Designing Technology for and with Developmentally Diverse Children - A Systematic Literature Review

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ABSTRACT

This paper presents the results of a systematic literature review of research papers on the involvement of developmentally diverse children in design. The review shows that there is a growing tendency to include developmentally diverse children in the design process. Compared to other groups of developmentally diverse children, children with high-functioning autism between 8 and 12 years old are the ones that are most often actively involved in the design process. Other groups of children often have a more passive role, being observed, both in the requirements, design and evaluation phase. Working with mixed groups of children, either children with different disabilities, or typically developing children together with developmentally diverse children, also occurs more seldom. Compared to design with typically developing children, adults are involved more intensively in the design, either as users, proxies, experts and/or facilitators. Specific guidelines for how to prepare and perform design sessions with developmentally diverse children often emphasize the need for a coherence of activities, a clear structure in the sessions, verbal as well as textual explanations, and the active participation of caregivers, teachers and therapists. Based on these findings we give several suggestions for further research.

Categories and Subject Descriptors

H.5.2 Information interfaces and presentation: User interfaces – Theory and Methods

General Terms

Design

Keywords

Participatory Design, User-centered Design, Children, Developmentally Diverse, Special Needs

1. INTRODUCTION

Over the last 20-30 years children have become important users of technologies, such as the Internet, smart phones, and iPads. However, in 2002 Druin [5] wrote that ‘a child’s role in the design of new technology has historically been minimized’. According to

Druin this was caused by several factors, such as getting access to children who attend school all day, existing power structures, biases and assumptions between adults and children, and young children’s difficulty in verbalizing their thoughts. Since then, much has happened, especially through journals and conferences dedicated to this topic, such as the International Journal of Child Computer Interaction and the Interaction Design and Children conference. However, while clear advances have been made for typically developing children, it may be less common to involve developmentally diverse children in design. In this paper we present a literature review of how this group of developmentally diverse children has been included in the design process, focusing on their role and the methods and techniques used. More specifically, we aim to answer the following research questions:

- Is there a growing tendency to include developmentally diverse children in the design process?
- What are the disabilities and ages of the children included in the design process and in which contexts are they included?
- What methods and techniques are typically used when including developmentally diverse children in the design process, and what types of technologies are developed?
- What design approaches are taken and what roles do children have?
- How are adults involved in the design process?
- What guidelines for involving developmentally diverse children in the design have been described?

2. DEFINING THE TARGET GROUP

As stated before, the focus in this paper is on the inclusion of developmentally diverse children in the design process. However, explicitly defining the target group is not without problems [12]. Sometimes researchers explicitly focus on a specific condition, such as Cerebral Palsy or Asperger syndrome, sometimes they specify the children as having Special Needs, (or in the UK Special Educational Needs), and sometimes the target group is specified as having intellectual or cognitive disabilities. Furthermore, many terms have rather negative connotations, e.g. mental retardation.

In this paper we choose to use the overarching term ‘developmental diversity’, where we combine the terms ‘developmental disability’ (‘a substantial handicap or impairment originating before the age of 18 that may be expected to continue indefinitely’ [11]), with ‘Neurodiversity’ [14]. The concept of ‘Neurodiversity’ grew out of a movement of people with autism wishing to remove the label of being disabled. Instead, they

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wanted to underline that diverse neurological conditions appear as normal variations in the population. Since then the movement has grown to include more disabilities [2]. While the term is used to indicate the diversity of people, it generally does not include people with Cerebral Palsy and may or may not include people having Down Syndrome. In this overview we want to emphasize the fact that we are talking rather broadly about diverse groups of children, which may have e.g. Attention-deficit/hyperactivity disorder (ADHD), Autism Spectrum Conditions (ASC), Down Syndrome, Cerebral Palsy, Intellectual Disabilities, or combinations thereof. However, we are aware that this term may also have some problems, being either too all-including, or becoming stigmatizing over time as well.

2.1 Design Roles and Methods

2.1.1 Children's Role in the Design

Druin's framework [5,6], containing the roles of user, tester, informant, and design partner, is often used to describe children's involvement in the design process. These roles differ in how the adults in the project relate to the children as well as in what phase of the design process the children are involved and what goals the designers or researchers have with including the children in the process. The roles are hierarchical, from least to most participation, so for instance the role as tester includes elements from the role of user, and the informant role includes elements from the tester and user role etc. However, there are no sharp boundaries between these roles. In a similar vein, Read et al. [13] have defined the IBF Participatory Continuum Model and made a distinction between design experts (academics) and domain experts (children and/or adult helpers). In 'Informant design' the domain experts' contribution is largely limited to informing the design experts, who will then realize the design. In 'Balanced design' there is an equal partnership between the design experts and the domain experts, and in 'Facilitated design' the domain experts initiate ideas and take the lead in realizing the design, with the design experts having a facilitating role. Concerning the inclusion of developmentally diverse children in the design process, Guha et al. [7] have created an inclusionary model in which children with disabilities can be included as full design partners. However, when doing so, the researchers have to take the nature and severity of the child's disability into account, as well as the availability and intensity of any support.

2.1.2 Methods, Techniques and Design Approaches for Involving Children

According to Jones [9] a design method is defined as any action one may take while designing. This can include e.g. brainstorming, interviews, sketching, or consulting an expert. (While there is a fine distinction between methods and techniques we will use these words interchangeably, as most of the papers included in this literature review also do). However, when focusing on involving the users in the design it might be beneficial to look more specifically at categories of methods and techniques as used in User-Centered Design. An example is Maguire [10] who categorizes methods and techniques under five phases: Planning, Context of Use, Requirements, Design, and Evaluation. In this paper we take inspiration from this categorization but we will only focus on methods and techniques used with children for the design of non-task oriented technologies. Furthermore, since some methods and techniques used in the Participatory Design approach, such as drawing and story creating with users, are not present in Maguire's model we choose to add all of these under Creative sessions. The resulting categorization is given in Table 1.

Additionally, several of these methods and techniques are used in combination, following a certain design philosophy that usually spans over several phases. We will use the term 'approach' to indicate such a combination of methods and techniques, although some authors call this a method. In this paper we will also provide an overview of these general approaches.

Table 1: Classification of method and techniques

Requirements	Design	Evaluation
Survey	Brainstorming	Participatory or assisted evaluation
Field study/User observation	Creative sessions	User testing
Diary keeping	Card sorting	Questionnaires
User requirement interview	Prototyping (<i>Paper, software, wizard-of-Oz</i>)	Post-experience interviews
Focus groups		

2.1.3 Roles for Adults

Druin noted in 2002 that concerning typically developing children, it is "*common for developers of new technologies to ask parents and teachers what they think their children or students may need, rather than ask children*" [5]. While children in general are being given a stronger voice in the design process, the role of parents, caregivers and teachers in the design of technologies for developmentally diverse children is still very prominent. For this reason, we also analyze how adults are involved in the process.

3. RESEARCH METHOD

Our literature review started with querying the databases Scopus, ProQuest and ACM Digital Library with the search query outlined in Table 2, for papers published from January 1st 1995 until September 30th 2014. Additional papers were found by looking at references in and citations of the included papers.

Table 2: Search terms using AND between columns

Search term 1	Search term 2	Search term 3
child kid adolescent minor youth teenager parent teacher assistant coach educator instructor lecturer supervisor tutor care-taker care-giver proxy	design method design process design approach design technique interaction design participatory design user-centered design human-centered design child-computer interaction human-computer interaction inclusive design universal design	special need special education need intellectual disability intellectual impairment cognitive disability cognitive impairment developmental disability developmental impairment pervasive developmental disorders social skill social competence social capacity social capability down syndrome autism, asd, asc fragile x syndrome cerebral palsy adhd neurodiversity
<i>Only the singular phrase and the most common spelling are shown. In the actual search both singular and plural as well as alternative spellings and synonyms were used, e.g. child and children, and user-centered design, user centered design, user-centred design etc.</i>		

3.1 Literature Selection

The first literature search based on the query given above resulted in 663 papers. The first author performed an initial analysis by reading the titles and abstracts in order to remove any obviously not relevant texts. This led to a total of 325 candidate papers that were divided among the four authors to assess whether each paper should be included or excluded from the review. The following types of papers were excluded:

- Papers about projects that do not include the target group in the design process, or only for summative testing
- Papers not focusing on the design of artifacts or technologies with the target group
- Papers merely focusing on a method without applying it in a design setting with the target group
- Papers not describing the design process in enough detail, also e.g. work in progress, demos or videos
- Papers not subject to peer-review
- Dissertations and theses
- Papers in another language than English

After the first round of analysis the papers were discussed to determine a shortened list and to ensure a common view on the criteria. During a second round the remaining papers were divided among the authors in a different way to ensure that each paper was analyzed twice. Once compiled, the individual lists of excluded and included papers were scrutinized together, which resulted in a final list of 88 papers. These papers form the basis of the literature review presented here and are listed in Appendix A¹. A list of the excluded candidate papers and the reason for their exclusion has been maintained.

3.2 Data Analysis

From each paper the following data were extracted; *publication details*, name and description of the *developed technology*, details about the *age* and *disability* of the children, the *phases of inclusion* of the target group in the design process, whether the authors stated a design approach (e.g. *participatory design*, *user-centered design*, or a more specific approach for developmentally diverse children), and the *methods and techniques* used with the target group in each phase. We also gathered information about the role of adults (non-academics) in the design process, as well as guidelines for involving children presented in the papers.

4. RESULTS

4.1 Inclusion of Developmentally Diverse Children

Of the 325 papers that were deemed interesting after the initial analysis only 88 papers contained enough information about the actual design process with the target group to be useful for further analysis. This suggests that while developmentally diverse children are an interesting target group for the development of technologies, it is still not very common to involve them actively, or, when they are involved to describe how they were involved in the design process in detail. However, an overview of the number of papers published per year as given in Figure 1 also shows a clear trend towards more involvement of developmentally diverse children in design, starting with no papers between 1995 and 2003.

¹ References to papers in Appendix A always start with an a e.g. (a1)

Figure 1: Number of papers per year. 2014* = Number of papers until September 2014.

4.2 Disabilities, Ages and Contexts

Figure 2 describes the actual disabilities described in the papers. Although this seems straightforward the categorization has some problems. Some papers for example only used the term Special Needs or Special Educational Needs, others mentioned several disabilities while in the design activities only including children with a specific disability, and sometimes terms like cognitive and intellectual disability were used without any further specification. Furthermore, some disabilities typically co-occur with other disabilities, e.g. according to APA [1] intellectual disability frequently co-occurs with ADHD, and ASC.

Figure 2: Disabilities of the children involved in the design process.

Papers explicitly working with mixed groups of children with different disabilities were categorized under *Mixed groups*. Papers not specifically describing the disabilities were categorized as *Other*. Papers describing different activities for several groups of children were categorized under each disability. This led to a total of 92 entries instead of 88. Looking at the specific disabilities of the children involved it is clear that children with Autism (but not Low or Medium Functioning Autism) were the main target group.

Figure 3 shows the ages of the children involved in the design process. Although children of all ages between 1 and 18 were represented in the papers it seems that the main focus was on children between 8 and 12.

Figure 3: Ages of children involved in the design process.

The most prominent context was the school (47%), followed by therapy centers or rehabilitation institutes (11%), and the home (8%). This is in line with Jensen and Skov [8] who found that natural settings are the preferred environment to conduct research with children. For developmentally diverse children, therapy centers or rehabilitation institutes can be considered a natural setting as well. Surprisingly, for 25% of the papers it is not specifically indicated in which context the children were involved.

4.3 Methods and Techniques

Table 3 gives an overview of the classification of the methods and techniques used in each of the phases (requirements, design and evaluation) for the various user groups. Whenever especially interesting methods, variants of methods, or techniques are developed these are mentioned by name.

4.3.1 ADD/ADHD

Only three papers discussed a design process involving children with ADD/ADHD. The design approach for this user group was not specifically adapted although an objective measure of activity was performed in one of the studies as part of the requirements phase. The applications developed with this user group specifically aim to train the children in things they experience difficulties with, such as games to train short-term memory (a2), toys and devices to support the learning process of suppressing undesired behavior on daily routines (a25), and Tangiplan, a set of tangible objects to facilitate organization, time-management and planning (a84).

4.3.2 Autism and Low Functioning Autism

From all developmentally diverse children, children with high functioning autism are the group most often involved in the design process. For these children there is a range of adapted methods, especially in the requirements and design phase. For both groups of high and low functioning autistic children, field studies or observations often contain the implicit goal of establishing rapport with the children. For instance (a47) reports on undertaking familiarization activities, and (a67) reports that they spent months building rapport with the students. Furthermore, in many cases the requirements phase contains observations of activities instigated by the researchers. So, instead of pure observations or field studies of children's behavior at home, in the therapy center or in the classroom, the researchers create different probes, materials or activities to see how the children respond to them, e.g. (a11, a24, a43). Based on these observations the researchers aim to discover needs and requirements for the technologies to be developed later.

In the design phase a similar approach is taken; instead of including the children in open creative design activities or brainstorming they are often given different prototypes to interact with. For instance during a “lunch bunch” (a43) in which both autistic and typically developing children are invited to a lunch activity where they jointly perform an activity involving the use of an application. For low functioning autistic children activities and applications were also introduced, but in this case only one or two children at the time were involved. In Scenario Design for ASC (a57), high functioning autistic students were involved in a suite of highly structured activities leading to the design of a computer game. The researchers adapted this method from previous scenario design sessions with typically developing children by making the activity more structured, using templates and concrete materials, and letting the children draw on a screen instead of a blank piece of paper. Similarly, Malinverni et al. (a30, a54) reasoned that it would be beneficial for the children to “create a feeling of continuity and progression between the different activities”. They followed the Fictional Inquiry technique, structuring the activities around the plot of a backstory created through interviews with psychologists. Children were then given scene cards for each chapter developed in the workshop and a cliffhanger to introduce them to the next chapter and workshop. The children could store their work and reward badges from each workshop in a personalized storage box. Typical types of applications developed for and with autistic children are applications for training emotion recognition, e.g. Photogoo (a43), cooperation e.g. Block Party (a57) and social initiation skills e.g. the Kinect motion-based game (a54).

4.3.3 Cerebral Palsy

Children with Cerebral Palsy are usually not actively involved in the requirements phase, especially not when they are communication-impaired. Researchers try to understand the children's needs by doing observation and field studies. Also in the design phase, the involvement is often in the form of feedback on actual products or prototypes. For example, in (a37) children with CP were given different chairs, controllers and versions of a game on which to provide feedback. However, there are some exceptions. In (a19) for example, the researchers presented and investigated the PD approach PD4CAT. Similarly, in (a42) the author held design session with two children and a speech pathologist to design dresses. The adults proposed ideas and physically built the prototypes based on the children's input given through the use of yes/no switches.

4.3.4 Down Syndrome and Intellectual Disabilities

Children having Down Syndrome or intellectual disabilities are relatively seldom included in the design and when they are they have a rather passive role. They are usually observed in a natural setting during the requirements phase, when using prototypes in the design phase, and when working with the final product during the evaluation phase. An example is (a18) where children with intellectual disabilities were first observed in the classroom and then asked to explore different tangible systems in an open-ended way. The types of applications developed for and with this user group often have a tangible nature, such as the tangible reading and writing method for children with Down Syndrome (a33).

4.3.5 Mixed / Diverse Groups

There are eleven papers that do not specifically focus on a certain disability, but work with groups of children with several types of disabilities. For example, Foss et al. (a20) worked with a whole

Table 3: Overview of methods and techniques used with developmentally diverse children in different phases of the design process

Main Disability	Requirements	Design	Evaluation
ADHD/ ADD	Field study/observation: [a25] (including e.g. measures of activity), Eye tracking [a2] User requirement interview: [a84] Focus group: [a25]	Creative sessions: Design sessions [a2] Prototyping: Concept testing [a25][a84], Interview [a84]	User testing: [a25] Post-experience interviews: [a25]
Autism (High functioning)	Field study/observation: [a3][a4][a8][a35][a40][a43][a55][a59] [a60][a67][a70][a71][a72][a79][a80][a82] The Comic [a24], Contextual Inquiry [a26] Demos of existing applications [a43], Desert Island [a24], Exploratory field trials [a73], Observation of Paper Prototyping by therapist and child [a11], Odd-one-out [a24], User requirement interview: Individual and Group Interviews [a67] Diary keeping: Video diary [a41] Survey of existing users: Questionnaire [a13] Focus group: [a62]	Creative sessions: [a6][a7][a8][a55][a62][a66][a69], Create prototype [a6], Fictional Inquiry [a30][a54] Interactional disruptions [a23], Projecting contexts [a23], Scenario Design [a56][a57], Brainstorming: [a67] Prototyping: Prototype testing [a3][a4][a11][a24][a29][a39][a41][a43][a56] [a66][a67][a70][a71][a76][a78], Group interview [a67], Interview [a29], Lunch bunch [a43], Verbal feedback [a64][a65][a41]	User testing: [a1][a3][a4][a10][a13][a21][a22][a26][a34] [a40][a41][a52][a53][a60][a66][a67][a69] [a70][a71][a72][a76][a85] Post-experience interviews: Design critique [a21][a22], Group interview [a67], Individual interview [a34][a52][a67][a72] Questionnaire: [a3][a6][a67][a85]
Autism (Medium- Low functioning)	Field study/observation: [a5][a16][a17] [a45][a46][a47], Emotion recognition study [a16], Visual and auditory feedback tests [a32]	Prototyping: Activities and applications [a43], Experience prototyping [a45][a47], Multiple small prototypes [a46], Observation [a43][a46], Prototype testing [a5][a46][a75]	User testing: [a5][a45][a46][a64][a65][a75][a78], Release and listen [a46], Video recording [a17][a61]
Cerebral Palsy	Field study/observation: [a9][a14][a19][a37][a42][a51][a87] Survey of existing users: [a36]	Brainstorming: [a37] Creative sessions: Design session with yes/no switches [a42], PD4CAT drawing sessions [a19] Storytelling with cards [a19] Prototyping: Concept evaluation [a51], Interview [a37], Observation [a36], Prototype testing [a9][a14][a19][a36][a37][a83][a87]	User testing: [a9][a36][a37][a51][a87], Comparison experiment [a83][a87], Observation by experts [a83] Participatory or assisted evaluation: Peer-tutoring observation [a83] Post-experience interviews: Focus group [a83], Interview [a37], Interviews with Talking Mats [a9], Verbal questioning [a87] Questionnaire: [a37][a83]
Down Syndrome	Field study/observation: [a33]	Prototyping: Prototype testing [a33]	User testing: [a33][a58]
Intellectual disabilities	Field study/observation: [a18] (including intervention with tangibles)		User testing: [a49]
Mixed groups	Field study/observation: [a12][a15][a20] [a44][a81][a88], Individual skill assessment [a44], Role playing [a44] User requirement interview: [a12][a81] Focus groups: [a28][a86] Survey of existing users: Questionnaire [a12]	Creative sessions: [a15][a20][a48] Prototyping: Prototype testing [a12][a31][a44][a88]	User testing: [a12][a15][a28][a44][a63][a77][a86][a88] Post-experience interviews: Critique session [a15] Feedback session [a88] Group interview [a12] Interview [a12][a86] Pictorial feedback [a63] Questionnaire: [a20][a48][a77][a86]
Other		Creative sessions: [a27] Prototyping: Design artifacts [a50] Video recording [a50]	User testing: [a38][a68][a74]

class of 10 boys with learning differences, various forms of autism, specific learning disabilities, and ADHD using the Cooperative Inquiry approach. Nissinen et al. (a63) also worked with a mixed group of children with e.g. autism, delayed development, and attention deficit disorder in 20 technology club meetings. In these meetings the parents and children worked at different workstations that were improved, mainly based on observations by parents and assistants, but also on suggestions from some children. After using each workstation the children used pictorial feedback to give their opinion, and those who were able to communicate verbally were asked to express their thoughts. The technologies developed with these mixed groups of children are often not focused on certain training or learning needs of the children. Instead they focus on the interests of the children, such as the game developed by Foss et al. and the workstations in the technology clubs. Zarin and Fallman (a88) explicitly state that instead of developing systems that deal with particular aspects of a certain diagnosis, one needs to design systems for mixed groups of children. They therefore developed Trollforest, a tabletop system with micro applications to exercise and improve key social skills that can help the group to communicate.

4.4 Design Approaches and Roles of the Children

While only papers were included in which children were in some way involved in the design process, their involvement differed in intensity. Fifty-seven of the eighty-eight papers explicitly mentioned that a participatory design (36 papers) or a user-centered design (16 papers) process or approach was followed (5 papers mention both). More specific approaches described to involve or design for developmentally diverse children were the following: Cooperative Inquiry (a20), IDEAS (a6, a7), Diversity for Design (a8), PD4CAT (a19), Narrative-based elicitation (a30, a54), Experience Centered Design (a15), and Meta Design (a11). Only a few papers explicitly mentioned that the children were involved as either Informants (9 papers) or Design partners (3 papers). For the other papers it might be possible to determine the role of the children by looking both at the phases in which they were involved as well as the methods used during each phase. However, both Druin [5] and Read et al. [13] describe children's roles in the design on a continuum. Therefore such a categorization would be rather unreliable. Instead we describe the number of papers including children in one or more phases of the design process, as in Table 4.

Table 4: Inclusion of children in different phases

Phase(s)	Number of papers
Requirements	10
Design	13
Evaluation	16
Requirements & Design	13
Requirements & Evaluation	11
Design & Evaluation	8
Requirements, Design & Evaluation	17

Table 4 shows that in many papers children were involved in a range of activities in several phases of the design process or even in all phases. However, the authors did not define the children's role as being a design partner. This is probably related to the level of direct influence the children had on the design process. Several papers mentioned the difficulty of involving developmentally diverse children as design partners, e.g. as (a55, a46).

4.5 Roles of Adults in the Design Process

The analysis of adults' involvement in the design process with developmentally diverse children showed that adults often have mixed roles. Generally, we can discern adults as users, proxies, experts, or facilitators.

- **User:** While the main focus in this paper is on how to involve developmentally diverse children as a target group in the design, other people surrounding them can also be users of the specific technology. For example, siblings and parents can also be users when developing a communication technology.
- **Proxy:** When other people surrounding the child are talking for this specific child, for example by explaining the child's use of Augmentative and Alternative Communication (AAC) to the researcher, they are considered proxies. This could be parents, caregivers or teachers depending on the context.
- **Expert:** When therapists, psychologists, teachers etc. aid in the design by talking for a group of children in general, they are considered experts. The difference to a proxy is that they do not refer to a specific child's experiences.
- **Facilitator:** When adults are present during design activities to introduce the children and researchers or designers to each other, to help build rapport, and to practically assist during the activity, they are considered facilitators.

However, the distinction between these different roles is not clear-cut. For example, if special-education teacher Jane is supposed to work together with the child Henry to observe and reflect upon his day in school, she might well be both user (it is a technology that helps them to communicate), proxy (Jane might be talking for Henry about his experiences with the technology) as well as an expert (she can reflect upon how the technology could affect others than Henry based on her expertise). One example of this is from Sampath et al. that describe how the mother acted as a proxy for the child during the design, but could also be considered a user of the designed communication system (a76). Another example is from Haro et al. that first interviewed a teacher about her experiences from special education, and then later held a post-test interview asking her to describe her observations and the reactions of the children (a33).

4.6 Overview of Guidelines

Several papers included guidelines and recommendations for involving developmentally diverse children in the design. Here we present an overview of these guidelines and the papers in which they were presented. The guidelines are grouped together under general themes. Note that there were also papers giving design guidelines for specific types of applications. These guidelines are not presented here.

Preparation

- Let people who know the child well mediate the first contact, approach the child gradually and observe how these people interact with the child (a19)

- Accept the feelings of awkwardness and nervousness (a42)
- Be flexible in the use of methods and prepared to adapt (a56)
- Involve researchers from a range of backgrounds, as it is important to have adult team members with technical skills as well as the psychological knowledge to best engage the children (a6)

Proxies and experts

- Interact with as many different caregivers as possible (a42)
- Engage experts as stakeholders, to find alternatives to overcome the child's limits and explore the abilities (a19)
- Empower the specialists on a specific area, so as to specify the child's therapeutic needs (a19)
- Work closely with teachers that know the children in order to adapt methods (a56)

Structure of sessions

- Have sessions of 90 minutes to allow for informal talk and socialization (a20)
- For children with ASD use a narrative-based elicitation to facilitate a common directionality in the requirements elicitation process with experts and end-users (a30)
- Have rapid iterations (a20)
- Decompose design activities into discrete subtasks (a42)
- Present the sessions in terms of timetables and show how you are working through the structure (a6, a56)
- Have a high ratio of researchers per child to help children with writing and keeping them on-task (a20)
- Work with multiple children in parallel for synergy (a42)

Creating interest and motivation

- Ensure that the children are familiar or can identify with the design topic (a6)
- Identify the child's interests and hobbies to incorporate in discussions and examples, especially when a child is distracted (a6)
- Engage the child in pleasant design activities, such as games, drawing, and storytelling (a19)

Materials and instructions

- Use low-tech interactions to design hi-tech applications (a42)
- Have both written and verbal instructions for the activities to accommodate for different children's needs (a20)

Communication during sessions

- Use the same techniques to communicate with the children as in their daily lives and check with a therapist or caregiver whether interpretations are correct (a19)
- If necessary, include a mediator to make drawings (a19)
- Be prepared to get very direct criticism. If the children do not like something, expect them to say so. Do not take offense and give clear explanations/solutions to issues (a6)
- Involve an enthusiastic member of teaching staff, who 'gets' the project, knows the children well and is able to reinforce the support structure and improvise where necessary (a6)
- Specifically learn how to hear "I'm done" (a42)
- Use the personal strengths of each child to build up their confidence in the sessions (a6)
- Advocate for the children's self-expression (a42) and empowerment (a19)
- Explore the child's potential and provide support to overcome limitations to understand the target user's capacities (a6)

5. DISCUSSION AND CONCLUSIONS

This systematic review of the literature on interaction design with developmentally diverse children is based on a sample of 88 papers out of 663 papers found in academic journals and conferences, and focuses on how developmentally diverse children are included in the design process.

The results show that indeed, there is a growing tendency to include developmentally diverse children in the design process. Children with autism and especially high functioning autism (HFA) are the ones that are most commonly involved in the design process. This phenomenon cannot be explained by the prevalence of autism in society [3]. There may be several other reasons, e.g. verbal communication with high functioning autistic children is easier than with some of the other groups of children, meaning that methods for typically developing children relying on verbal communication can relatively easily be applied or adapted. Another possible explanation may be found in the interest for technology that is shared between many children with autism (a43). Similar to Yarosh's [15] finding that typically developing children involved in the design are generally between 6 and 12 year old, developmentally diverse children involved in the design are also within this age range. Most research is performed in the children's natural setting, e.g. the school or the rehabilitation/therapy center.

Besides a relatively strong focus on children with high-functioning autism, many technologies are only designed for and with children with a particular diagnosis. As Zarin and Fallman (a88) point out this is problematic when technologies are to be introduced in the real world, such as a school, which is the most common context for working with developmentally diverse children according to this overview. In many schools, especially in Northern Europe, children with a range of different diagnoses are often grouped together, and in some cases they also attend the same class as typically developing children. This means that not only the technologies themselves, but also the methods for involving children in the design of these technologies, should be adapted to accommodate diversity within groups. Many of the methods and techniques used with these children are also used with typically developing children. However, the approach is often slightly different, giving more weight to the coherence of activities, a clear structure in the sessions, verbal as well as textual explanations, and the active participation of caregivers, teachers and therapists (especially visible in approaches such as Meta Design (a11) and PD4CAT (a19)). When necessary, additional tools, like Talking Mats and pictorial feedback, are used to facilitate the communication. These tools are often the same tools as the ones used by children and their caregivers or therapists during daily interactions. Most of the approaches and guidelines could also be beneficial for typically developing children, something that Benton and Johnson [4] also suggested when investigating the benefits of the IDEAS approach for mainstream school children. We suggest that in some cases, instead of focusing on the disabilities of the children, it might be more fruitful to talk about the environment in which the children reside. Based on this literature review we can give several directions for future research:

- An increased focus on how to develop and adapt design methods in order to fit the level and needs of other groups of children than those with high functioning autism.
- Devise and investigate approaches and methods for mixed groups of children, both children with different disabilities as well as developmentally diverse and typically developing children.
- Investigate how to involve developmentally diverse teenagers in design.

This systematic literature review has several limitations that need to be mentioned. First of all, since we only used Scopus, ProQuest and ACM Digital Library for our initial literature search we may have missed some relevant papers. However, because we also used the references in these papers to determine additional papers we are confident that most relevant papers are included. Second, although we used inspiration from Maguire's categorization of methods [10], the classification is still not completely without difficulty. For example, some methods used during the very first stages of design, could either be classified under the requirements phase or under the design phase. Third, although the authors worked together to determine which papers were to be included and excluded from the set of 325 papers, only the first author was responsible for the first analysis that decreased the number of papers from 663 to 325. This may have introduced a bias.

It is the hope of the authors that this overview and analysis of the approaches and guidelines to design technology for and with developmentally diverse children, can act as an inspirational guide for researchers and practitioners who intend to start working with this user group.

6. ACKNOWLEDGEMENTS

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8. APPENDIX A: List of Papers 1995-2014

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