is also adopted in a home setting where the child is allowed to retreat to when going through stressful situations. There is no factual data to prove the effectiveness of these therapies but they are widely followed by therapists and parents to give some of relaxation for the children with Autism.

2.3 Existing Techniques for Relaxation

Sensory products

Helen developed a therapeutic cloth for children with Autism that helps them speak out without getting anxious. The cloth has sensors, LED and microphone where the child can speak in and interact without feeling conscious. The sensors inturn relaxes the child and helps him surpass the social anxiety. (Helen, 2014)

In a recent research done by Greis (Greis, 2014), they created a game using multi touch interface that helps children with severe Autism to interact with each other. This

game is designed in the way that users exchange information with each other actively, passively and together to be able to communicate in a systematic way. The main idea behind this game it to help the children or people with Autism communicate in an organized fashion so that it helps them get rid of the anxiousness of figuring out what to talk or how to talk to people. This relaxes the person with Autism. More so than often, people are anxious about how to interact than the act of interacting.

Fahd Albinali (Fahd, 2009) with his research mates recognized that repetitive motor movements help autistic children with their classroom behavior. They use ubiquitous monitoring tools such as three accelerometers for the automated detection of stereotypical behavior observed in 6 children diagnosed with Autism. It was observed that the children do the following behavioral activities a lot: body rocking, mouthing and complex hand and finger movements. In this paper, researchers mention that these habits are socially inappropriate and considered self-injurious behavior. This experiment helped therapists to monitor children's behavior and address the issue by providing them with some form of relaxation so that they do not perform the above mentioned habits.

Massage technique

Escalona (Escalona, 2001) report that children with autism who have a 15 min massage session every day for 1 month exhibited less stereotypic behavior and showed more on- task and social relatedness behavior during play observations at school, and they experienced fewer sleep problems at home.

Grandin (Grandin, 1992) presents clinical effects of ‘deep touch pressure’ using a ‘squeeze machine’. She reports deep pressure stimulation is beneficial to calm children with autistic children. Opposed to deep touch effects, soft and slow touches haven’t been fully investigated by scientists and practitioners. Recently eTextile techniques have expanded creative opportunities in terms of soft and flexible touch interfaces.

Robots help with relaxation

Over the past 20 years, researchers have developed interactive technologies that advance our approach to autism. According to Picard, interactive technology has contributed to these fields in at least 4 ways: a) novel sensing technology that helps us to understand children with autism better through multimodal information; b) new techniques to infer a person’s affective or cognitive state; c) interactive system to respond to children with autism; and d) self-monitoring technology (El, 2006).

Simple robot systems have been utilized to investigate how they have the potential to improve autistic children’s communication skills (Kozima, 2009). It is known that children with autism tend to have low interest towards other humans. However, they prefer interacting with robots than with humans (Miyamoto, 2005). Kozima et al. developed a little toy robot, Keepon and they found that Keepon attracted the attention of and caused emotional relationship in the autistic children (Kozima, 2009).

Recently many interactive environments and wearable projects have been developed for children with autism to help them to reduce their anxiety (Tware, 2014) and to learn social interactions (Garzotto, 2014).

Wearable technology

Likewise, several previous studies have shown the effectiveness of such an approach. Sitdhisanguan (Sitdhisanguan , 2012) demonstrated that tangible user interfaces (TUI) and touch-based systems provided superior ease-of-use and skill improvement with ASD children, whose motor skills may also be limited. Koo's TellMe system provided a series of wearable sensors and interactive elements to reduce the anxiety levels of ASD boys and improve emotional communication. Different robot characters represented different emotional reactions and opinions, such as Nobot, which represented negative sentiments and disapproval, and Joybot, which represented positive affect and approval (Koo, 2014).

According to a research done in Cincinnati Children's Hospital Medical center, therapists often stated that the use of therapeutic weighted vests increased the child's on-task behaviors, ability to remain in his/her seat, and attention. Therapeutic weighted vests were generally used with preschool and young elementary school-aged children with diagnoses of autism or attention deficit disorder. So, a lot of the children who have HFA or LFA use weighted jackets or weighted blankets to relieve stress and calm down

when tensed. This is a proven and a very effective method of relaxation. Although these products are found to be very expensive and not all parents can afford them.

2.4 Use of Tangible Products

There are many Tangible products that are used for the purpose of relaxation. Some of which are mentioned in the above Sensory products section such as squeeze balls and stretchy toys. Some other widely used tangible products for relaxation are soft toys and pillows. These specialized soft toys and pillows provide relaxation in terms of some feedback or the way they are designed. Children are known to be attached to soft toys and this incorporated as a form of therapy is a good way to help them relax.

+me project is an emotionally responsive body plug-in for adults and a motivational transitional object for the children with autism to allow them communicate better. Children with autism can communicate with the prototype, which is a soft collar pillow with visual, auditory and haptic sensory integrations with the way he/she likes such as hugging, sleeping, squeezing or carrying. The wearable prototype consists haptic interface, color and density changing lights, speakers with sensor technologies and a remote controller that allows therapists or parents to adjust the actual sensory feedbacks. The main aim of the prototype is to produce specific sensory feedbacks controlled by an adult to implement social competence and social conversation between children with autism and their parents in daily life or during therapies with therapists. After having positive sensory feedbacks as a reward, children with autism tend to focus more on the

interpersonal communication and achieving their goals during the learning activities. It can be used by adults as a body plug-in to provide wonderful deep calming pressure and a soft feel.

3. METHODOLOGY

3.1 Participatory Design

Research

Participatory research methods such as co-creation and ethnographic probes allow us to understand and empathize with our stakeholders.

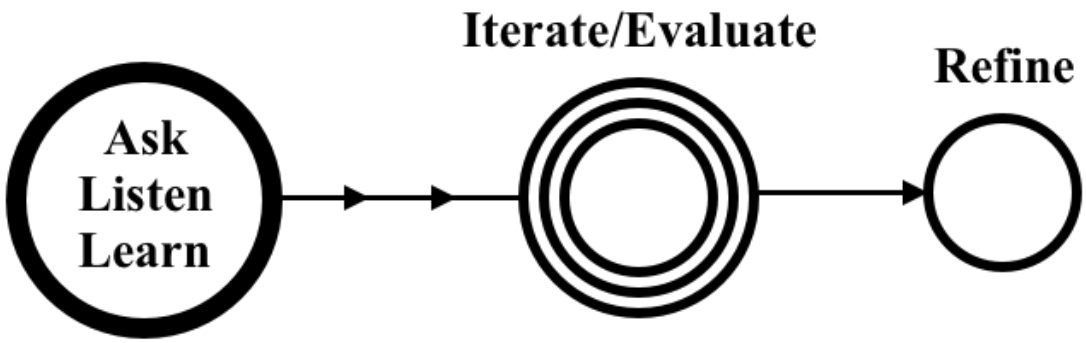

Figure 1. Participatory design wireframe

Design

As shown in the Figure 1, the design process is iterative and the outcomes are informed by the research findings.

Testing & implementation

The design solutions are evaluated and refined based on feedback gathered through user testing.

This Participatory design method has been adopted for the User study. The prototype was developed based on the observations made of the participants and the way they reacted with the soft toy.

3.2 Key Design Concept – DIY for Health

DIY is a abbreviation for Do It Yourself and it is a popular term used for something that people can create themselves from an inspiration that they had. A lot of people who have Autism and other disabilities find it quite hard to afford therapeutic items. So, a lot of the products are recreated at home. Some of the Autism sensory products that are recreated are:

a. Bubble tubes
b. Bright flickering lights
c. Sensory room
d. Quiet room

So, the DIY element is also incorporated into the soft toy to make it very affordable and customizable for the parents who have children with Autism.

3.3 Qualitative Research

According to cslub**,** Qualitative research is a major field of academic research study, and the basis for awarding theses and dissertations (i.e., the making of a Doctorate) in the US and worldwide. The aim of a qualitative research may vary with the

disciplinary background, such as a psychologist seeking to gather an in-depth understanding of human behavior and the reasons that govern such behavior. The qualitative method investigates the why and how of decision making, not just what, where, when, or "who", and has a strong basis in the field of sociology to understand government and social programs, and is popular among political science, social work, and special education and education majors.

In the conventional view by statisticians, qualitative methods produce information only on the particular cases studied (e.g., ethnographies paid for by governmental funds which may involve research teams), and any more general conclusions are considered propositions (informed assertions). Quantitative methods can then be used to seek empirical support for such research hypotheses. In contrast, a qualitative researcher holds that understanding comes from exploring the totality of the situation (e.g., phenomenology, symbolic interactionism), often has access to large reams of "hard data", and begins with propositions proceeding in a scientific and empirical way throughout the research process.

A popular method of qualitative research is the case study which examines in-depth "purposive samples" to better understand a phenomenon (e.g., supports to families); hence, smaller but focused samples are more often used than large samples which may also be conducted by the same or related researchers or research centers.

4. IMPLEMENTATION

4.1 Iterative Design Studies

Eight soft toys were developed to test the different features and feedbacks and the affect it had on the children with Autism. The preliminary study or observations were conducted in the Brazos Valley Rehabilitation centre (BVRC) and Dallas Museum of Art (DMA) Autism convention. In BVRC, the study was conducted for 3-4 months during a social club held for 2 hours every Tuesday and Thursday. The soft toy was tested with different materials such as cotton, soft fleece, hard fleece, patterned fleece, hard felt and soft felt. The material was tested with different variation of bright, dull and pale colors. The characteristics tested for the soft toy was that of a cat, cloud, cube and cylindrical. The different feedbacks tested were light, sound and vibrations. The different conductive methods used were a sandwich of velostat and conductive fabric; and a crochet with conductive yarn.

Prototypes

Prototype 1

The initial design was to develop a soft toy with a Haptic feedback. From the literature view it was clear that haptic feedback and tangible products help children with Autism. Children in general like soft toys and so based off the concept, the soft toy with haptic feedback was planned to be developed.

Based on the sensory room products, we chose light as the feedback with pressure sensor made from conductive crocheted yarn. The shape chosen was that of a cloud to make it seem simple and at the same time evoke children's imagination as a cloud is something that they do not interact with on a daily basis. Lilypad Arduino was used as a microprocessor with conductive fabric and Lilypad LEDs for the light output.

This cloud pillow as shown in Figure 2 was tested in the Dallas Museum of Art (DMA) Autism Convention where families with Autistic children attended the event. There were many therapists that the families could interact with, sensory products and innovation that they children could test and get to know about. We tested our soft toy in the event and we found that the bright lighting in the center diminished the brightness of the light in the soft toy hence not providing the necessary sensory output as expected. This product is a good sensory room product but the main idea behind this was to make it accessible everywhere and in all conditions. Also, the cloud shape was something that the children did not relate to because it was not a character and was abstract.

Figure 2. Prototype 1

Prototype 2

The second prototype as shown in Figure 3 was a cloud with a sound feedback. The sound was from a Lilypad buzzer and it was programmed to play a popular children's rhyme. This had no lights as feedback. The feedback was something that the children liked but still they were not relating to the cloud shape.

Figure 3. Prototype 2

Prototype 3

We went on to research on various characters that the children's like. And by interacting with the children in the Brazos Valley Rehabilitation center (BVRC) Social Club, we came to know that children love pets. This preliminary iterative user study was done for 4 months from February 2015 to May 2015 for 2 days a week where a social club was help where children from ages 3 to 10 would meet and interact with each other, the therapists and volunteers. It was to foster social relationships and behavior. From the observations made here and the questions asked, it was found that almost all children had pets at home which helped them improve their tactual sense and majority of the families had cats. So, a cat character was chosen with the idea of a soft toy plus a pillow that the children can hug.

So, as shown in Figure 4, a cat with bright yellow fabric and polka dots was developed with a buzzer and vibrator made from a vibe board. Slender structure was chosen so that it is easy for the children to hug and hold. The way this worked was when the children hugged the soft toy, they indirectly touched the pressure sensor which then activated the buzzer. The children associated the vibrations to a purring of the cat. This prototype was both tested in the BVRC Social club as well as the DMA Autism convention and all the children liked it. They approached it, hugged it, talked about it and a lot of the children befriended it immediately because of it's friendly demeanor. They also wanted to take it home.

Figure 4. Prototype 3

The one drawback with this prototype was the fabric, it made the children hyper instead of calmer. It was because of the bright yellow fabric. The buzzer was a good addition to the cat but it wasn't very audible because the children are usually noisy and also the vibrator got much more response than the buzzer. Children would hug it and feel relaxed.

Prototype 4

We then decided to go for a more neutral color with felt fabric. It seemed like the children really liked the cat character and the shape of the soft toy but we wanted to test it with different sizes. So, we went for a shorter cat soft toy with hard felt and a longer cat soft toy with a softer felt as shown in the Figure 5. These soft toys had no circuitry or feedback in them to purely test the fabric and the size.

The shorter one was almost like a ball and the children played around with it and threw it around and didn't take it so seriously. Where as the longer one was something that kept the children grounded and they seemed to treat it more as a relaxation toy and a pillow better. So, we went for the longer one. Some children did not like the feel of the soft felt because it felt rough. They preferred the softer one and wished that it was more softer.

Figure 5. Prototype 4

Prototype 5

We then chose the longer cat soft toy and decided to experiment with different types of felt and characters. We went for a monkey character with different and softer felts as shown in the Figure 6. The children seemed to recognize the cat and relate more to it. Because, a monkey is something that they do not relate to on a daily basis. They did not prefer the fabric in the image because it has bumps on the fabric and that is something that they would not prefer. They liked the earlier one better because it didn't give them additional sensory that is not required.

Figure 6. Prototype 5

Prototype 6

We then chose a silkier fabric which was tested in BVRC and DMA with vibration feedback and the children loved it. They thought it was really soft which instantly calmed them when they were facing a stressful situation and also when they hugged it, the soft toy vibrator, which then calmed them even more. They spoke about the cat like character to their siblings and parents. The prototype is shown in Figure 7.

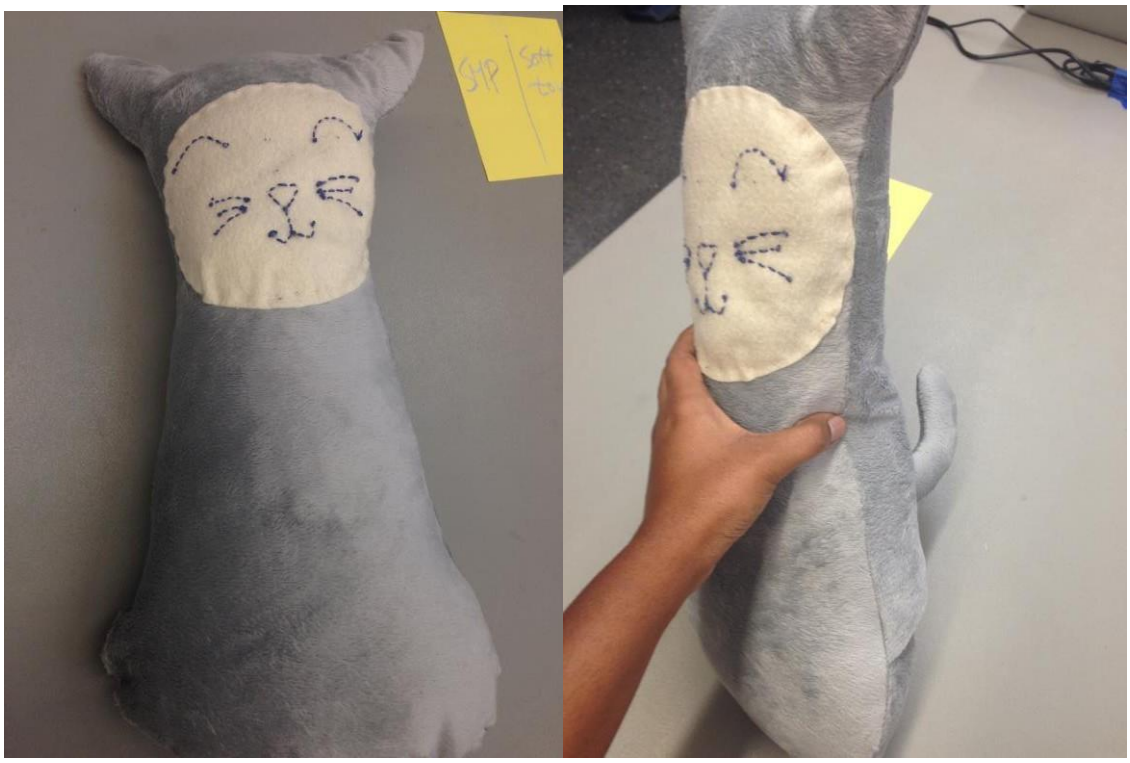

Figure 7. Prototype 6

Prototype 7

This prototype was very similar to the earlier one but had 3 different vibration patterns; breathing, heart beat and phone. We tested these in the In-depth user study which we are going to explain about later in this paper. This prototype as shown in Figure 8 was also refined during the study and another feature, weight was also added.

Figure 8. Prototype 7

Material

Figure 9. Soft fleece fabric

The children were made to interact and play with the soft toys. The data was collected based on observations made on how they reacted with the soft toys. From the data collected, we came to a conclusion that the material that children prefer was cotton and soft fleece as shown in Figure 9. The colors they preferred were bright colors. The characteristics that the children liked were a cat as they related it to a real cat and most of the children like cats. The feedback that the children enjoyed a lot and, which seemed to relax them and calm them were vibrations. When a cat soft toy with vibration was presented to them, they associated it with the purring of a cat. So, the soft toy will be made with cotton fabric on the inside and will use soft fleece fabric as a cover on the outside. And so, the soft toy will produce haptic feedback.

Design

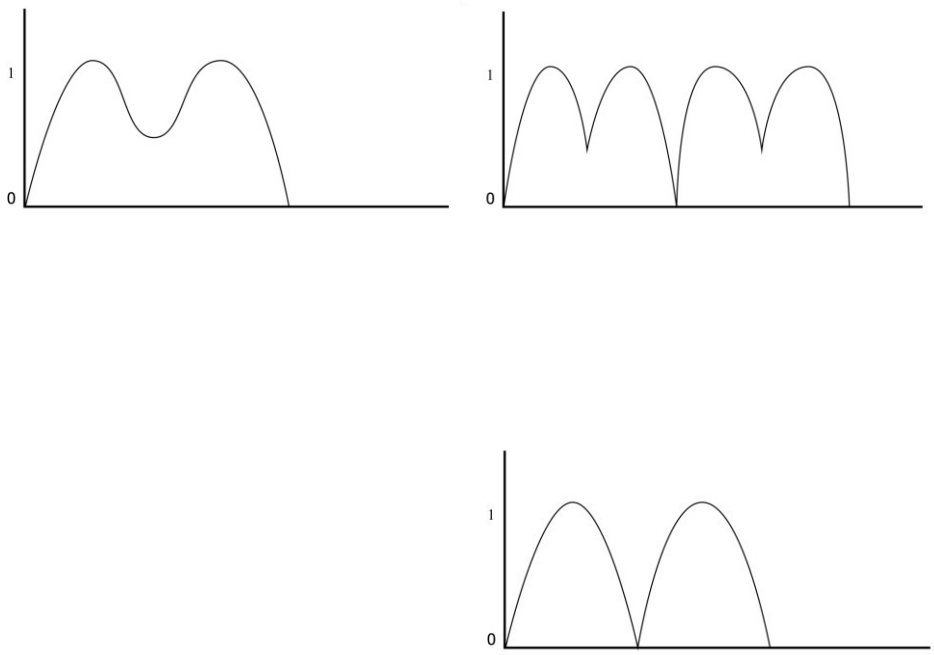

Figure 10. Different vibration patterns

There are three patterned vibrations as shown in Figure 10. One of the three vibrations will be used in each soft toy and there will be one soft toy with no vibration. The first graph in Figure 10 represents a heartbeat, the second one represents a phone's vibration pattern and the third one represents a breathing pattern. The haptic vibrations will be achieved using a vibe board. There will 2 vibe boards stitched on to the soft toy as shown in Figure 11. The soft toy will then be enclosed inside the soft fleece fabric sleeve. The conductive method that had more success rate was the sandwich of the velostat and the conductive fabric. The microprocessor used for the programming and

controlling the circuit is a Lilypad. The soft toy will be made with cotton fabric and the circuitry will be stitched on to it with conductive fabric acting as the connecting wires.

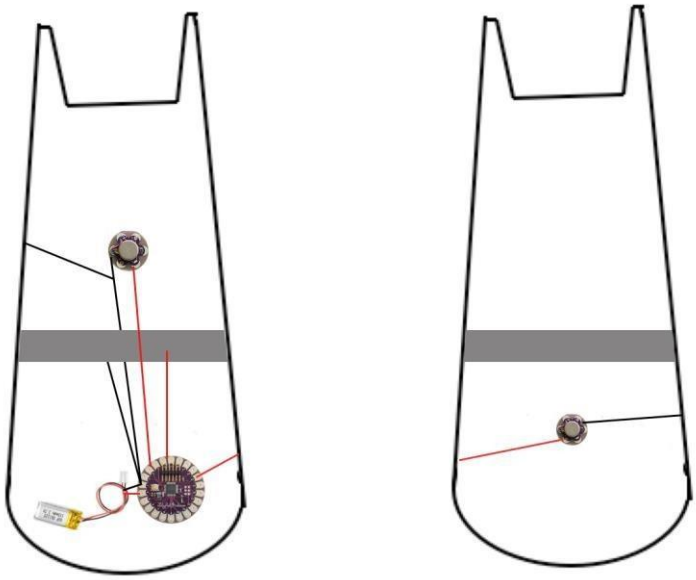

Figure 11. Circuit design of the soft toy

Interaction design

In addition to the haptic feedback, the soft toy will have a pressure sensor that is made of conductive fabric and velostat or a conductive yarn. When the child hugs or pressed the soft toy, the soft toy produces haptic feedback that is vibrations.

4.1 In Depth User Studies

User study

The target user group for this study is Children diagnosed with Autism, with the aim of having 6 participants. Research indicates that Children with HFA experience discomfort due to loud noises, if someone refuses something and other such actions. Their nerves tense up and they feel the need to dissipate the tension and do it in the form of shouting or crying or throwing things. It was observed during the preliminary study that at such situations, the children clutch something really hard or bite their fist. This helps them relax. And studies show that vibrations relax people. This study will have duration of 1 week for each participant in a setting shown in Figure 12. Two weeks will be allotted for the entirety of the study. The survey will ask the users' parent the condition of the user and also what methods are taken when they get tensed.

Figure 12. User study setting

When the user is about to experience one of the stressful situations mentioned in Figure 13, he will be prompted to hug the soft toy to feel the vibrations. Throughout the sessions, the user will be monitored for any signs of relaxation. Figure 4 illustrates a rough user flow planned for this study.

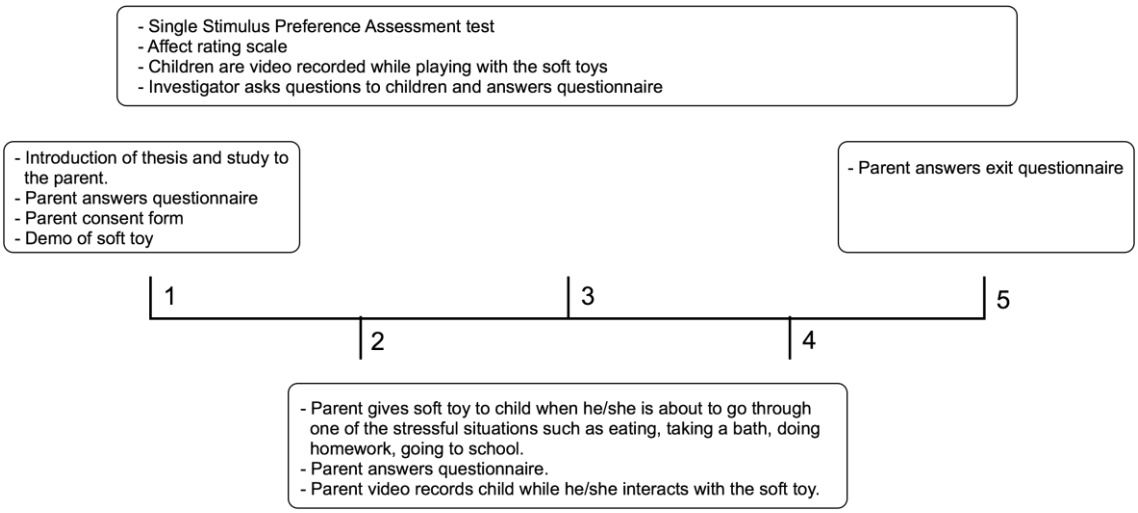

Figure 13. User flow timeline planned for the study

The study will consider one independent variables and one dependent variable. The independent variable is haptic feedback. The dependent variable is the user ’s comfort level. The haptic feedback has 3 vibration patterns. Figure 14 provides descriptions of each soft toy.

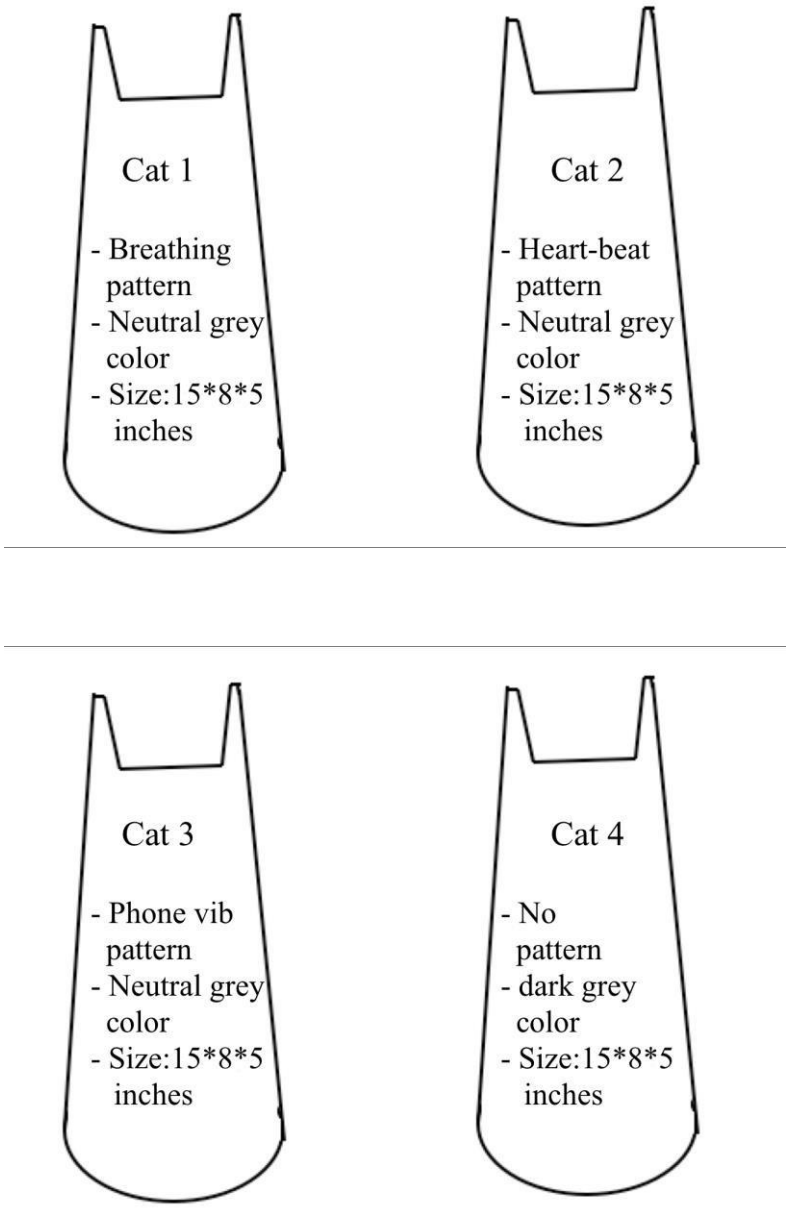

Figure 14. Description of each soft toy

5. EVALUATION

5.1 User Study Preparation

Participant recruitment

The Texas A&M mailing system was used to send out emails about the user study. We wanted to recruit 6 people with the age groups of 5 to 8 who were diagnosed with High Functioning Autism. We were contacted by many candidates but, some of them had Asperger's syndrome and other additional disabilities along with High functioning Autism. As per the requirements, 6 people were recruited for the study who qualified for the initial requirements.

Environment setting

Figure 15. User study environment

The user study as shown in Figure 15 was held in one of the rooms in the ETB building in Texas A&M University. The room was designed as a playroom for children. The room was made as hospitable and comfortable for the children as possible with the help of toys, snacks, drawing tools and children's furniture. A camera was mounted to capture everything going on in the room during the study to analyze the children's behavior and their interaction with the Investigator and Co-investigator as well their reactions to the soft toys. The adjacent room had a simple seating arrangement for the Investigator to interact with the child's parent. The room had a voice recorded set up to record the interview question during the study.

Development of soft toys

There were 8 soft toys that were developed for the user study. In the first week, there were 8 soft toys each with one of the four vibration patterns. In the second week, due to parent's recommendation and the User's response to the soft toys, 8 different soft toys were developed. A new feature weight was added along with just 1 vibration pattern.

5.2 User Study

User study flow

The User study was conducted for 10 days. The study was distributed into 2 weeks. The first week had 3 participants for a session each conducted on Monday, Wednesday and Friday. Each session was hourly, constituting the parent interview and

user testing. The second week had a similar schedule with 2 participants. The general timeline was the first 30 minutes of each session was spent with the Instructor interacting with the user's parent in the second room whilst the user interacted with the Co-investigator in the main room. The main room session was video recorded where as the secondary room session was audio recorded. In the first session, the co-investigator played with the user using the soft toys and other amenities in the main room. The co-investigator also asked the user questions related to the soft toy that would help get insight on the user's preferences in the comfortable setting. The second half of the session was the investigator and the co-investigator interacting with the child. The same information was being obtained in the secondary room but in the parent's perspective.

On the first day of each week, in the first session, the parent was asked to fill out an entry questionnaire which discusses the stressful situations when the child gets tensed, existing techniques used for relaxation, the child's attachment to any tangible object, the reaction of the child to the existing techniques, digital methods of relaxation and the rating of the ease of calming the child with the existing techniques. In the second session, the investigator conducted a preference assessment test or the single stimuli test, which rated the amount of time the child spent with each of the soft toy. The likeness of the child to the soft toy was measured on the duration of the child interacting with the soft toy. The test was timed and 2 trials were conducted. Based on the trials, the most favorite and the least favorite soft toy was procured and given to the child to be taken home for interaction in the home setting.

On the second day, the child interacted with the soft toys in a home setting and the parents filled out a questionnaire in addition to capturing videos and pictures of the child interacting with the soft toy. This dealt with factors such as the use of the soft toy by the child, the circumstances and situation based on when the child used the toy, initial and continued reaction to the toy, comments and comfort level of the child, affect of the soft toy on the child, emotional quotient that the child related with the soft toy and comparison with the existing techniques based on ease of use, comfort level, calming mechanism and time period.

On the third day, it was the same setting as the first day but we had a different set of questions for the parent. The questions were related to how the child used the soft toy, what scenarios and situations occurred where the child was used the soft toy, if the child used it himself or was prompted to use, other individuals who were involved with the child and the soft toy during the study and what could be improved about the procedure of the study in the home setting. In the second session, the Investigator conducted a Affect rating scale test where the user was prompted to point out in the scale how he/she felt about the soft toy. The user was also asked questions related to the soft toy factors such as the comfort level, softness, touch, relation to another thing, feedback and color. The preference assessment test was conducted again and the users took the most favorite and the least favorite toy.

The fourth day was similar to the second day but with different soft toys and to see if the children had sustainability with the same soft toys.

The final day had a similar setting as the first day but we had a different set of questionnaire for the parent. The questions were regarding their reflection on the study and the soft toys. Any possible recommendations for the soft toy, the beneficiary of it, if they would recommend it to others and how it helped their children in the day to day life. Similar questions were asked to the user in the second session. The user was then given a gift card and a Thank you card as shown in Figure 16.

Figure 16. Gift card

5.3 Participant Information

General information

There were 5 participants in the study. All the participants are diagnosed with High Functioning Autism with no additional disabilities. They were all aged between 5 to 8 years. There were 3 male and 2 female participants. The individuals who accompanied with the participants were mothers with occasionally siblings and therapists. Based on the data collected from the parent questionnaire, user questionnaire and observations, the characteristics of the participants were noted and are shown in the Figure 17.

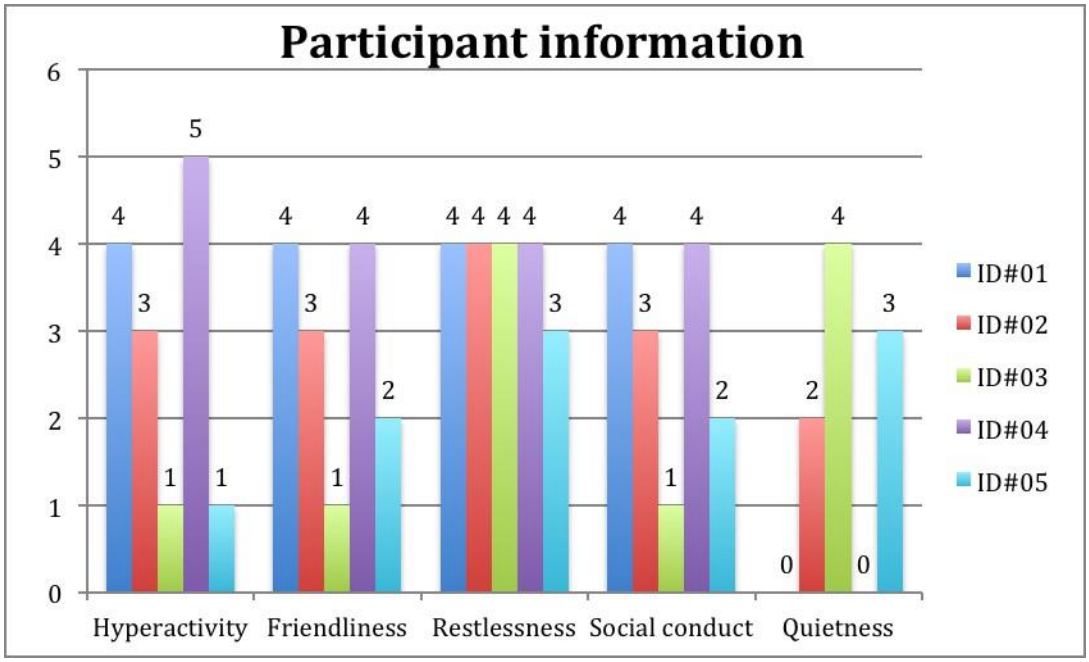

Figure 17. Participant general information

Stressful situations for participants

There were many stressful situations for the participants. From the Figure 18 it is shown that the most common stressful situation for any participants was to be told not to do something, to be stopped from doing something or to be told no for something that the participant asks. Common stressful situations predicted by the Investigator such as homework, having a meal, morning routine, going to bed and taking a bath were trivial comparatively. These predictions were made based on the observations and data collected in the preliminary user study. The data was collected from parents through

questionnaire and interview about their child's daily habits and fears.

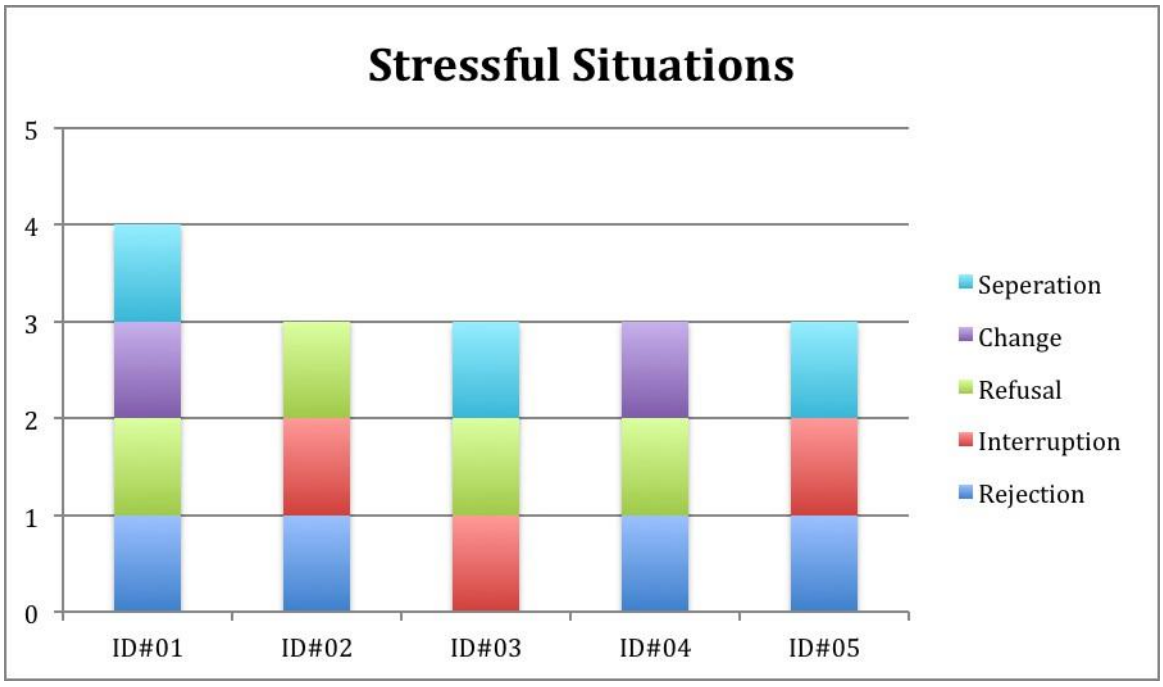

Figure 18. Stressful situations

Existing techniques used for relaxation by participants

There are many organizations, rehabilitation centers and help that the children of Autism have. From the interaction with the parents, it was acknowledged that there are many resources and a strong community in every city to help people with Autism. There is a box called the 'safe place', which contains cards, squeeze balls and other such tools to help the children in relaxation. According to parent's answers about what techniques they use for their child's relaxation, common methods were found and plotted in Figure 19.

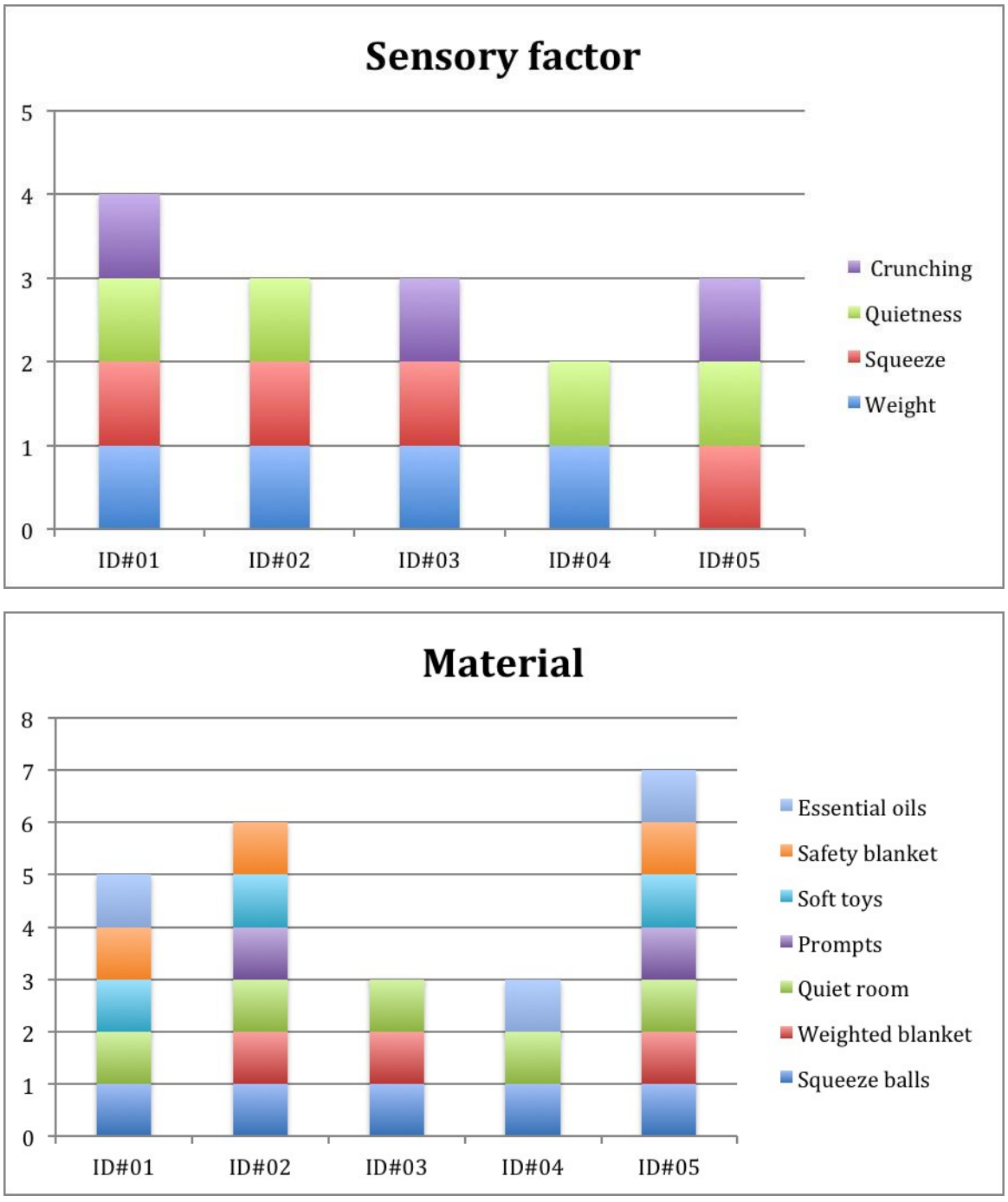

Figure 19. Soft toy sensory and materials

Digital methods such as apps and games are used more for distraction than for relaxation.

Absent or defective traits in the existing techniques

Most of the parents mentioned that the existing techniques were the most simplistic and the most common form of relaxation techniques that were used by people and children with Autism. It very expensive and gives temporary relaxation. The parents mentioned that things such as weighted jacket, sensory room, sensory tubes and bottles and pressure pads were something that give long time relaxation and improve the

sensory feel of the children but are very expensive and most parents cannot afford it. They find therapy and essential oils more beneficial than these expensive tools. So, affordability and customizability are the ones that make the existing techniques bleak and not desirable.

5.4 Qualitative Analysis

Behavioral analysis during the study

There were some common traits displayed by the users during the user study, both in the home setting and the controlled room setting. Most of the traits Ware explained in the above general information of the user study participants. These traits may or may not influence the way the children interacted with the soft toys. Autism has a wide spectrum and each and every child has a different reaction and toleration level.

Design aspects

Touch

The participants had a higher tolerance level than children with Low Functioning Autism. One of the participants had issues with the sense of smell and one of the participants had issues with sense of light. But generally, the participants were very tactual. So, they were okay with touching and hugging the soft toy. It was also good that the soft toy had responsive feedback because continuous feeling of vibration could irritate the children and counteract to what the soft toy is designed to achieve. Also, the responsive feedback gives the users the sense of squeezing something, which is proven as a popular method of relaxation. This tactual factor was plotted based on the Single Stimulus Preference Assessment as in Table 2. 3 out of 5 children held the soft toy for more than 1 minute and they were totally okay with touching the soft toy. This was found based on the video recordings that were made in the user study.

Comfort

The participants found the soft toy very comfortable and the most popular comment was that it was very fuzzy. Some of the comments mentioned by the participants about the comfort level of the soft toy are as follows.

ID #02 “Very fuzzy”

ID #05 “Nice to hug”

ID #04 “Feels like my mom”

ID #01 “I want to hug it and sleep”

ID #03 “Very comfortable”

Weight

During the first week of the study, the weight feature was not taken account. But due to the analysis done in the first week, it was found that weight is something that would really help the children relax in addition to vibration and touch. So, during the second week, this feature was tested as well. This had significant results as both the participants loved it and chose the weighted one over the heavier one. This helped them stay grounded and had some pressure on them to help them relax better. The downside was that they couldn't carry it around easily but it was also an upside because it meant they did not throw it around like they did with the other soft toys. It gave more meaning and value to the soft toy.

Vibration

This feature had a very varied response from the participants. Some of them really liked and it seemed to relax them from the feedback we got from them and the parents. But some did not find it desirable. A popular comment was that they associated the vibration to a purring of a cat. There were 3 different vibration patterns mimicking phone, heartbeat and breathing but the children couldn't differentiate between different vibrations. It was either a high vibration, low vibration or no vibration to them. 2 children preferred high breathing vibration. 2 children preferred low heart beat vibration. 1 child did not prefer vibration because he doesn't like soft toys having any feedback.

Size and shape

The size and shape feature got a unanimous response. All the participants loved the shape of the soft toy. It was perfect for them to hold it and carry it around. It's long slender shape gave them the freedom to wrap it around their arms. The size also wasn't too big or small. The slight curve along the neck region of the cat soft toy gave them a nice grip for them. Overall, this was something that the participants loved.

Color

Children with Autism love bright colors in general. They are more attracted towards bright colors but a major drawback is they get very hyper when they see bright colors. It does the opposite of relaxing them. So, it is highly mandatory to use light colors in products meant for relaxation. So, the grey color was something that the parents and the children agreed with. The children did not want to substitute with any other color. The grey had a calming effect on the child and helped them stay calm and composed and did not rise their hyper activity levels.

Characteristic

This was something that was tested in the initial study and the cat characteristic came into ideation and execution because of it. The children also liked the cat because all the 5 participants had cats at home. So, they related their own cats to the cat soft toy. One of the participants wanted to give the cat a name, a tail, whiskers, big eyes and shirts. One of the participants wanted a lion instead of a cat on the second day. This issue is addressed in the later section.

Emotional quotient

It was quiet interesting to see the attachment of the children to the soft toy. Some of the participants got attached to the soft toy a lot over the week but some of the participants didn't mind too much. The reason being it was new at first and then they got bored with it. This was plotted based what the children told about the soft toy. Some of the comments they told were;

ID #05 "I put a seat belt for the soft toy because I wanted him to be safe"
ID #04 "I want to give the cat a bigger tail, bright open eyes and stitch shirts for him" ID
ID#03 "I took him around town and showed him to all my friends and sister"

Affordability

Affordability was a unanimous answer as well. All the parents were told how much the soft toys cost and what it takes to make them or buy them and they all agreed that this is something that is definitely affordable then the therapeutic tools that are out there for prolonged relaxation. Below mentioned are the features combined together in this soft toy, which users get individually in many different products. So, this soft toy has a combined usage of many features found in products and hence proves to be very affordable. This is depicted visually in the Figure 20.

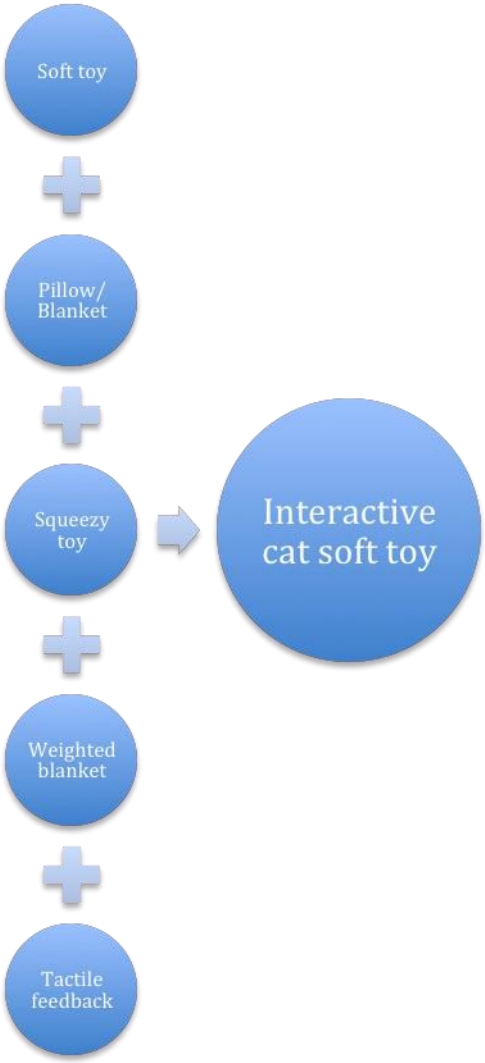

Figure 20. Affordability

Customizable and homemade

This soft toy has a pillowcase like design and so the skin of the soft toy which depicts the characteristic can be removed. So, this leaves room for the parent and the child to very creative and imaginative. The skin can be designed to be a cat, a lion or anything that the child desires. This can be easily made at home whether or not the user knowing sewing. The circuitry part is very simple and can come in a simple DIY (Do It

Yourself) kit that can be put together. The code is also fairly simple which can be provided with the kit. The circuitry and code can be changed as desired. The feedback can be sound or lights instead of vibration if required. The circuitry kit gives freedom to insert it into an existing soft toy or blanket and anything that child likes. So, this soft toy is totally customizable and can be put together easily.

Sustainability

The above feature also means that the soft toy is very durable and sustainable. From the user study the common complaint that the parents had were that it was very hard for them to wash the soft toys or the blanket that the children had. The reasons being that the children did not want to let go off their soft toys even for a single second and some soft toys had circuitry in them, which were not removable and could be damaged with water. This soft toy with its removable skins not only makes the soft toy creative but also the washable feature is taken into account. Also, children tend to get

bored with the same soft toy and this interchangeable skin avoids the parent from buying a whole new soft toy and just design and create the skins.

6. DISCUSSION

6.1 Significance of the Design Guidelines

This design that is developed can be a future guideline for researchers who want to investigate more on development of sensory products to improve relaxation in children with Autism. Based on the user study results, it is proven that this soft toy if further improved can also be helpful for children with ASD.

6.2 DIY and Workshop Integration

A workshop could be conducted to help parents recreate this soft toy as per their child's liking. Also, older children who have the ability to make a simple soft toy can participate and make the soft toy. The circuit as mentioned earlier is very simple to make and this can be taught to parents and children by providing simple instructions and code and a demo on how to do it. The soft toy can have different characteristics and not just a cat.

7. CONCLUSIONS AND FUTURE WORK

7.1 Conclusion

There has been a lot of work done in the area of Health and disabilities. Autism is one of the major disability and a lot of research is being done in it. There are a lot of sensory products and developed for children suffering with autism. So, this is an upcoming research field not just for therapists but also for designers to create a better interface. The results showed that the soft toy is proven as not only a toy that helps improve relaxation when the children go through a stressful situation but it is also proven that the soft toy acts as a friend and that children get emotionally attached to it. The design criteria could be used to create more such soft toy prototypes to help with relaxation and also communication. The soft toy could act as a communicating tool for children with LFA who lack verbal skills.

7.2 Future Work

In the future, more time would be allotted for the entirety of the study. Longer duration could test the interest of the children on the soft toy and also help us in recognizing the attachment level. This test can also be done in a home setting instead of a classroom environment. This could get the children in their comfort zone which could reveal different and possible better results with more detail. Also, additional participants could be recruited to get more data on the study. As the study results show, younger participants from the age 3 to 6 would be a better age group for the soft toys.

7.3 Plan for the Dissemination of Project Outcomes

Table 1 indicates upcoming conference deadlines planned for project submission.

Name of conferences	Dates	Deadline
CHI 2016	2016, May 7th –	2015, 11th -13th
HCI 2016	2016, July 17th to	2016, 19th February
ABAI 2017	2017, January 31st	

Table 1. Planned conferences for project submission

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APPENDIX A

1. How does your child react when tensed or irritated?
2. Do her anxiety levels rise when doing the following chores.
    1. Homework
    2. Having a meal
    3. Morning routine
    4. Going to bed
    5. Taking a bath
3. What do you do to calm your child?
    1. How long does it take to calm your child?
    2. Do your relaxation techniques work all the time?
4. What relaxation tools do you use?
    1. Do you think the relaxation tools and methods are affordable?
    2. Do you think it helps your child relax?
5. How does your child react when you try to calm him/her?
    1. Do you use any type of digital technology (e.g. mobile phone apps, videos, etc.) for relaxation?
    2. Please mark how easy it is to calm your child with the existing techniques.

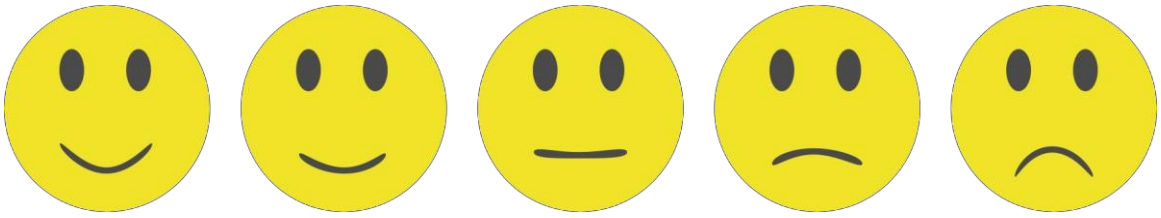
Very hard Hard Neutral Easy Very Easy

APPENDIX B

1. Which of the following chores is the child about to do?
    1. Homework
    2. Having a meal
    3. Morning routine
    4. Going to bed
    5. Taking a bath
2. What did you do to calm your child?
3. Did the child hold the soft toy?
    1. Did the child hug the soft toy?
    2. Where did he/she hug, the place where the vibration is felt or any other part of the soft toy?
    3. Did the child put the soft toy away?
    4. How long did the child hold the soft toy?
4. Did the child quieten and refrain from doing the actions mentioned in question 1 when he/she held the soft toy?
5. Did the use of soft toy affect the children's anxiety levels in anyway?
6. Which cat did the child like? Why did she/he not like the other cat?
7. Did the child talk about the cat? If yes, what did she/he say?
8. Please describe how the child uses the soft toy. (Take pictures or videos if possible)

APPENDIX C

Please pick one of the following which is the closest expression of the child while picking up or holding the toy:



1 2 3 4 5

The investigator will ask the following questions to the user,

1. How do you feel is the softness of the soft toy?
2. Do you have a pet cat or do you like cats? How much do you think the soft toy relates to a cat?
3. How much do you like the color of the soft toy?
4. How comfortable do you feel when you hug the soft toy?
5. How much do you like the purring effect of the soft toy?

APPENDIX D

Exit Interview

1. How was your overall experience in the study?
2. What did you think about the product? Why?
3. What did your child say about the product?
4. Do you think you will prefer this technique to other relaxation techniques?
5. Would you use this product to calm your child? How did it affect?
    1. If yes, why? Would you recommend this to your family or friends?
    2. If not, why?
6. Do you think this will help children with Autism?
7. Do you have any other comments you would like to add?

APPENDIX E

Sample Single Stimulus Data Sheet

Item	Duration in Minutes and Seconds trial 1	Duration in Minutes and Seconds trial 2

Table 2. Single Stimulus Preference Assessment

APPENDIX F

Procedure

The user protocol that was formulated for the overall study is as follows:

Day 1

1. Short interview for user's Parent to find out about the Autism level, anxiety level of the child and the techniques they use to relax the child when tensed. (Appendix A)

2. Get Consent form signed from parents.

3. Give introduction of the investigator, the research to the parent.

4. In the toy room, the child will be prompted to play with the soft toys. A video recoding will be taken.

5. The user will be put through a Single Stimulus Preference Assessment (Pace et. al) of the soft toys. (APPENDIX E)

   1. The user will be presented with the four soft toys.
   2. 5 seconds will be allowed for the child to approach the soft toys.
   3. If the child does not approach the soft toys, one of the soft toy will be handed to them and let them interact with it for 5 seconds. This is 'failure trial' and no data will be recorded.
   4. If the child does approach the soft toy, a stop watch will be started to record the time the child interacts with it.
   5. The stopwatch will be stopped when the child drops, turns away from, or disengages from the soft toy.
   6. The soft toy will be removed from the child's view and the duration of their interaction with the soft toy will be recorded.

7. Present next soft toy to the child.

6. Detailed description and demo of the prototype and the test to the user's parent.

7. The user will take home both the least preferred and the most preferred soft toy.

Day 2

1. Parent will answer the provided questionnaire after giving the soft toy to the child when he/she is about to experience the following 'stressful' situation. (Appendix B)

1. Homework
2. Having a meal
3. Morning routine
4. Going to bed
5. Taking a bath

2. Parent will take photos or videos of the child.

Day 3

1. Single stimulus preference assessment test will be conducted to find out the least preferred and the most preferred soft toy.

2. The investigator will ask the children questions and mark them on the questionnaire. Also an affect rating test will be taken. (Appendix C)

3. User will take home the two soft toys.

Day 4

1. Parent will answer the provided questionnaire after giving the soft toy to the child when he/she is about to experience the following 'stressful' situation. (Appendix B)

1. Homework
2. Having a meal
3. Morning routine
4. Going to bed
5. Taking a bath

2. Parent will take photos or videos of the child.

Day 5

1. The investigator will ask the children questions and mark them on the questionnaire. Also an affect rating test will be taken. (Appendix C)

2. Single Stimulus Preference Assessment (Pace et. al) will be conducted. (APPENDIX E)

3. Exit interview (Appendix D).