Designing Smart Objects with Autistic Children Four Design Exposès

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ABSTRACT

This paper describes the design work being conducted as part of the OutsideTheBox project. Within the time-frame of eight months, we engaged four children with autism in a participatory design process to develop their own smart object. We re-interpreted Future Workshops and Co-operative Inquiry to demonstrate that a) autistic children can lead processes with a deliberately open design brief and b) this leads us to explore design spaces that are un-imaginable for neuro-typical, adult designers. To capture these four design cases, we have developed Design Exposès, a concept that is inspired by annotated portfolios and Actor-Network Theory. We apply this concept to our cases and present four exposès that subsequently allow us to draw out intermediate-level design knowledge about co-creating technology with autistic children. We close by critically reflecting on the design processes as well as our concept of capturing them.

Keywords

children; autism; participatory design; research through design; annotated portfolios

Categories and Subject Descriptors

H.5.m. [**Information Interfaces and Presentation (e.g. HCI)**]: Miscellaneous

1. INTRODUCTION

When technology is designed in the context of people with disabilities, the starting point is commonly provided by the functional limitations of the particular user group. Consequently, work ranges from practical support, such as way finding for the blind [42], to learning interventions, such as enhancing emotion recognition in autistic[1] children [22]. While such work certainly has improved the lives of many people with disabilities, we argue that it ignores a design space that goes beyond mitigating functional needs (cf. [31]). Well-being and disabled experiences in our society are more complex and multi-faceted as this reductionist view on function would allow to infer (cf. [15]).

This paper describes the work in OutsideTheBox, a research project aiming to explore new meaningful roles of technology in the lives of children with autism. It aims to go beyond functional limitations and engage with ideas, desires and problems of autistic children in a holistic way. In a radically participatory process and taking advantage of the UbiComp opportunity space, we work with children to co-create their own smart objects. The design brief only postulates two requirements: a) the design should meaningfully fit into children's life and afford positive, interactive experiences and b) it should embed qualities to scaffold the child in sharing those experiences. While the brief is deliberately open, it focuses on a holistic notion of overall well-being and support. With OutsideTheBox, we want to demonstrate that it is possible to develop design processes that enable autistic children to lead as experts in their lives and with their own ideas, opening design spaces that are un-imaginable for neuro-typical, adult designers. In this sense, OutsideTheBox also aligns itself with critical design [1] and more broadly research through design [45]. As scientific outcome, the project maps a conceptual space of participatory design methods alongside with a number of case-studies that ground the underlying argument in concrete processes and artefacts.

OutsideTheBox has completed its first full circle, which is the basis of what we report here. We have engaged four autistic children and worked with them over the course of eight months to develop and realise four smart objects.

The contribution we want to make with this paper is twofold. Firstly, we will focus on the design process and our interpretations of participatory methods, with the goal to add to the knowledge about how to effectively engage autistic children with an open design brief. Secondly, we were challenged by the lack of concepts and tools that would have the descriptive power to capture the richness of these design processes and their outcomes. Knowledge production in interaction design is currently a hotly debated topic [27]. In this paper we evolve the concept of annotated portfolios [5, 20] through incorporating concepts that we borrow from Actor-Network Theory (ANT) [30] to describe how the participa-

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[1]This paper uses both, person-first and label-first language to reflect that many self-advocacy groups have recently expressed that the traditional person-first language is not reflecting their sense of self while many professionals in the field still prefer it [29, 37].

tory design work with our children unfolded over time and within its evolving socio-technical context. We call the format we have developed to describe design case studies *Design Exposès*, which become the constituent parts of our portfolio.

The following section lays out related work, both in terms of the context of our research, autism and technology, as well as previous efforts to capturing interaction design knowledge. We follow by introducing OutsideTheBox in more detail, present the concept of Design Exposès. We then apply this format to present the four case studies from our work and provide a synopsis across them to identify more generic design knowledge for creating technologies with autistic children. We critically reflect on OutsideTheBox and the approach we have developed to capture the case studies before we conclude by laying out future work, both in terms of the project as well as evolving the methods to capture its outcomes.

2. RELATED WORK

2.1 Autism & Technology

Autism Spectrum Conditions (ASCs) are a broad range of neuro-developmental disorders that are believed to be rooted in a complex interaction between genetic and environmental factors [12]. Across the spectrum, these conditions share traits that also represent the main diagnostic criteria: 1) impaired social interaction, 2) impaired communication and 3) rigidity of behaviour and thought patterns. Its prevalence is estimated to be above 1% (e.g., 1.57% in [2]).

Computer based intervention programmes are seen to be a particularly promising route for this population due to their affinity for technology as a predictable and safe medium [34]. However, designing and evaluating technology for learning or intervention in the context of autism is highly challenging and evidence for its effectiveness, particularly in terms of generalising taught skills, remains in short supply [14, 23]. These challenges are largely rooted in the heterogeneity of autism: while the triad of impairments is present across the spectrum, manifestations on the spectrum can range from people with very little language and multiple other impairments to high-functioning autistic people who have not received a diagnoses until later in life. Moreover, even within comparable levels of skills and abilities, the way autism impacts on behavioural patterns, perceptual sensitivities, special interests or intrinsic motivations varies widely which makes one-size-fits-all technology not viable.

A number of recent works have looked into exploiting technology to address specific functional limitations in autism, either as an educational intervention (e.g., the Transporters - an emotion recognition intervention [22]) or as a practical aid (e.g., vSked - an interactive, collaborative scheduling system [25]). Increasingly, the involvement of children with autism in the design process is seen as particularly valuable [6]. However, it also presents specific challenges ranging from managing narrow interests, perfectionism and social anxiety (cf. Frauenberger et al for a more detailed discussion [16]) which has led to an over-representation of high-functioning autistic children in research studies. Examples of involving autistic children in technology design include the work by Millen at al who co-designed an educational collaborative virtual environments for children with ASC [32] and Hourcade et al developing multi-touch tablet applications to enhance their social skills [26]. Benton and Johnson have recently presented an extensive literature review on the inclusion of children with special needs in technology design which included a number of projects with autistic children [3]. Their overview shows that children's roles, the quality of participation and the potential scope for impact ranges widely within participatory projects.

Benton and Johnson's review also sheds light on the motivations behind projects, which often align themselves implicitly with reductionist models of disabilities. As Mankoff et al point out [31], most assistive technology pragmatically focuses on functional needs, as they provide specific targets for technology as well as suitable outcome measures for evaluation. However, disabled experiences are increasingly seen as a more complex interaction between personal and societal factors (cf. Shakespeare [36]) with fundamental consequences for what can drive the exploration of meaningful roles of technology in the lives of people with disabilities [15].

2.2 Research Through Design

Along with what has been called the third paradigm in HCI [24], designerly approaches have become central to researchers and practitioners in the field. The real-world complexity of the problems and the turn to designerly practice has, however, also created challenges for HCI's relationship with theory, or science more generally [38]. In an attempt to dispel the "black art" of design [43], a discussion ensued about how research through design can be rigorous and contribute theory while not loosing its relevance in the wild [13]. Pointing to the shortcomings of design research for knowledge production, Zimmermann et al advocate formalising the approach to be able to effectively build on each others work [46]. In response, Gaver argues that conformity and standards might diminish the unique affordances of design as a research approach and advocates for acknowledging the diverse range of theoretical contributions design can make [21].

We argue that the meta-physical questions about *what can be known?* and *in which ways can we know about it?*, are at the very core of this debate. The seminal works by Schön [35] and Cross [7] have laid the foundations for our understanding that there are different ways of knowing in design and HCI (also compare Olson and Kellog's recent book, showcasing the diverse range of perspectives [33]). The main challenge for Research through Design becomes how to capture knowledge that can be integrated vertically with other kinds of knowledge, made accessible for theorising, advancing the foundations of the field, and be practically (re)applied in ways that are true to the spirit of design.

2.3 Capturing Interaction Design Knowledge

In a workshop at CHI 2015, Höök et al addressed the challenge of knowledge production in Interaction Design, highlighting many different previous attempts to capture what they call intermediate-level[2] knowledge [27]. These range from design patterns [4] to strong concepts [28] and annotated portfolios [5]. While the format and scope of these concepts varies, they all represent attempts to strike a balance between re-use and situated validity, literally connecting theory and practice.

While most of the intermediate-knowledge formats above are descriptive and retrospective in nature, Schön's concept of knowledge-in-action foregrounds that much of the design knowledge is tacit and embodied, inaccessible after the fact, but invaluable resources in action. Along these lines, Dalsgaard and Halskov have developed a tool that allows designers to document their decisions within the process [8]. They see their tool serving multiple purposes, that of documentation, reflection and being a source of insight. In related work, Dalsgaard, Halskov and Nielsen also explored maps (overview, strand and focal maps) as a more visual way to reflect and document design processes [9].

[2] In their use of the term "intermediate" they refer to knowledge that neither has reached the level of a universal law, nor is knowledge that is exclusively bound to a specific instance.

As the approach to describe OutsideTheBox builds on the concept of annotated portfolios, we would like to discuss it here in more detail. Initially introduced by Gaver [21], his co-inventor Bowers elaborated on the concept, also providing a working example of annotations to the design portfolio of the Goldsmiths Interaction Research Studio [5]. Annotated portfolios identify family resemblance across a collection of designs with the goal to connect the ultimate particular [38] with "broader concerns". They stress that portfolios can be annotated in different ways, serving particular audiences and that the connection between material (artefact) and text (annotation) is mutually informing. Bowers concedes that annotations have limited rationality, giving them weak predictive or explanatory power. Nevertheless, he argues, annotated portfolios are descriptive and generative-inspirational, which might be what design theory should be about.

2.4 Actor-Network Theory (ANT)

Despite being called a theory, ANT might better be characterised as a constructivist philosophy and a tool. Originating in the context of Science and Technology Studies (STS) and sociology more broadly, its fundamental idea seems simple, but has some radical implications: the social is constructed by virtue of the relations between actors, which can be human and non-human and form in a network [30]. The symmetry between human and non-human actors is controversial as it attributes objects with agency (but not intent) as soon as they have a relationship with other actors in the network [39]. Latour, one of the founding fathers of ANT, stresses that the social he refers to is not something that could be separated from other disciplines, activities or aspects of life. He would argue, that there cannot be "social aspects" of computing (or physics, or economics), as it is the dialectical associations between computing artefacts and humans, the "glue" as Latour puts it, what is social.

In an exploration into materiality and interaction design, Fuchsberger et al have already hinted at the potential of ANT to be used to describe design [19]. They state

> ANT would explicitly include the *activity* of the involved actors into the descriptions, i.e., of materials, designers and users.

and go on

> It would provide a common way of describing the design examples, and thus facilitate a shared understanding especially in the materiality discourse.

With Design Exposès we take up this idea and develop a format that is inspired by the relational principles of ANT.

3. OUTSIDETHEBOX

Motivated by exploring technology co-creation that responds to desires, ideas and needs of autistic children that go beyond mitigation of functional limitations, OutsideTheBox was initiated as a three year research project that is organised in three cycles. In each cycle we engage four to six children in a design process that re-interprets two different participatory approaches (i.e., six in total over the course of the project) to investigate how children with autism can lead processes with a deliberately under-specified and open brief. A cycle starts with a phase of contextual enquiry (e.g., [40]) that allows us to learn more about the child, their social environment and the situated context. Subsequently, the design phase commences with workshops conducted around every fortnight. The natural end point of the design work is reached when the child is receiving their co-created smart object to take home, upon which the evaluation phase starts. Overall we aim at eight to 15 design sessions over the course of six to eight months.

In year one, i.e. the first cycle, we invited four boys, Lucas, Thomas, Bruno and Holger[3], who all attended integrative mainstream schools in Austria. We re-interpreted Future Workshops [41] with two of them and Co-Operative Inquiry [11] with the other two. Over the course of eight months, we met the children between 10 and 14 times until their smart object was finished. Table 3 provides a summary of age, official diagnosis, approach, the name of their smart object and the number of meetings with them. More details on their individual profiles are provided in the respective case studies.

ID (Age)	Diagnosis	Approach	Object name	#
Lucas (8)	Autism	FW	LSmart	14
Holger (6)	HFA	FW	ThinkM	13
Bruno (6)	HFA	CI	Adaja	14
Thomas (8)	PDD-NOS	CI	ProDraw	10

Table 1: Research Partners in the first year of OutsideTheBox together with diagnosis, age, design approach used, name of the finished object and number of meetings; FW: Future Workshops, CI: Co-Operative Inquiry; HFA: High Functioning Autism, PDD-NOS: Pervasive Developmental Disorder - Not Otherwise Specified

Before meeting the child, parents and teachers received information about the project and the planned activities. They then were asked for written consent for participation, the collection of data and their anonymised use. We then conducted semi-structured interviews with mentors, teachers and parents[4]. Provided with this initial background information, the first meetings with each child aimed primarily at getting to know each other and building rapport. Meetings would always take place at the child's school, typically in a separate room adjacent to the classroom. Teachers or mentors were sometimes present in the beginning to make the child feel safe, but in all cases this was not necessary anymore after the first few meetings.

Throughout the collaboration, we assigned the role of a Play Partner to one researcher and that of an Active Observer to the other researcher present. We developed these roles, inspired by work in special needs pedagogy, specifically to overcome power differences (publication forthcoming). The two approaches, Future Workshops and Co-operative Inquiry, were interpreted freely and flexibly, responding to what the researchers perceived as the most promising routes to support the child's creative capacities. Every workshop was planned individually and on the basis of all previous experiences with the child.

After concepts for smart object emerged from the workshops, prototyping became increasingly important in the sessions and in between them. After a period of intense implementation with less frequent meetings, the finalised prototypes were handed over to the children at the end of the school year. Currently, the working prototypes rest with the children and we collect data from diaries, logs and interviews for an in-depth evaluation of these technologies, which will be reported elsewhere.

[3]All names changed to protect their privacy.

[4]In the local education system each autistic child is assigned a "mentor", a special needs pedagogue with extensive experience with autism to support the child, the school and the parents in transition periods or in times of crises. Additionally, integrative mainstream classes typically have one main teacher and one special needs support teacher present at all times.

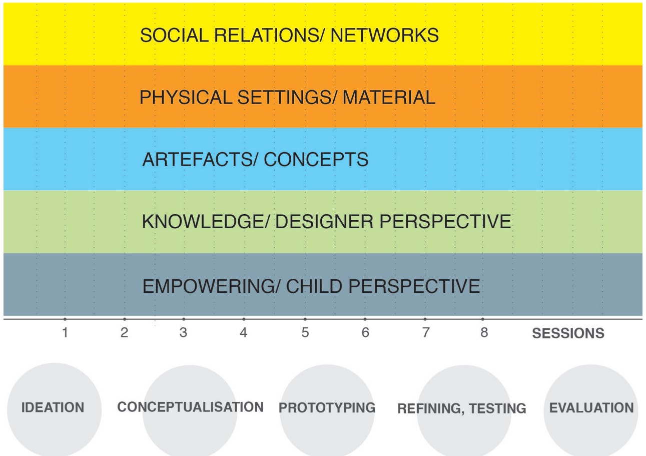

Figure 1: Blueprint for a design exposè in the OutsideTheBox portfolio

4. ANNOTATED PORTFOLIOS EVOLVED - DESIGN EXPOSÈS

Before we go on to describe the four design processes with Lucas, Holger, Bruno and Thomas in more detail as case studies, we present here the format we have developed to capture the kind of design experiences we have made over the last year. We have called these descriptions *Design Exposès* to emphasise that they are concise descriptions of design processes that *expose* multi-faceted aspects from which a kind of "intermediate-level" knowledge can emerge [27]. In this work we build on annotated portfolios [5] and Actor Network Theory (ANT) [30] as introduced above.

From annotated portfolios we take their fundamental focus on the artefact and the concept of family resemblances across designs that can be annotated to point to something more fundamental than the ultimate particular. From ANT we borrow the core concept that human and non-human actors are forming networks that dialectically influence each other and can evolve over time. Each artefact can be seen as a product of the interaction between actors, both human (e.g. children, researchers) and non-human (e.g., materials, methods or values), whereby the artefact itself emerges as an actor in the network. We argue, that to be able to capture the essence of creative design processes such as the one we have experienced, it is essential to understand and analyse the nature and quality of the relationships between these actors over time.

Figure 1 provides the blueprint for a design exposè, the description of a design case study in the OutsideTheBox portfolio. It consists of various parts that we subsequently will introduce in more detail. The overall organising principle is time. While the meetings and workshops with the child are marked as the most prominent events on this time line, we want to stress that the times in between are equally important and filled with activities such as analysis, interpretation, planning or making.

The upper half of the exposè consists of five layers of reflections over time which each take a specific perspective on the process. Here we build on the work of Frauenberger et al [17] who proposed a "tool-to-think-with" for structured reflection on participatory design processes to expose their internal validity and coherence. Their tool consists of four lenses: values, stakeholders, outcomes and knowledge. For the purposes of design exposès we modify these slightly: the central layer (blue), serving as a reference to all other annotations, is called **Artefacts / Concepts**. Annotated pictures of evolving artefacts or prototypes serve as anchors to ground the process in the physicality of the objects created. The **Social Relations / Networks** layer (yellow) focuses on the relationships of people within the design process. This includes annotations about fostering rapport between design partners, the emergence of roles and responsibilities, but also power differences and conflict. The next layer (orange) concerns itself with **Physical Settings / Materials**. It looks at how the physical spaces in which the design takes place influence the process and it marks the introduction of materials and how their qualities and affordances impact on the creative work. The final two layers (green and grey) take the perspective of designers and children respectively. In **Knowledge / Designer Perspective** we track key insights for us as designers that have informed decisions, both in terms of the design itself and the development of the methodology. The **Empowering / Child Perspective** collects expressions of children that provide hints of how children see their own role in the collaboration. This includes, for example, quotes that implicate value statements about the work or observational notes on behaviour changes that indicate that a child becomes more confident in expressing their ideas or in manipulating artefacts. Figure 2 provides an example slice from the design exposè created for the Lucas case study to illustrate the concept and nature of annotations.

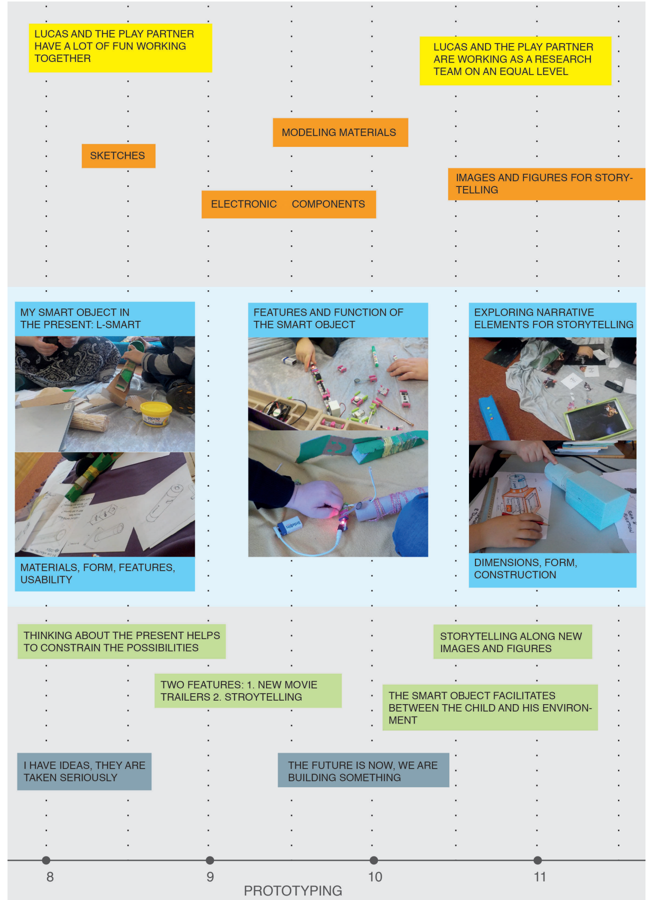

Figure 2: Example from the layered reflection part of Lucas' design exposè

The lower half of the exposè, while still organised along the same time line, exposes very different aspects of the design process. Inspired by ANT, it depicts the networks of human and non-human

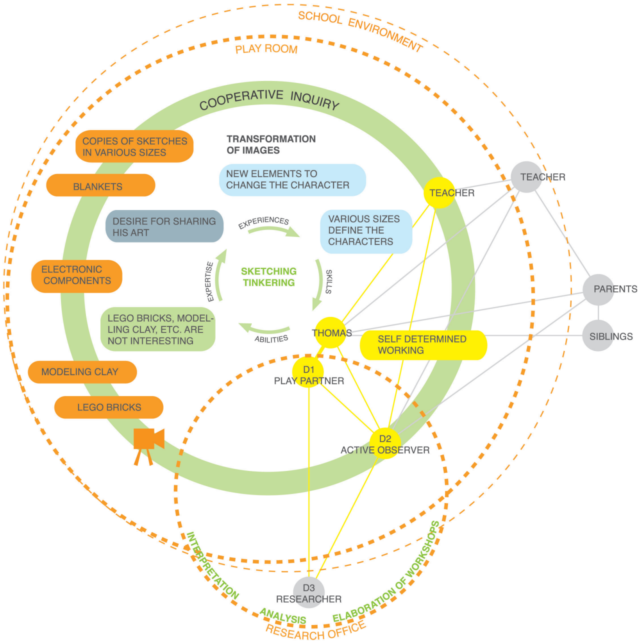

Figure 3: Example from Thomas' design exposè showing the network at the conceptualisation stage.

actors as they unfold over the course of the design process. We have identified five major stages in our work: ideation, conceptualisation, prototyping, refining / testing and evaluation, for which the exposè contains one network graph each[5]. These network graphs contain *nodes* that are of the nature of people, methods, concepts, materials, and objects. Their *relations* are framed not only within the temporal stage, but also in physical settings, the methodological approach and core activities taking place. Figure 3 shows an example from the design exposè of Thomas at the conceptualisation stage. Active human actors (yellow) include Thomas, the Play Partner, the Teacher and the Active Observer. The latter frames the work conceptually by implementing the design methods (circle in green and activities in the middle). Other framing elements include materials (orange) such as the Lego bricks and the different physical environments (dotted circles). Within the frame design concepts emerge: adding elements to change the character of a drawing and the scaling as determining the narrative. A relevant child perspective is also present in the network: the desire for sharing his art, which at this stage has not yet been translated into a design concept.

Creating design exposès is in itself a process of reflective analysis regardless whether it is done retrospectively like for the case studies below, or in-action as we are currently using them. Populating the upper half with meaningful notes requires identifying and interpreting data points from different perspectives, for example looking for quotes in transcripts that point to how children experience their own role. In a second step, these notes need to be aligned on the common time-line and the resulting dependencies provide a first opportunity for insights to emerge. Creating networks for the lower part of design exposeès can be a complex undertaking. Firstly, the temporal scope for a network needs to be defined. In the case studies below we have found traditional design stages (ideation, conceptualisation, prototyping, refining / testing and evaluation) to be the most appropriate, but depending on the context and the analytical perspective taken, these might be different. Subsequently, relevant *nodes* and *frames*, like stakeholders, materials, spaces or concepts, need to be identified which is by no means trivial and requires good judgement about the potential impact of actors on the network—and thereby about the scope and the direction of analysis. Lastly, relations between nodes need to be qualified which can be informed by a great diversity of data, e.g., observations, transcripts, diaries or log data. The level of complexity at this stage is potentially infinite and again, this activity relies on good judgements about appropriate sources that describe relations in meaningful ways.

[5] As the evaluation stage is beyond the scope of this paper, we have omitted this stage in the exposès below

5. DESIGN CASE STUDIES

The following are the textual summaries of the four case studies and are meant to complement the full, graphical representations of the design exposès. Since the available space here does not allow to include the exposès directly, they are attached to the paper as supplementary material. Figure 4 shows the four finished designs

5.1 ThinkM

Holger has been diagnosed with High-Functioning Autism. He engages animatedly in verbal discussions about his favourite topics, but is easily overwhelmed by demands of social interaction which, for example, repeatedly leads to difficult situations in class with his class-mates or his teachers. We met with Holger in a separate room inside his school building, down the hall from his classroom. During the very first session one of his teachers was present, but was not required for further meetings. From the start, Holger identified himself as a researcher. Therefore, our working space was framed as a research lab, which Holger divided into designated areas for brainstorming and prototyping. We initially enquired into his interests through drawing activities and by discussing objects he liked. After a few sessions, Holger considered his play partner as equal and respected the active observer as authority figure. He delegated tasks to his play partner when he had difficulties doing them by himself (i.e., writing long words). On several occasions he displayed pride of results obtained in collaborative work and indicated that he felt like being part of a research/design team.

Re-interpreting Future Workshops (cf. [41]) as our co-design method, we started to investigate current tools for research, before projecting them into future scenarios. Holger focused his interests on two main ideas: a machine to better concentrate with (Thinking Cap) and a machine to remind a user of forgotten events (Remembering Machine). Initial paper prototypes allowed Holger to test out forms and sizes quickly. That way he could make informed decisions about the form of the head mounted part of his object working simultaneously as a Thinking Cap and as a recording device for the Remembering Machine – ThinkM. He also specified certain interaction modi, e.g., data transmission had to be wireless and directed to a certain screen device. He stated, that he could not remember events in which he became aggressive, which led us to frame ThinkM as a device to capture and reflect on such situations in a calm environment. We thus decided to introduce Holger to the possibility of using a pulse sensor and included this data in the visualisation of captured events. When trying out a pulse sensor, Holger quickly linked the data with his emotional state through self-paced experiments. The more Holger understood that ThinkM would actually be a functional device at some point, the more he was able to make compromises between what his skills allowed him to do, what was technically feasable and his perfectionism.

ThinkM now consists of a wearable device – headphones – and a base station. The wearable device holds a camera and a pulse

Figure 4: The four finished prototypes (left to right): ThinkM, LSmart, Adaja and ProDraw

sensor; both record data when being put on. When base station and headphones meet, pictures and pulse data are transferred and shown in a loop on the base station. Over time, ThinkM looses some of its memory in order to mimic the behaviour of a human brain. Using ThinkM, Holger can share activities e.g., on school trips, with his parents and reflect on individual situations. It provides him with a way to make sense of situations he cannot comprehend completely at the time and helps him to reflect on his own behaviour in what he sees as a "scientific" activity.

5.2 LSmart

Lucas has been diagnosed with autism at a very young age and subsequently received Applied Behavioural Analysis Therapy. As a result, he has excellent verbal skills in two languages and appreciates structures and being in control while also being considerate of other people he interacts with. For our sessions with Lucas we were able to use a play room adjacent to his classroom. During our first, brief meeting in the classroom, his mother and two teachers as well as other class mates were present. The actual design sessions were conducted without any other adults present. Through initial tasks for contextual enquiry (such as sampling audio) we learnt that he is very enthusiastic about movies and storytelling. It took Lucas a few sessions to gain trust and confidence in the collaboration. Initially, he rarely voiced his own opinion. Very soon, however, he started defending his play partner and over the course of the year, he was able to share activities and tasks with them. The play partner's function was less direct support, but rather trying out activities that were unknown to Lucas to show that they are safe. This encouraged him, to e.g., use finger paint although he found it uncomfortable before.

For the conceptualisation phase, we adapted Future Workshops (cf. [41]) with elements of Fictional Inquiry (cf. [10]). We started by planning the second episode of his favourite film, "Brave", which would play in the future. That made it possible for us to explore future everyday activities in the movie and more generally. The fundamental concept of LSmart emerged which would combine watching trailers of upcoming movies and supporting Lucas in telling his own stories by providing appropriate prompts and inspirations.

During the prototyping phase, we first had to develop the concept of prototypes as a stand-ins for a functional object. For example, we experimented with forms for LSmart using cardboard, but it was conceptually hard for Lucas to also incorporate electronic materials in the cardboard prototype. However, he frequently used prototypes as props for storytelling.

In its final stage, LSmart is now able to show video trailers and support storytelling via the display of characters or potential settings. The form of LSmart is inspired by a kaleidoscope. Lucas can share interesting trailers and story prompts with others by aiming the in-built projector at a larger surface, or choose to view the content by himself using his hand as a private screen.

5.3 Adaja

Bruno was diagnosed with High Functioning Autism shortly before entering school. At the time, he was already able to read and write in two languages, albeit his young age, but was easily distracted from tasks and had short attention spans. With Bruno we worked initially in a scarce room that usually hosts the school nurse, but had to change to a larger play room after a few sessions. During the first meeting, a special education teacher was present to provide a stable point of social safety; however, their presence was not required in further meetings. Bruno is very curious and has many interests. He uses writing to emotionally regulate himself in moments of distress. He also likes playing with letters or words and is obsessed with cars. The structure of the sessions was soon clear to him and he started accepting the roles of his play partner and the active observer early on. When we changed our setup from working on a table to working on the ground, the sessions became much more lively and interactive.

For a very long time we were trapped in the conceptualisation phase. Bruno's interest in the sessions was challenged by the surrounding toys in the play room. At the same time we were committed to not simply creating a toy for him, even though our design brief is deliberately open. While the name of a potential smart object, Adaja, was set early on, we found it difficult to establish a longer-lasting interest besides cars. Using Co-operative Inquiry (cf. [11]) we determined that the finished object would have to offer flexibility to continually capture Bruno's attention in various contexts. We explored his use of a digital camera, electrical components for a smart car and his view on hidden letters in pictures – all to no avail. Finally, when he interacted with a kinect, we found that he was interested in exploring his surroundings whenever there were visually intriguing effects. After that, we decided that Adaja should visualise surrounding sounds and be a shareable device for exploration with peers.

We then experimented with different forms of visual representations of sounds on variable display sizes using wall projection, smartphones and bracelets. We noticed, that Bruno preferred to interact with the prototypes in an ambient manner to calm himself.

Adaja is a wearable with which Bruno can explore the sounds of his environment. He can share the display exhibiting a visualisation of the loudness of incoming sounds with others or tilt it so that he alone can interact with it. Whenever a certain thresh-hold is reached, Adaja displays the words 'too loud', in order to help him regulate his own voice.

5.4 ProDraw

Thomas has been diagnosed with a Pervasive Developmental Disorder – Not Otherwise Specified. He has limited operational language, but is tremendously talented at drawing. Our first few meetings with Thomas were helped by the presence of his teacher. We met in a play room adjacent to his classroom for this and all subsequent sessions. Thomas is rather shy, does not like meeting new people and uses language on a barely functional level. He loves to draw – especially princesses. With his drawings, he communicates and non-verbally tells stories. Only after a few sessions, he started directly interacting with us. There was a pattern for each meeting, where he first refused to work with us at all, needed persuasion to finally do so and later reported to his teacher how amazing he found the things we did together. This convinced us to continue with him, even though he indicated at the beginning of each session that he would rather do something else.

It was difficult for us, to engage Thomas in shared activities with his play partner. He rather worked for himself or delegated tasks. E.g., Thomas took over sketching, but asked his play partner to do modelling tasks. We used Co-operative Inquiry (cf. [11]) as a method for co-design with Thomas. We explored a set of drawings he made in one of the initial sessions, scaled them up to different sizes using a photo copier and observed his interactions with them. He started to draw on various of the snippets to alter their character and started playing with them. This led us to define two modes for Thomas' smart object: a drawing surface and an animation mode. He liked sharing some of his drawings, but not all, so we additionally chose to incorporate the scaling concept by using a projector.

We created a mockup using a combination of a projector and a Magic Trackpad for drawing, using Scratch for animating his drawings. Thomas cared less about the look and feel of his object than about what he could do with it. He was, however, very keen on defining key colours for ProDraw: pink and purple.

In its final realisation, ProDraw is a single object with a touch enabled surface on which Thomas can draw and switch between modes. He can also animate figures by moving a controller, based on a Nintendo Wii controller quickly, e.g., while running on the spot. When showing his drawings to his peers with ProDraw, he was praised and envied – the first time since he entered school, as his teacher assured us. He tends to share finished drawings and only rarely includes others in the process.

6. SYNOPSIS OF DESIGN CASES

The above accounts along with the graphical exposès provide a rich and multi-faceted description of the design processes and their outcomes. The format we have developed, however, also serves us as an analytical tool in that it enables us to reveal connections, relations and patterns in time and structure that represent starting points for eliciting design knowledge. In what follows we conduct a synopsis across the exposès in search for "family resemblences" [5] within our portfolio, that connect the situated designs with "broader concerns". These can be seen as intermediate-level knowledge similar to "strong concepts" [27] in that they represent design insights that do not possess universal applicability or predictive powers of theory as traditionally conceived, but provide valuable guidance for research and design when interpreted within its context and historicality.

A central concept that emerges from the exposès is the strategy to engage autistic children through their special interests and translate them into a **frame for exploration** that gradually opens up the design space. Narrow, special interests are a hallmark feature of autism and we found them being strong motivational drivers in all of our participants. But we also found that they can provide motivating vehicles into the creative process: Lucas, for example, was obsessed about a particular movie that provided narrative entry points for subsequent design work and established the fundamental theme of storytelling that shaped his smart object. Thomas frequently fell into drawing as a repetitive activity that helped him to emotionally regulate his excitement levels. Drawing and sketching became the frame for exploring the design space and, again, was shaping his smart object in fundamental ways. Holger's fascination with researchers allowed us to introduce scientific instruments and measuring tools as a fundamental idea that was both meaningful to him and useful for us as a design theme. Bruno's affinity with words and letters equally determined the directions we took with his work. In this case, this route turned out to be a cul-de-sac, as his interests proved extremely volatile and context depended.

To further explore the design space by using these frames as vehicles, required the re-interpretation of the chosen design methods. Future workshops proved powerful in creating scope for children's own ideas, e.g., by developing future episodes of his favourite movie in Lucas' case. With Co-opertive Inquiry the physicality of materials served a similar purpose, like with the scaled paper snippets of his drawings in Thomas' case. Despite the differences in method, a common concept here is the careful management of **structure, inspiration & freedom** in creative processes. For autistic children, structure is key to cope with anxieties and it can be provided in various ways: through constraints in materials, through narrative frames, in scheduling sessions, by physical environments or in designing clear roles for all design partners. Some structures also act as inspiration, like our use of littleBits as an explorative material[6]. Creating open spaces that give children the freedom and scope to develop their own ideas can be intimidating for autistic children. However, we found without exception that each child had unique creative potential, the realisation of which depended on finding the individual balance of structure and freedom. An empty, white sheet of paper, for example, was perceived as irresistible opportunity for Thomas while Lucas would freeze. At the same time, Thomas would require fixed rites and environments to be drawn into workshop sessions at every meeting, while this was of no concern to Lucas. Thus, exploring design spaces with autistic children is also a matter of fathoming their creative potentials by continuously adapting structures and opportunities.

Looking at the times when and the ways how sharing qualities were being introduced to the designs, it becomes apparent that this was very much our own agenda, not necessarily that of the children. Even in the case when Thomas wanted to show off his artwork to his teacher, it was our interpretation that this is an opportunity for wider sharing and not his idea to make it a feature of his smart object. The emerging insight here is that it is possible, even in very open design processes, to **incorporate other design goals** that are more aligned with an intervention mindset rather than child desires, if they are folded into the overarching themes and concepts being developed. We argue that the embeddedness into meaningful interactions would also make such interventions much more relevant, motivating and ultimately also more effective. For example, for Holger to reflect on and talk about difficult social situations is no small feat and was only made possible by folding the sharing quality into the narrative of using a scientific instrument to capture such situations and revisit them at home to be able to properly analyse them.

We have engaged children in designing their smart objects as experts in their lives. However, the sustained collaboration over a long period of time has **blurred the boundaries** between the domain experts (i.e., the child) and the design experts (i.e., the researcher). As Yip et al discuss in their paper, there are different affordances and benefits to engaging children with subject expertise and children with design expertise [44]. While the collaboration was initially framed along distinctive sets of expertise, we experienced that the increasing closeness between researchers and children facilitated

[6] http://littlebits.cc/

a mutual learning effect that led to the researchers understanding the child's life-worlds better and the child becoming increasingly versed in design skills. This was particularly apparent in the way children responded to brainstorming techniques in an increasingly natural and creative way or how children were increasingly conscious about their material choices in low-fi prototyping sessions. While we saw this boundary becoming blurred, it is important to note that this does not mean that the principle authority, and consequently responsibility, for design decisions has shifted. As designers, we ultimately provided much of the structure and mindfully interpreted input to inform design decisions (see Frauenberger et al for a discussion on interpreting children's input in design [18]).

Looking across the exposès for family resemblances also made us acutely aware of how **different** they were. Each process took a different path, stages were very different in length and most importantly, design concepts, artefacts and prototypes were very diverse in nature and functionality. While many design decisions relied on our mindful interpretation and we also had our own agenda in the process, we argue that the four exposès clearly support our hypothesis that a) open, child-led design processes are possible in an autism context and b) that these processes lead to technologies that would have been un-imaginable for adult, neuro-typical designers.

7. REFLECTING ON DESIGN EXPOSÈS

The format for reflecting on, analysing and describing our design cases has proven useful to us. The temporal order provided insights into how the work unfolded and changed over the course of the process while the ANT inspired networks allowed us to see structures, framings and relations that shaped us, the collaboration and its outcomes. Design exposès are summaries and thus necessarily limited in detail. The experiences we have made over the past year were rich and complex, but we found the exposès suitable representations that allowed us to refer to other data or experiences quickly. The common representation across design cases also was a significant factor in being able to analyse our experiences across cases. This analysis in turn enabled us to develop intermediate-level design knowledge, i.e. formulate insights and concepts that are more generally valid and more easily transferable.

Like all representations or formalisms, design exposès are riddled with compromises. The biggest challenge for us was to do justice to the richness and complexity of our experience, while working towards a simple and effective tool for analysis. In particular ANT has provided us with a host of new perspectives on our work, for which we were often short of adequate representations. For example, we would have wished to be able to include somehow more in depth information on the nature and quality of some associations, not only between humans, but also how materials framed our collaboration. Furthermore, actor networks are per definition never complete as all actors would connect to an infinite number of others that would impact on their behaviours or programmes (ANT terminology for goals or intentions). The actions of parents of autistic children, for example, are significantly shaped by the medicalised system of diagnosis or state support. Equally, parent support groups, extended family and friends are important actors that shape parent's lives and consequently impact on how they scaffold the live worlds of their children. Each of these seemingly far removed actors can greatly impact on the way the child perceives its own creative capacities or scopes for contributions. In creating design exposès it becomes important to use good judgement about which actors to include, which to blackbox or which to leave out entirely.

Unsurprisingly, the format we developed suited the context of our design cases. However, we are well aware that other contexts, approaches, audiences or working styles might require attention to other perspectives, not covered in the current format of design exposès. For example, we have intentionally left out a designated "value" layer in the reflection part. This was not because we deemed values less important, but because we found that values in OutsideTheBox are strongly ingrained in our approach and there was little conflict or change that would have led to new insights. This is likely to be different in other contexts, however. Also, as Frauenberger et al highlighted too [17], other contexts might warrant the inclusion of particularly relevant perspectives such as ethics. The main stages we identified in our work, by which we organised the networks, might also be different in other contexts. This would mean to identify other times in the process at which creating actor networks is meaningful. While we envision a flexible way in which design exposès are instantiated, we argue that the fundamental concept of layers of reflections over time combined with actor networks at key stages is a useful means to describe design research.

The development of design exposès was prompted by the lack of formats that could capture the kind of design experiences we made in OutsideTheBox. While the result has been a retrospective exercise, we are beginning to see the potential of design exposès as a tool for reflection in action. Following Schön's argument [35], we anticipate can be a powerful tool to inform design processes in that they provide additional framings and perspectives to what is going on. We therefore plan to evolve design exposès into a tool-to-think-with and incorporate it in the following cycle of work in OutsideTheBox.

8. CONCLUSION

In this paper we have presented work from the first cycle in OutsideTheBox in which we co-designed four smart objects in collaboration autistic children. We have situated our work in autism & technology literature as well as relevant work from design research and participatory design, which are the main methodological fields we operated in. Inspired by annotated portfolios and actor-network theory, we have developed the concept of design exposès as a format to capture the rich and complex experiences we have in each case study. We introduce the concept of design exposès and subsequently used them to describe the design processes of four case studies. The resulting exposès (attached as supplementary material) and the textual accounts in this paper make up our portfolio. The descriptive and analytical power of design exposès allowed us to develop intermediate-level design knowledge for involving children with autism in technology design.

Future work will include evolving the concept of design exposès to address the challenges of complexity and flexibility as well as developing it into a tool-to-think-with that can be incorporated into our design practice, i.e. to be used in-action. In terms of the project, the second cycle will see a re-interpretation of two more co-design approaches: Drama Workshops and PD in a Digital Fabrication context.

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