Designing for Children with Sensory Processing Disorders

Dr. Louise R Manfredi, Syracuse University

Dr. Manfredi holds a Ph.D. in Mechanical Engineering (2011) and a BDes in Product Design (2006) from the University of Leeds, UK.

Dr. Manfredi's primary research interest centers on sustainable product development, and how the decisions designers and engineers make affect the environment during the life cycle of these products.

Prof. Bekir Kelceoglu, Syracuse University

Prof. Bekir Kelceoglu was born in Ankara, Turkey and attended Anadolu University, where he received his B.A. in Interior Architecture. Even before his graduation, he started to work as a free-lance tutor, product designer, and interior architect. In year 2006, he received his Master of Fine Arts degree from the Ohio State University, concentrating on design development process in industrial design. His research interests are: humanitarian design, design development process, and emerging technology integration in design.

Designing for children with Sensory Processing Disorders

Abstract

Complex design issues require a multi-disciplinary approach. Building an environment where students can work with experts from different fields can be incredibly beneficial to not only the students working to solve the problem but also for the intended user of their work. This approach was piloted in a Human Factors for Designers class at Syracuse University, centering on the topic of sensory processing disorder (SPD). Specifically, students focused on sensory processing in children with autism spectrum disorder (ASD) and how they can be over- or under-responsive to tactile, auditory, or visual stimuli.

Five groups of three students enrolled in the industrial and interaction design program spent six weeks learning from a variety of experts who work on SPD, then employing their design and engineering skills to find solutions to existing problems. The specific research goal was to learn about the connection between sensory processing and behavior from a team of academic neuroscientists and local occupational therapists who support the children and their families. In addition to these experts, students spent time with the education director of a local science and technology museum to learn how the museum temporarily reworks exhibits to accommodate children and parents affected by SPD.

Using this research as a foundation, students were required to design either a toy or a therapeutic device to solve a problem they had encountered. The toy was required to possess educational value, and the therapeutic device needed to offer a function that facilitated interaction between the parent and their child. A working physical prototype, presentation, and process book were required deliverables. Experts provided feedback about the designs to the professor solely for the evaluation of the course.

In addition to detailing the outcomes of the project, this paper discusses the merits and drawbacks of short timeframe multi-disciplinary teaching collaborations along with recommendations for further development.

I. Introduction

A. Industrial design and usability

Industrial design is a user-centered discipline and has developed many tools in its rich history to enhance usability by helping designers to make better design decisions [1]**.** This could be in the form of interviews, discussions, focus group studies, or co-design [2]. In one way or another, the user is typically involved in the process. Specifically, for a project to be successful, one must fully understand who they are designing for, what challenges they face, and determine how they can ultimately improve someone’s experience.

B. Autism spectrum disorder and sensory processing deficit

It is estimated that 1 in 68 children in the United Stated are affected by autism spectrum disorder (ASD) [3], with global prevalence estimated at between 1% and 2% [4]. Autism is a neurodevelopmental disorder that manifests in different ways. Difficulty with social communication and interaction is common, with specific challenges surrounding eye contact, gestures, and the reading of social cues. Individuals with ASD typically have a strong aversion to change, thus require robust routines [5].

Sensory behavior differences in individuals with ASD may, in fact, drive core social behavioral features of autism, such as selective attention, and the inability to read facial cues thus communicate effectively [6], [7]. Disturbances in sensory processing can also affect how some individuals cope with their environment. For example, they can be easily overwhelmed (hyper sensitive) by a visual stimulus such as blinking light or crave (hypo sensitive) tactile stimulation such as the need to be held firmly. The other sensory modalities are also affected, and can often been multimodal, such as picky eating due to hypersensitivity in taste and smell [8]. Simply put, autism spectrum disorder is heterogeneous; each person's experience is different.

C. Designing for ASD

Relatively few studies have looked at designing products for autistic children with sensory processing deficits, and those that have, have been more technologically driven [9], [10], [11]. One of the major challenge that is presented in these studies centers on the inclusion of the user group: How do you work with a user who in unable to verbally communicate with you well enough to offer insight? Multiple studies from the LINKX project at TU Delft present design guidelines for including toddlers with autism in the design process [12], [13], [14]. While this is an important step for inclusion, their methods heavily rely on the advice and guidance of specialists and care givers, which is resource heavy, especially for the context in which this paper is set: an undergraduate course. An expert-based approach was also adopted by Warren [15] in his exploration of designing for autism with engineering students.

The specific objectives of this undergraduate project were (1) to expose industrial design students to a user group that they could not meet, constraining them to rely solely on the knowledge of experts and published literature, (2) to show evidence of research driven design decisions, and (3) to challenge them to work efficiently and harmoniously in small groups.

II. Methods

A. Students

Fifteen 3rd year industrial design students were enrolled in a Human Factors for Designers class at Syracuse University. For the first 11 weeks, students learned about the fields of anthropometrics, ergonomics, and usability testing methods. They were also introduced to methods in reading and interpreting scientific articles, and how to use data to guide design projects. The final project for this class was to design for children with autism spectrum disorder (ASD), specifically for those who exhibit sensory processing deficits (SPD). The students were tasked with narrowing their focus to a specific persona within this large group of potential users, explore the issues they may encounter in daily life, and present a solution that attempted to address them. The students self-selected their groups of three and were responsible for meeting milestones as a group.

B. Timeframe and assessment

This was the final project for the course and lasted six weeks. During this six-week period, the groups were responsible for crafting a design brief that outlined their target audience and specific ‘symptoms’ of SPD they were focusing on, the synthesis of secondary research with design criteria, ideation, and prototyping. Each group was required to produce a process book that detailed this information, a physical prototype that exhibited some functionality, and a presentation for a final critique with all course enrollees. Grading criteria was given to the students on the same day as the project announcement:

- Creative interpretation of the project brief that encompasses the research.
- Evidence that your group has explored secondary research that is appropriate to the design project.
- Craft a coherent narrative in the process book.
- Process book is finished to a professional standard.
- Prototypes that show model making skill and illustrate intended use.
- Presentation that showcases your final design and its functionality.

Each group was required to meet with the course professor every week to provide evidence of meeting project milestone. They were not graded on their ability to meet these checkpoints; it was merely a strategy to help them meet the final deadline and move through the design process effectively. The milestones are shown in Figure 1.

In addition to the graded submissions, each group member was asked to complete an online survey, detailing who was involved in each stage of the project. This allowed the students to confidentially air any grievances and give credit to other team members for their contribution. It was communicated, and understood, that all members of the group would receive the same grade.

C. Project resources

To assist the students with their understanding of SPD and ASD, three experts were invited to share their knowledge and experiences. Dr. Natalie Russo from the College of Arts and Sciences at Syracuse University is an expert diagnostician of children with autism, as well as a researcher focused on the processing and integration of sensory modalities in children with developmental disabilities. Dr. Russo gave a lecture at the beginning of the project about autism, developmental implications, and how one might diagnose SPD. Students had the opportunity to ask questions during the talk and were encouraged to continue communicating with her through email. They were also given a comprehensive list of web-based resources to use, in addition to the lecture materials.

Week	Topic	Milestone
1	What is sensory processing disorder (SPD)?	Start process book. Glossary of terms, population affected. Front cover, font, colors, and layout design should be settled on.
2	Science behind SPD. Guest speaker: Dr. Natalie Russo.	Ask Dr. Russo questions, present data and key points from her talk in your process book. Map out design brief and design considerations. Research products targeted at this market.
3	Engagement in the environment. Guest speaker Angela Gaige, Education Director at MOST.	Minimizing over stimulation, whilst encouraging engagement. Document visit to Museum of Science & Technology (MOST). First round of ideation. List of questions for Chelsea Leonard, Occupational Therapist.
4	Transcript of Q&A with Chelsea Leonard. Design and prototype.	Ideation, preliminary prototypes. Photograph models for the process book.
5	Design and prototype.	Ideation, secondary prototypes. Photograph models for the process book.
6	Design and prototype.	Process book, prototypes, and work allocation forms handed in.
-	Course final.	Presentation and critique.

Figure 1: Project milestones

Next, the students had the opportunity to propose questions to a local occupational therapist. Chelsea Leonard works in the local community to support adults with ASD, in addition to children and their families. Due to scheduling conflicts, Ms. Leonard was only able to answer questions via a Skype interview with the author. A transcript was given to the students to assist them with their research and formation of the design brief. During week 3 of the project the groups were asking targeted questions that directly related to the specific tasks they were designing for, for example: How does a child cope with a meltdown in a public space? What does that look like? How does a parent care for a child in a meltdown situation?

Lastly, two visits to a local science and technology museum were arranged for the groups to attend. The first was as a passive observer at a sensory processing evening. This museum (Museum of Science and Technology), in collaboration with a local interest group, hosts an evening that gives children with SPD the opportunity to visit when it is much less stimulating. The museum will dim the lighting and turn off noisy exhibits. While these evenings are designed for guests with SPD, anyone can attend. For this visit, the students were not permitted to interact with parents or children, simply to observe the changes in the environment and how that affected the visitors. The second visit was during a typical day at the museum. Students attended a talk from the director of education, who curates the sensory processing evenings. This perspective was included in the project schedule so that the students could see how the museum tries to cater for all visitors and take inspiration from exhibits design with SPD in mind.

D. Initial ideation exercises

Ideation is the initial stage of visualizing ideas in a design project. For this project, it was the collective communication of thoughts that guided the generation of design solutions. During the ideation kick-off, two methods were introduced to the students. The purpose of selecting these two methods at the start of ideation was twofold: deter procrastination and encourage comfort in writing and drawing in front of each other. These methods also encouraged mini-critiques as a way of further exploring each other's ideas.

The first was a simple brainstorm of potential areas of problem solving for their central design question. Each team sat around a table covered on one large sheet of newsprint paper. The students were given 10 minutes to write out key words and thoughts. After 10 minutes, they moved clockwise to review, critique, and expand on the ideas written by their team mate. The process was repeated until all original thoughts had been thoroughly expanded upon. These was presented to the students as the catalyst for designing their solutions. Before they could freely ideate, one more exercise was presented. Each student had 30 minutes to design three of the worst possible ideas for the design question. This was a chance for the groups to build their design criteria: what should they consider and design for and what should be avoided.

E. Product prototyping

At Syracuse University, industrial and interaction design students are trained to use all model making facilities including woods, plastics, metals, and electronic prototyping workshops. They were encouraged to start with low-fidelity prototyping and work up to producing a functional prototyping that demonstrated some mechanical and electronic capability.

F. Process book

It is typical in design disciplines for designers to produce a process book. Traditionally, this book is a well-organized document that contains a 'cleaned up' version of the processes used to arrive at the final design. For this project, the groups were required to document everything in their process book: from notes taken in lectures, to quick drawing produced on scrap paper. The process books were graded more favorably if they had a strong narrative that tied insights with design considerations. The aesthetic flow of the document was secondary.

III. Results

In a six-week design project, five groups each designed products that were intended to improve the lives of children with ASD exhibiting sensory processing deficits. The project titles are show in Figure 2.

A. Common design considerations

The design brief for the class was deliberately left as open as possible. Groups had to design a toy or therapeutic device to help children with ASD, specifically with sensory processing deficit. Through the meetings with experts and their own research, they were evidentially aware of the heterogeneity of their user group. The focus on specific ‘symptoms’ allowed them to design an appropriate product to improve social interaction, or behavioral traits such as needing a fully defined schedule.

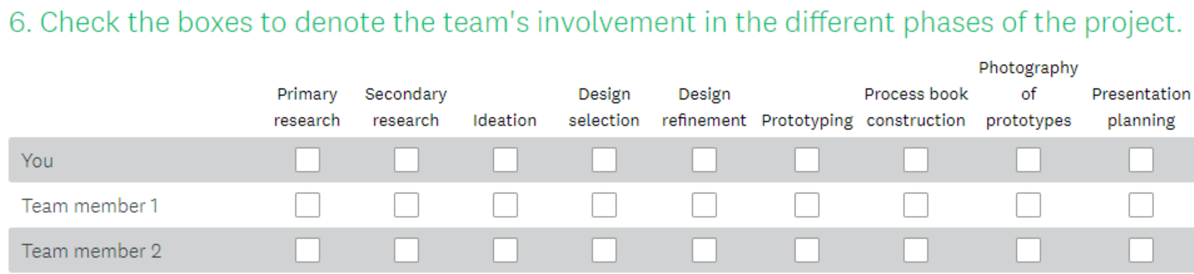
Group Number	Design problem	Product designed
1	Preventing meltdowns due to auditory hypersensitivity	Active noise cancelling beanie for a non-obvious meltdown intervention. This group wanted a discreet way to block out distracting or distressing auditory stimuli.
2	Focusing attention with tactile stimulation	Magnetized gloves that repel or attract fingers so wearer can fidget whilst outdoors in a cold climate. The idea was to focus attention on communication and learning.
3	Early alert system for meltdowns	Smartwatch and app to alert user to signs of stress through heart rate monitoring, giving the wearer a chance to remove themselves from stressful situations. Parents have access to data to see how their child’s day went, especially when verbal communication is difficult.
4	Food compartmentalization for lunch	Bento box style lunchbox with various compartment configurations and placement for utensils. The idea was to assist with picky eating habits, by separating and organizing food items.
5	Sleep cycle disturbances	Intelligent nightlight with programmable function for parents to communicate routine with light color change. The system was designed for easing the user into a change of schedule, which can be difficult for the child and parent.

Figure 2: Design problems, and solutions

Through the weekly project meetings, it was clear that all groups wanted to ensure that they could help ‘their child’ in inconspicuous ways, as to not differentiate the child from anyone else in the population. Students focused on certain sensory modalities, and suggested way that the products could be augmented to suit other sensory processing combinations.

B. Peer review, and student evaluations of the course

The students appeared to appreciate the inclusion for the peer evaluation as seen in the high completion rate (80%) on the survey. Most groups operated with an equal division of labor except for one group who had a member that did not participate as much as the other two. The team member who did not contribute as much did disclose this in the peer evaluation. In general conversation with the group, they appreciated a formal way to show who had completed which tasks (Figure 3).



6. Check the boxes to denote the team's involvement in the different phases of the project.

	Primary research	Secondary research	Ideation	Design selection	Design refinement	Prototyping	Process book construction	Photography of prototypes	Presentation planning
You	☐	☐	☐	☐	☐	☐	☐	☐	☐
Team member 1	☐	☐	☐	☐	☐	☐	☐	☐	☐
Team member 2	☐	☐	☐	☐	☐	☐	☐	☐	☐

Figure 3. Question from peer evaluation form

Overall, students seemed to enjoy the project. Unfortunately, not a lot of data was collected regarding the success of the topic. From formal reviews of the course, students who wish to add comments can do so. Promising comments from the questions:

Which aspects of this course were most valuable to your overall learning experience?
Learning about researching skill was the most valuable.
Loved that she brought in guest speakers and professionals in the field
Talking with experts

Please provide any additional comments that you feel are pertinent to this evaluation process
Great class with a lot of additional knowledge to offer. I really enjoyed the teacher's knowledge of engineering and the contacts in the field.

C. Expert feedback

The student projects were also reviewed by experts who have worked, or currently work with children with autism and sensory processing deficits. This data was collected at the end of the project and was collected solely for the professor's assessment. Each project received a rank order, 1 for strongest idea to 5 for the weakest, and specific comments about the viability of the technology or general concept (Figure 4) were provided.

VI. Discussion for future course offerings

A. Six-week format

As an initial introduction to designing for children with ASD, we believe that our pilot was successful due to the quality of the design proposals, that student evaluations were positive, and that general communication with students throughout the process was positive. We were very fortunate to be supported in this collaborative design project by experts who generously gave their time and knowledge to the students.

This was the first offering a sensorial design topic in a 300-level class at Syracuse University in the department of industrial and interaction design. The organization of this short project seemed almost counter-intuitive to the user-centered approach of design as the end user was not involved in the design process. Iterative design is not something that can realistically be achieved in 6 weeks when the class meets once a week for 4.5 hours, so in this format, the students could not learn from the user or experts, then revisit the design. This course is currently offered in two sections taught by different professors. It has been proposed by the author to create a lab and lecture format for this course, rather than one weekly lab. The idea would be to create more instances of contact and bring both sections together once a week for lectures from experts.

Project	**Scores**	**Comments**
Preventing meltdowns due to auditory hypersensitivity (noise cancelling beanie)	1, 1, 2	Good idea, especially for teens. Would need to make sure that there was a good seal around the ear. Not ideal for those with tactile sensitivity.
Focusing attention with tactile stimulation (fidget gloves)	3, 2, 3	Great cross over for young children with ADHD. Good for use in the classroom with younger children too.
Early alert system for meltdowns (smart watch)	2, 5, 1	Great for capturing data for parents and children – determine what the triggers are. Concern ab out adding a vibration to the wrist of someone who is already agitated.
Food compartmentalization for lunch (lunch box)	4, 3, 4	Exploring healthy eating is valuable but not sure if this would help. Nice idea but does exist.
Sleep cycle disturbances (intelligent night light)	5, 4, 5	There are good sleep intervention devices on the market already. Extra features need to be explored further concerning the handling of routine changes.

Figure 4. Expert ranking and feedback

There was a reasonable degree of flexibility in the way this class could be taught, so the professor can be responsive to the needs of the students. For example, if this course were to be offered again, it would be advised to refresh students on human biology, and how a normal sensory system responds to its surroundings before launching in to SPD symptoms. Having an introductory lecture from a neuroscientist proved to be a great start to the project, as she has knowledge authority. Having live interaction, rather than recorded responses from the occupational therapist would have been more ideal, instead of posing questions and waiting a week for the answer. Perhaps having an occupational therapist come to the class work with the students to narrow down their design questions might have helped them find their path in the project a week or two earlier. Working with an education specialist for the Museum of Science and Technology in Syracuse added a fresh perspective to the project. Only a handful of students came to the sensory evening over the weekend at the museum, which was disappointing but expected. More could have really benefitted from the experience.

The opinions gathered from the experts were useful to the author for evaluating the potential of the design ideas but did not impact the students after the completion of the course. These students wanted more immediate feedback during the project rather than after the final grades were posted. If offered again, it might be more advantageous for the groups to present to the experts and professor and receive the instantaneous feedback they need to improve their work. This might encourage students to pursue their design ideas after the conclusion of the course and explore further user testing and potential start-up initiatives.

Confidential peer review worked well as each team member was held accountable for different parts of the project. This added a layer of transparency and held team members accountable. This was not a graded part of the assignment, and perhaps in the future could form part of the grade to ensure that everyone submits a review.

B. Longer format (6 weeks +)

If this project were to be delivered in a longer format, students would be able to have a more authentic design iteration experience. If this were to happen, the author would propose a formal collaboration with the mentioned experts and their research students, so that iterative design with the users could happen, in a similar way to the LINKX project [14]. Experimenting with two separate iteration cycles could be an interesting concept: Do you end up with similar products if a product is co-designed (so designed with the intended user), or if it is modified after user feedback (iterative design cycle)?

C. Conclusion

We would seek to formalize a partnership in the future with our mentioned experts and the local community. From the author's viewpoint, there is a strong skillset across these academic disciplines (engineering, industrial design, and neuroscience), and are well positioned to create solutions that could help our students become better designers and serve those in our local community and beyond.

References

[1] W. Lidwell, K. Holden and J. Butler, Universal Methods of Design, Beverly, Massachusetts: Rockport, 2010.

[2] B. Martin and B. Hanington, Universal Methods of Design, Beverly, Massachusetts: Rockport, 2012.

[3] D. L. Christensen, J. Baio, K. Van Naarden Braun and et al., "Prevalence and Characteristics of Autism Spectrum Disorder Among Children Aged 8 Years — Autism and Developmental Disabilities Monitoring Network, 11 Sites, United States, 2012," *Surveillance Summaries,* vol. 65, no. 3, pp. 1-23, 2016.

[4] "Autism Spectrum Disorder (ASD)," 11 07 2016. [Online]. Available: https://www.cdc.gov/ncbddd/autism/data.html. [Accessed 30 January 2018].

[5] R. C. Schaaf, S. Toth-Cohen, S. L. Johnson, G. Outten and T. W. Benevides, "The everyday routines of families of children with autism. Examining the impact of sensory processing difficulties on the family," *Autism,* vol. 15, no. 3, pp. 373-389, 2011.

[6] E. J. Marco, L. B. N. Hinkley, S. S. Hill and S. S. Nagarajan, "Sensory Processing in Autism: A Review of Neurophysiologic Findings," *Pediatric Research,* vol. 69, pp. 48R-54R, 2011.

[7] A. E. Robertson and D. R. Simmons, "The Relationship between Sensory Sensitivity and Autistic Traits in the General Population," *Journal of Autism and Developmental Disorders,* vol. 43, no. 4, pp. 775-784, 2013.

[8] A. E. Lane, M. E. Geraghty, G. S. Young and J. L. Rostorfer, "Problem Eating Behaviors in Autism Spectrum Disorder Are Associated With Suboptimal Daily Nutrient Intake and Taste/Smell Sensitivity," *ICAN: Infant, Child, & Adolescent Nutrition ,* vol. 6, no. 3, pp. 172-180, 2014.

[9] J. Leaf, A. S. Preston, D. P. E. Richter and R. E. Gerlick, "An Undergraduate Service Learning Research Project using a Humanoid Robot to Enhance Treatment for Children with Autism Spectrum Disorder," in *2017 ASEE Annual Conference & Exposition*, Columbus, Ohio, 2017.

[10] A. Clavet, M. Lucas, G. Lachiver and F. Michaud, "Designing Toy Robots To Help Autistic Children An Open Design Project For Electrical And Computer Engineering Education," in *2000 ASEE Annual Conference*, St Louis, Missouri, 2000.

[11] H. M. Clever, A. Graham and V. Kapila, "Using an AR Drone Lab in a Secondary Education Classroom to Promote Quantitative Research," in *2016 ASEE Annual Conference & Exposition*, Noew Orleans, Louisiana, 2016.

[12] H. van Rijn and P. J. Stappers, " The puzzling life of autistic toddlers: Design guidelines from the LINKX project," *Advances in Human Computer Interaction,* vol. 2008, 2008.

[13] H. van Rijn and P. J. Stappers, "Expressions of ownership: motivating users in a co-design process," in *Proceedings of thr Tenth Anniversary Conference on participatory Design*, Bloomington, Indiana, 2008.

[14] H. van Rijn and P. J. Stappers, " Codesigning LINK: A case of gaining insight in a difficult-to-reach user group," in *International Association of Societies of Design Research 2007: Emerging Trends in Design Research*, Hong Kong, 2007.

[15] S. Warren, "Student Proposals for Design Projects to Aid Children with Severe Disabilities," in *ASEE 123rd Annual Conference and Exposition*, New Orleans, Louisiana, 2016.