Designing for Care Ecosystems: a Literature Review of Technologies for Children with ADHD

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ABSTRACT

This paper presents a systematic review of HCI literature focusing on children with ADHD, the prevailing mental health diagnosis in children. Its aim is to (i) chart the state-of-the-art in this domain (e.g. methods used), (ii) identify the ways the HCI community has addressed the needs of children with ADHD (e.g. technologies deployed), and (iii) describe the involvement of the various stakeholders playing a role in their everyday experiences (i.e. their care ecosystem). Our findings show limited engagement of the care ecosystem in the design, development and user studies of current technologies, and shortcomings in designing for multiple ecosystem stakeholders, despite their crucial role. We also find that most HCI contributions are systems aiming to address ADHD-related symptoms. Based on our findings, we provide suggestions for further research and design considerations for future systems that empower and promote the well-being of children with ADHD, while considering their care ecosystem.

CCS CONCEPTS

• **Human-centered computing** → **Interactive systems and tools**; **HCI theory, concepts and models**; **Human computer interaction (HCI)**.

KEYWORDS

ADHD; Literature Review; Neurodiversity; Neurodivergence; Children; Assistive Technologies; CCI

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1 INTRODUCTION

Attention deficit hyperactivity disorder (ADHD) [45] is the most prevalent mental health diagnosis in children [54, 74]. ADHD has an occurrence of approximately 5% worldwide [52], a number which exhibits significant variability. For example, it affects up to one in 20 children in the USA [20]. Children with ADHD exhibit symptoms across two broad areas: inattention and hyperactivity/impulsivity [1]. Various systems and guidelines have been developed within the research community aiming to assist and support individuals with ADHD. For example, ParentGuardian by Pina et al. [50] provides guidelines to parents of children with ADHD when it detects stress, such as "Take a deep breath", via a wearable physiological sensor. Sonne et al. [62] aimed to support families of children with ADHD to establish effective morning and bedtime routines. Zuckerman et al. [77] developed a tablet-based app that measures selective and sustained attention, and a social robotic device for students with ADHD, providing immediate feedback for inattention or impulsivity events in the form of gestures. Here, the question arises to what extent aspects that go beyond specific artefacts designed for children with ADHD or their parents should be considered in HCI research.

From a broader perspective, children have increasingly taken the role of the target users of technology over the last decades [4], resulting in an increased need to understand how to design technologies for them. The rise of research fields such as Child-Computer Interaction (CCI) has contributed to that endeavour [4]. In particular with regard to interventions and technologies for children with ADHD, it is essential to consider not only the child as a sole actor, but the entire care ecosystem [13]. The care ecosystem encompasses all actors who play a role in children's lives, such as parents, siblings, extended family, friends, educators, school teachers and potential therapists or specialists. The term care ecosystem has already been broadly used in scientific literature. For instance, Cigarini et al. [16] explored the role of different groups of a mental health care ecosystem, including professionals of the health and social sector, formal and informal caregivers, relatives, and friends. Formal caregivers refer to professional, paid personnel, while informal care refers to unpaid care provided by family, close relatives, friends, and neighbors [34]. Weisz et al. [71] also sketched out the mental health ecosystem for clinically referred youths to include multiple layers, such as their families, caregivers and practitioners. Amir et al. [2] already referred to the term "care ecosystem" with regards to the diverse team of caregivers for children with complex health conditions, including multiple types of medical professionals, parents and community support organisations. The term has also been used within autism spectrum disorder research, e.g. in clinical contexts [33]. To the best of our knowledge, the term "care ecosystem" has not been explicitly used with regards to children with ADHD, but the condition still falls under the broader spectrum of mental health, where the term is present [16, 71]. Nevertheless, variations can be found in ADHD literature; for instance, Cibrian et al. [13] refer to the social actors surrounding the child as its "caregivers".

Exploring the role of these different social actors involved in their everyday experiences could provide a more comprehensive overview and valuable insights to consider when designing for children with ADHD. Along similar lines, HCI research has already pointed out the importance of considering the entire "use ecology" in which technologies are deployed [57], referring to the inclusion of the sociality and spatiality of the environment where technologies are integrated [57]. The importance of considering all stakeholders rather than a single user was also discussed by Forlizzi [21], who argues for a shift from a user-centred design to a stakeholder-centred one. It is crucial to understand how the technologies for children with ADHD could be used in collaboration with the whole spectrum of children's support systems, who can offer motivational and emotional scaffolding [13], and who strongly influence quality of life, social activity, and success in school environments [27, 49]. Specific guidelines for design sessions with developmentally diverse children in general have often highlighted the need to actively involve caregivers, teachers and therapists [6]. However, designing technologies for children with ADHD considering their entire care ecosystem is an inherently complex process, given the number of social stakeholders and their interwoven role in the child's everyday experiences. To the best of our knowledge, no comprehensive overview of HCI literature on children with ADHD exists, outlining the methods and contributions to-date, and charting the roles of their care ecosystem.

This paper is intended to benefit HCI and CCI researchers, technology designers, and ADHD professionals aiming to support the well-being of children with ADHD and their care ecosystem, by contributing an understanding of factors involved in designing technology for children with ADHD. In particular, this work presents results from a systematic review of 27 HCI papers focused on children with ADHD. The aim is to create a state-of-the-art overview that can serve as a starting point when designing for children with ADHD, while considering the roles of stakeholders of their care ecosystem. In this paper, the term children refers to ages up to 18 years. With this systematic literature review, we seek to address the following research questions (RQs):

- RQ1: Who are the intended users of technologies for children with ADHD and how are the various stakeholders of their care ecosystem involved by current approaches within the HCI field?
- RQ2: What are the characteristics of current technologies for children with ADHD concerning types of technologies, objectives, and contexts of use?
- RQ3: What are the methodological approaches employed, and how are the developed technologies for children with ADHD evaluated?

We found that the majority of HCI contributions are systems aiming to address and improve ADHD-related symptoms. Our results also show that the most represented group in HCI research on children with ADHD are eight-year-old boys, and that of the 23 systems identified, four are games. Regarding the context in which technologies are deployed, most papers in our corpus do not specify the physical environment, i.e. the location where their contributions are deployed, but rather the context of use in the form of a situation (e.g. the Chillfish biofeedback breathing game to support relaxation [58]). Moreover, we reveal trends regarding the engagement of the care ecosystem in the design, development and user study phases of the proposed systems. We find that there are shortcomings in the involvement of the various care ecosystem stakeholders in these phases, with only five systems in our corpus considering additional stakeholders beyond children with ADHD as their target group (i.e. entire families or children and their caregivers). This contradicts the known importance and crucial role of the care ecosystem [13, 27, 49]. We also provide an overview of the results that the studies in our corpus report, thus pinpointing areas where future research could focus.

This paper contributes the following: (i) a systematic literature analysis charting the state-of-the-art in HCI literature focusing on children with ADHD, considering the role of their care ecosystem; (ii) identification of current trends and gaps that suggest how the field should move forward; and (iii) considerations for designing future systems that empower and promote the well-being of children with ADHD and their care ecosystem.

2 BACKGROUND & RELATED WORK

This section describes attention deficit hyperactivity disorder (ADHD) in more detail. We then engage with literature reviews in HCI focusing on neurodivergent populations to contextualise our work.

2.1 Attention deficit hyperactivity disorder (ADHD)

ADHD is categorised into three types: predominantly inattentive, hyperactive-impulsive, or combined presentation [25], depending on which of these characteristics is prevalent. In the inattentive presentation, the main symptoms relate to difficulties sustaining attention, which often lead to forgetfulness and distractability. In the hyperactive-impulsive presentation, children demonstrate hyperactivity, inability to sit still and restlessness. Additionally, they can have issues with excessive talking and blurting, as well as not waiting their turn in games or conversations. The combined type exhibits symptoms from both of these presentations. Furthermore, ADHD has been associated with academic underachievement, disruptive behaviours, bedtime resistance and poor self-regulation of emotions [19, 63]. To date, standard treatment for ADHD includes mainly psychosocial treatments (behavioural or cognitive-behavioural), medication treatment with stimulants (mostly methylphenidate), and their combination [51, 66, 68]. For example, psychosocial treatments for ADHD focus on the parents, the teacher, and the child, with variants of (cognitive) behavioural therapy [68], emphasising the crucial role of the care ecosystem. Behavioural therapy utilises techniques such as conditioning and reinforcement to teach desired behaviours, for instance by praising or rewarding good behaviours and eliminating unwanted ones (e.g. by allowing children to experience the logical consequences of negative behaviours) [40]. For children with ADHD, this approach can often help improve behaviour and self-control [40].

2.2 Literature Reviews in HCI focusing on Neurodiversity

Neurodiversity refers to a divergence from the norms that usually define individuals as neurotypical, expressing a variety in the human brain activity [65]. There has been an increasing interest by the HCI community in neurodiversity, particularly in building a systematic understanding of technologies for neurodivergent populations. This interest is reflected in literature reviews on neurodiversity within the HCI domain. Börjesson et al. [6] performed a systematic literature review on the involvement of developmentally diverse children in design. They found that developmentally diverse children are increasingly involved in the design process, especially children with high-functioning autism, and that the role of adults is also more prevalent than when designing with neurotypical children. Their results highlight the importance of active participation of the caregivers, teachers and therapists when designing for neurodivergent children. Another example is the work by Spiel et al. [64], who reviewed the purposes of HCI technologies for children with autism and how these discursively conceptualise their agency. They identify a focus on autism as a deficit that requires "correction", showing that these technologies do not cater to the needs of children with autism but rather embody the expectations of a neurotypical society. Baykal et al. [4] present a systematic literature review on collaborative technologies for children with special needs, demonstrating how the subject has gained traction and that the most frequently represented group is boys with autism, pointing out the need for more demographically diverse studies. Mack et al. [36] recently published a literature survey of accessibility papers in CHI and ASSETS, underlining areas that have received disproportionate attention and those that are under-served. For instance, cognitive disorders (where ADHD is categorised) account for less than 10% of the papers. These examples demonstrate the increasingly strong interest of the HCI community in understanding and designing for neurodivergent children. In combination with the prevalence of ADHD, the need emerges for an integrated understanding of how HCI has addressed the subject and for charting of possible ways to move forward towards meaningful ways to support the population and its care ecosystem.

2.3 Technology Design for People with ADHD

Sonne et al.'s [61] mapping of assistive technologies for children with ADHD, published in 2016, proposed a design framework comprising two dimensions (technology, ADHD symptom), and a set of practical design strategies. Additionally, they identified unexplored opportunities for assistive technologies for the ADHD domain, and illustrated how their design framework could be applied. Altogether, Sonne et al. [61] classified nine systems for individuals with ADHD based on i) their use at home or school, ii) their target user group (children and/or parents or adults), and iii) the functionality the assistive technology offers from a technological, information-providing point of view. More recently, Cibrian et al. [12] published a book that reviews available technologies for individuals with ADHD, with a focus on how technology has advanced in this domain. Their aim is to provide a resource for product developers to deliver a better user experience to people with ADHD, and to enable individuals with ADHD to be content-creators themselves. Further, they strive to inspire the development of new assessment, diagnostic or therapeutic tools. Cibrian et al. [12] classify interactive technology research based on the role of technology in the following domains: i) diagnosis and assessment of ADHD, ii) training cognition and attention skills, iii) social and emotional skills, iv) supporting behaviour management and self-regulation, v) supporting academic skills, vi) supporting everyday life skills and employment; and vii) improving motor skills, physical access, and physical behaviours. Additionally, Cibrian et al. [14] recently published a review of technological interventions that specifically assist in and assess the self-regulation of behaviours and emotions supporting children with ADHD. They found that such technologies are deployed within the following settings: the family (home), educational (school), and clinical, and that lab-based studies are often necessary in early development stages, e.g. to validate feasibility. They demonstrated how the different kinds of technological interventions they identified (robots, serious games, virtual reality, sensors, web-based, m-health) can provide opportunities for self-regulation of children with ADHD, offering a "safe environment" to practice behaviours and receive feedback.

We extend previous work by conducting the first systematic literature review in HCI with a focus on children with ADHD. In contrast, Sonne et al. [61] and Cibrian et al. [12] explored assistive technologies for individuals with ADHD, without specifically focusing on children. In our review, we position the child in the centre while considering the role and involvement of the care ecosystem. The role of the care ecosystem has not been addressed by previous work, despite its defining role [13, 27, 49]. Additionally, Cibrian et al.'s [14] recent review focused on technological interventions specifically for self-regulation of children with ADHD, while our review is not focused on a specific aspect that the proposed technologies aim to address. Based on our analysis, we outline current approaches in HCI with respect to: (i) the intended users of technologies for children with ADHD, (ii) their types and aims, (iii) their contexts of use, (iv) the methodological approaches employed, and (v) how and by which stakeholders they are evaluated. By analysing these aspects and the role of the various actors of the care ecosystem, we not only chart the state-of-the-art in the field, but also point out shortcomings in current approaches and provide design considerations for designing future technologies that promote the well-being of both children with ADHD and their care ecosystem.

3 METHOD

We aim to build an understanding of how current approaches support children with ADHD and their care ecosystem. To the best of our knowledge, this is the first systematic literature review in HCI focusing on children with ADHD. Our review followed an adaptation of the PRISMA statement [43], structured in four main phases:

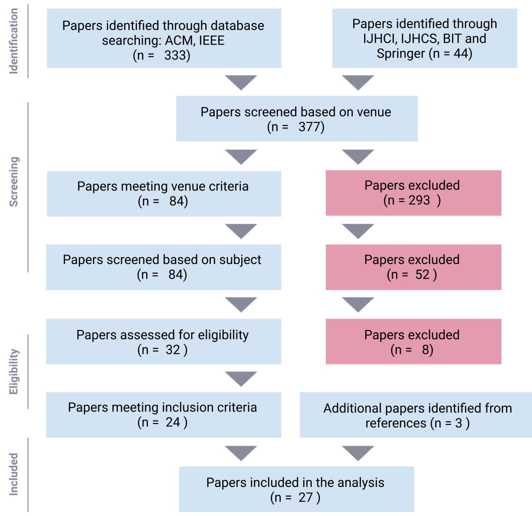

Figure 1: Adapted PRISMA statement, structured in four phases: (i) identification, (ii) screening, (iii) eligibility, and (iv) inclusion of papers.

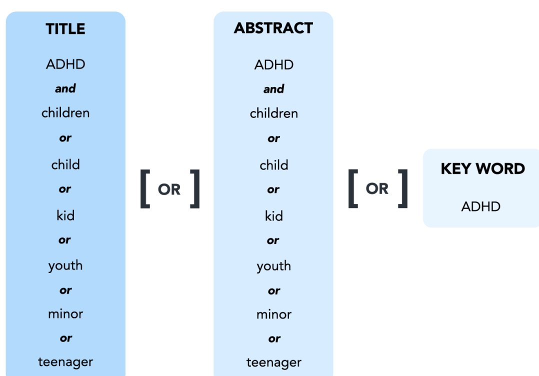

Figure 2: Visualisation of our search query.

(i) identification, (ii) screening, (iii) eligibility, and (iv) inclusion of papers (see Figure 1).

3.1 Literature Selection

All studies published in the top twenty HCI journals and conferences based on the Google Scholar Ranking [55] were analysed, similar to other literature reviews published within the HCI community (e.g. [8, 26]). The following venues were included: CHI, CSCW, Ubicomp/ISWC, HRI, IEEE TOAC, UIST, IJHCS, IEEE THMS, BIT, TOCHI, ICMI, IEEE ToH, IJHCI, DIS, UAIS, IUI, HCII, Mobile HCI, IEEE VR, and TEI. We also included the proceedings of IDC (Interaction Design and Children), CHIPLAY, and ASSETS, due to their relevance to our review. We used the ACM Digital Library and IEEE Digital Library for our search. IJHCI, IJHCS, BIT and HCII were not indexed in either of the two databases, so we searched for these on the Journals' websites and on Springer respectively.

Our search query used the terms "ADHD", and "children", and its variations (see Figure 2). In the case of the International Journal of Human-Computer Studies (IJHCS) we used the simpler query: "ADHD AND (children OR child OR kid OR youth OR minor OR teenager)", since the search engine required fewer Boolean connectors. We did not restrict the search to a specific time-frame. We concluded the research of articles in December 2021. Our search resulted in 377 papers in the identification phase. An initial screening resulted in 84 papers. We then screened the title and abstract of the 84 papers, applying the following exclusion criteria:

- Papers where the target population did not include children (aged 0-18)
- Papers where ADHD was not the sole condition of focus
- Papers not subject to peer-review
- Dissertations and theses
- Papers in a language other than English

This process led to the exclusion of 52 entries. For the remaining entries, the full-text was read and assessed for eligibility. At this stage, another eight papers were removed. Thus, a total of 60 papers were removed due to their subject and scope (e.g. papers focusing only on adults with ADHD). After this exclusion round, 24 papers remained. Upon scanning the reference lists of these papers, another three entries were added, following Wohlin's guidelines for snowballing in systematic reviews [73], resulting in a final corpus of 27 papers. The full list of the 27 articles in our final corpus, along with their publication venues and years, can be found in the supplementary material.

3.2 Coding Process

The initial category system was determined by previous work and our research questions. Based on the initial category system, all 27 entries were coded. Two authors coded a representative sample of the corpus (16 papers). This was followed by a discussion to resolve disagreements and resulted in a refined category system. One author then coded the rest of the material.

4 RESULTS

The following section presents the results of our analysis, structured according to the categories and associated codes identified. For an overview see Table 1, as well as Table 2 and Figures 8, 9 for user study data. We start with a demographic overview of our corpus, and then discuss our findings based on our category system. We provide a detailed description of the identified categories: (i) *target group characteristics*, (ii) *involvement (both in the design & development and user study phases)*, (iii) *context of use (including location and situation contexts)*, (iv) *contributions (with respect to the overall contribution of the research, the type of technology if applicable, and the objective of the research)*, (v) *methods used and user study data* of the papers in our corpus, and (vi) *the measures* of the studies reported in our corpus.

Table 1: The applicable coding categories for each paper in our corpus.

Category	Codes & respective papers
Target group	Children with ADHD [3, 7, 9–11, 15, 18, 37, 41, 47, 56, 58, 59, 63, 67, 70, 75, 76], Children with ADHD-I and -C [32], Children with ADHD-HI and -C [31], Children with ADHD and their families [46, 60, 62], Children with ADHD and their caregivers [17, 61], Caregivers of children with ADHD [24], Not clear/not specified [42]
Involved in design & development	Children with ADHD [7, 15, 17, 18, 60, 63, 67, 70, 75, 76], Experts [3, 7, 10, 31, 46, 47, 58–60, 62, 63, 70, 75, 76], Parents of children with ADHD [46, 60, 62, 70, 75, 76], Caregivers [15, 17, 47, 63, 67], Children not diagnosed with ADHD [47], Not clear/not specified [9, 11, 24, 32, 37, 41, 56], Not applicable [42, 61]
Involved in user studies	Children with ADHD [7, 9, 31, 32, 47, 56, 59, 60, 62, 63, 70, 76], Experts [3, 9, 31], Parents of children with ADHD [7, 31, 47, 60, 62, 70, 76], Caregivers [9, 24, 56], Adults not diagnosed with ADHD [24, 56, 58], Children not diagnosed with ADHD [11, 37, 63], Future evaluation plans [10, 41], No study reported [15, 17, 18, 46, 67, 75], Not applicable [42, 61]
Methods	User requirement elicitation [18, 46, 63, 70, 75, 76], Focus group [15, 18], Brainstorming [18], Prototyping [18, 58, 67, 70], Workshop [15, 17, 67], Questionnaire [47, 60, 76], Personas & scenarios [17], Lab study [3, 9, 10, 24, 31, 37, 56, 58, 59, 62], Field study [7, 11, 32, 56, 62, 76], Post-experience interviews [9, 31, 47, 56, 59, 60, 62, 76]
Context of use: situation	Execution of morning routines [70, 75, 76], Execution of morning & bedtime routines [60, 62], Execution of daily home routine [46], Understanding ADHD [24], Going to sleep [61], Calming down [58, 59], Assistance in healthcare, school, and socialisation contexts [67], Self-regulation (e.g. mood, reflection, emotion) [15, 17, 41, 67], Neurofeedback therapy [3], Learning (e.g. mathematics instruction, e-learning, in school) [10, 32, 37, 63], Regaining Attention [63], Controlling impulsive speaking [56], ADHD assessment [31, 42], Multiple contexts specified [7], Not clear/not specified [9, 11, 47]
Context of use: location	Home [46, 60–62, 70, 75, 76], School/classroom [32, 41, 42, 56, 63], Multiple contexts specified (e.g. home, shower, school, clinic) [7, 18], Online learning environment [10], Not specified [3, 9, 11, 15, 17, 24, 31, 37, 47, 58, 59, 67]
Contribution type	Design guidelines, considerations or insights [9, 15, 58, 60, 61, 63, 67, 70, 75], System, tool or algorithm [3, 7, 10, 11, 17, 18, 24, 31, 32, 37, 41, 42, 46, 47, 56, 58–63, 70, 76]
Technology type	Tangible [70, 75, 76], Mobile [17, 46, 58–60, 62], Biofeedback [11, 58, 59], 3D-printing [31], Brain-Computer Interface [3, 47], Wearables [15, 17, 18, 31, 56, 63, 67], Voice-bot [46], Neurofeedback [3, 41], PC software [24, 32, 37], Touch screen [31], Tablet [7], Machine Learning Model [10, 42], Haptic Feedback [18], Virtual Reality [11]
Objective	Executive functioning [70], Calming down by breath control [58, 59], Morning routines [75, 76], Morning & bedtime routines [60, 62], Avoid blurting [56], Self-regulation (behaviour, emotions) [15, 17, 41], Daily routine tasks [46], Social motivation [3], Adherence to therapy [3], ADHD assessment [31, 42], Improve or regain attention and time on task [11, 32, 37, 47, 63], Conceptualise and tell time [18], Detect or predict attention [10, 37], Foster understanding of ADHD [24], Support therapeutic work [9], Reading ability [47], Improve behaviour inhibition [47], Sleep assistance [61], Improve learnability [7]
Measures	Effects on ADHD-related states & traits [11, 47, 56, 60, 62, 63, 76], System usability [7, 9], Intermediate evaluation [3, 24, 31, 32, 37, 56, 58, 63, 70], General perception (feedback, satisfaction, acceptance) [9, 56, 59, 76]

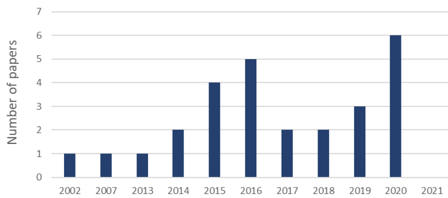

Figure 3: Number of papers according to year of publication.

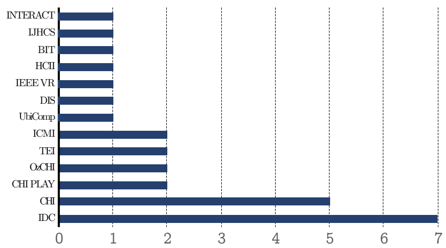

Figure 4: Distribution of papers across venues.

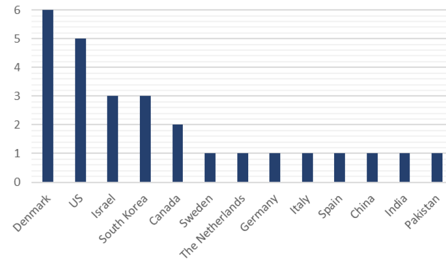

Figure 5: Geographical distribution of the papers.

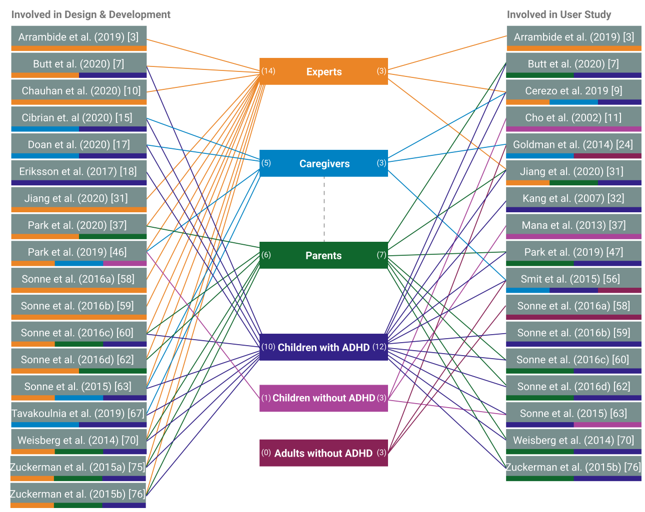

Figure 6: Identified stakeholders involved in design, development and user study phases.

4.1 Distribution per Year, Venue and Region

Figure 3 visualises the number of papers focusing on children with ADHD based on our corpus. Remarkably, regular annual publications only started in 2013, and from the 27 identified papers, 22 were published after 2015. This underlines the relatively new-found interest of the HCI community in the area, deeming pertinent research timely and of high importance. Interestingly, after applying our inclusion criteria to the retrieved articles from 2021, no publications remained. Looking at the distribution of the selected papers across different venues (see Figure 4), the most represented conferences are Interaction Design and Children (IDC) and the ACM Conference on Human Factors in Computing Systems (CHI), with seven and five entries respectively. The geographical distribution of the papers is shown in Figure 5. To determine this aspect, we scanned the articles for the affiliation of the first authors and information about the study location (if specified). In case of inconsistencies, we additionally cross-checked that information with any details on the funding agency in the Acknowledgements. The majority of papers in our corpus are from Denmark, with six entries, and from the US with five. With regards to continents, Asia is the only continent represented besides Europe and Northern America. As the number of research submissions per country varies, this should be considered as an influencing factor on this statistic.

4.2 Intended Users and Involvement of Care Ecosystem Stakeholders

Out of 27 papers, only five include stakeholders of the care ecosystem in their target user group. In particular, three include the family of children with ADHD, while two include caregivers. Instead, the majority of publications focus solely on children with ADHD (18/27). This is interesting taking into account the outlined importance of the care ecosystem of children with ADHD [13, 27, 49]. Additionally, the majority of papers do not specify the type of ADHD they focus on, with only two specifying that they focused on either the inattentive and combined [32], or the hyperactive/impulsive and combined presentations of ADHD [31]. Further, one paper [24] did not target children with ADHD but rather people surrounding them, aiming to promote understanding of the condition, and one paper [42] did not specify the user group, as it presented an ML model for predicting ADHD risk from touch interaction data. In this category, each paper is associated with a distinct code. It is worth clarifying that we coded "caregivers" as a wider category than family; in particular, we coded for family or parents when other caregivers were not included, and for caregivers when at least one of the following groups were involved in addition to the family: teachers, or school staff. Moreover, in this context "experts" includes one or more of the following groups: (children) psychiatrists, (educational) psychologists, medical doctors or researchers, clinicians, or special needs educators.

HCI theory emphasises the importance of considering various stakeholders in the design, development and evaluation process of technologies [53]. To examine how this was implemented by the papers in our corpus, we coded the groups that were involved in the design and development of the proposed systems, as well as who was involved in the study processes reported in the papers (second and third row of Table 1). As we found that sometimes different groups were involved in the design and development phase from the user study, we split these into two separate sub-categories. Our results show that fewer than 50% of the papers included children with ADHD in each phase, with 10 papers including them in the design and development phase, and 13 papers in the user study phase. Regarding other actors of the care ecosystem, a notable decrease in the number of experts can be observed from the design and development to the user study phase, with only three out of the 27 papers involving experts in their studies.

Figure 6 demonstrates the identified stakeholder groups and their involvement by the papers in our corpus across the design and development and user study phases. Note that parents constitute a sub-group of caregivers. We applied the code "parents" when only the parents were involved, and the code "caregivers" otherwise. We can observe that the maximum number of different groups involved at a certain phase was three. Also, while some papers used the same group of people in both phases (e.g. Arrambide et al. [3], who used experts), others used completely different groups in the two phases (e.g. Sonne et al. [58], who involved experts in the design and development phase, and adults without ADHD in their study). However, none of the papers in our corpus involved all six identified groups in any phase.

4.3 Types of Technologies, Objectives, and Contexts of Use

The first coding phase led us to two separate codes for the context of use: location, and situation, as can be seen in the respective rows in Table 1. To illustrate, Sonne et al. [58], developed a tangible biofeedback game meant to calm down children with ADHD before going to bed, after an emotional outburst or due to a stressful situation. However, the location of use is not specified, as going to bed can take place in a number of places besides the apparent choice of "at home", such as at a relative's place or at a hotel during holidays. Therefore, this entry along with 12 others does not have a specified location of use, while two papers mention use in multiple contexts. Other identified locations of technologies developed for the benefit of children with ADHD are the home (7/27), the school/classroom (5/27) and an online learning environment (one paper). The most commonly occurring situations of use include (i) self-regulation, e.g. with a focus on mood, reflection, emotion (4/27), (ii) learning, such as mathematics instruction (3/27), and (iii) the execution of morning routines (3/27).

We also analysed the papers in our corpus with respect to their contribution types, the technologies they proposed, when applicable, and the objectives they put forward (codes "Contribution type", "Technology Type", and "Objective" of Table 1). We identified two main types of contributions: (i) papers that contribute design guidelines, considerations or insights (9/27), and (ii) papers that contribute systems, tools or algorithms (23/27). As these numbers indicate, five papers contribute both a system and guidelines [58, 60, 61, 63, 70]. As can be seen in Table 1, various technologies have been employed in the context of assisting and supporting children with ADHD. The most commonly used technology appears to be wearables (e.g. smart watches) and mobile applications, with seven papers each. Some systems belong in more than one category, i.e. they employ more than one of the identified technology types. For instance, Chillfish by Sonne et al. [58] is a tangible biofeedback game, thus encompassing two codes (Tangible and Biofeedback). Another key aspect is the objective each paper aims to achieve. Most papers in our corpus aimed to help children with ADHD improve or regain their attention and time on task (5/27) or assist them in self-regulating their behaviour and emotions (3/27). Finally, we found that five papers contributed some sort of gamified system. All games presented in our literature review address the training of specific characteristics of children with ADHD: (i) getting the child to calm down via breath control, (ii) increasing adherence to therapy regimens and encouraging social motivation, (iii) improving reading ability, sustained attention and behavioural inhibition. We found no games in the literature search with a ludic purpose, whose primary goal was not addressing a specific challenge associated with ADHD.

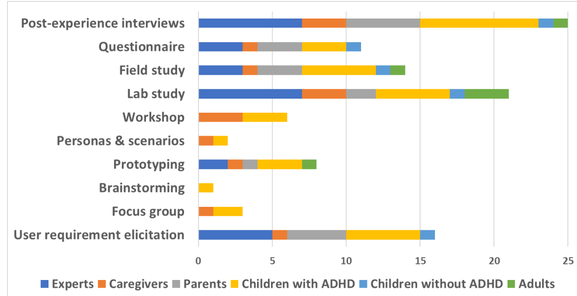

Figure 7: Number of stakeholders from each group involved in each of the identified methods.

4.4 Methods, User Study Data, and Evaluated Measures

Understanding the methods the papers in our corpus used, how they conducted their studies, and what measures they evaluated was an integral part of our work. The majority of the papers in our corpus conducted one or more user studies (20/27). If we look at the methods the papers in our corpus applied, the most common are conducting lab studies (10/27), using post-experience interviews (8/27), eliciting user requirements (6/27), and performing field studies (6/27). One article reported utilising brainstorming techniques [18], and one other reported creating personas and scenarios [17]. Interesting correlations can be drawn from Figure 7. For instance, most parents are involved in the user requirement elicitation phase of design as well as in post-experience interviews. At the same time, over 50% of participants in lab studies reported in our corpus are experts, adults without ADHD, or children without ADHD. The most commonly used method when children with ADHD are involved are post-experience interviews. Finally, we can see that methods such as workshops, personas & scenarios, brainstorming and focus groups have shortcomings with respect to the diversity of groups authors involved (e.g. only children with ADHD were involved in brainstorming).

Table 2 shows the participants reported by the user studies in our corpus. We analysed the reported number and kind of participants, the number of children participants, as well as their gender, when available. In the cases where the user studies were comprised of multiple phases, the numbers were summed up to reflect the total number of participants. Seven studies did not report the number of at least one user group involved in the study, e.g. Butt et al. [7] did not specify the number of parents, while Cerezo et al. [9] did not mention the number of participating educators. Sonne et al. [60, 62] mention "the family" as participants, without specifying its size or structure. We report on participants for the two papers by Sonne et al. [60, 62] together as this work by Sonne et al. [60] is a follow-up of another paper by Sonne et al. [62]. However, it should be noted that the follow-up study [60] did not specify the gender of participants. Regarding gender, four papers did not specify the number of boys and girls that took part in their studies ("NA" in Table 2). For instance, Sonne et al. [63] reported the gender for only a subset of their participants (for 8/20 children who participated in the second out of three studies reported). With regards to participants' ages, we report those of children taking part in the studies, and not any adults. In any of our sources, the age, or even the number of participating adults were rarely reported, e.g. Tavakoulnia et al. [67] specify that 24 students participated in their study, but do not mention the number of teachers and school staff who took part. As can be seen in Figure 8, the most represented group are boys aged between seven and twelve, with the majority of papers reporting participants of the age of eight. While there are a few papers concerning teenagers up to the age of 18, we found no articles that reported studies with children of five and under. Regarding the study types, the majority used mixed methods (16/27); seven papers reported on qualitative studies, two on quantitative, and for two this distinction was not applicable (see Figure 9). In particular, the user study from Park et al. [46] is described as future work, and in Sonne et al. [61] the system is only proposed as an idea.

For the 20 papers that included user studies, we analysed the measures they applied. Based on this analysis, we identified four different foci: evaluating (i) the effects on ADHD-related behaviours, (ii) system usability, (iii) the general perception (feedback, satisfaction, acceptance) of systems; and (iv) intermediate evaluations, which relate to feasibility or suitability of systems (penultimate row in Table 1). Despite the lengthy list of objectives that the papers in our corpus presented, many studies ultimately focus on initial design validations or usability evaluation. For instance, we classified the works from Sonne et al. [63] and Smit et al. [56] both under the "intermediate evaluation" code, as well as evaluating effects on ADHD-related states & traits, as they both consisted of more than one study phase. Smit et al. [56] aimed to assess their system's (BlurtLine) most suitable placement on the body, and its suitability to recognise breathing patterns in adults in a lab study. Then, they performed a field study to gain first insights into the child's experience of wearing BlurtLine to regain control of their blurting behaviour, determine whether the child or teachers derived any benefit from it, and gain insight into whether child, teachers or parents experienced moral concerns regarding its use. They found that the most comfortable and suitable placement of BlurtLine was worn on the chest and identified positive experiences by child, mother and teachers. Additionally, the signals from BlurtLine were described as clear and non-invasive, although sometimes too present due to their frequency. Children using BlurtLine did not mind wearing it, and the caregivers expressed no concerns if the system helps the child. Therefore, this work also belongs in the evaluating "general perception" code, as they looked at users' acceptance of the system. The work by Cerezo et al. [9] is coded as both evaluating system usability and users' general perception to their tangible tabletop activities with children with ADHD. They show that the activities and interactions seem to be quite usable for children with ADHD, who played with their tabletop without any difficulties, showed their satisfaction, and could complete the activities. Their educators gave positive feedback regarding the tabletop system's potential, notwithstanding some aspects of the activities that could be better tailor-made for children with ADHD.

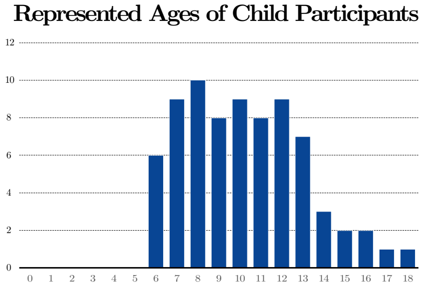

Figure 8: Number of papers for each age.

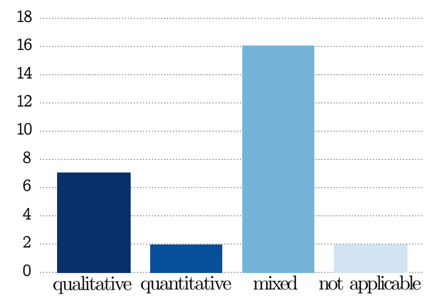

Figure 9: The types of the studies reported in our corpus.

5 DISCUSSION

In this research, we analysed how past HCI papers approached designing technologies for children with ADHD. To that end, we conducted a systematic literature review. The main lens under which we examined the papers in our corpus was the care ecosystem of children with ADHD. Analysing the available literature under this lens, and in particular charting the involvement of the various care ecosystem actors in current approaches, revealed several trends as well as opportunities for further research that can be used to inform the design of future technologies.

Engaging (with) the care ecosystem. Despite the defining role of the care ecosystem [13, 27, 49] and the known importance of involving relevant stakeholders in research, current approaches entail limited engagement of both children with ADHD and their care ecosystems. We found that the care ecosystem of children with ADHD is not sufficiently involved in the requirements elicitation, design, development and evaluation of technologies that are designed to benefit children with ADHD *(RQ1)*. Therefore, the

Table 2: User study participants: reporting trends.

Paper	Participants	Children	Boys	Girls
Arrambide et al. (2019) [3]	5 neuropsychologists	0	0	0
Butt et al. (2020) [7]	5 children w/ ADHD, unsp. N parents	5	3	2
Cerezo et al. 2019 [9]	unsp. N educators, 1 system expert, 1 psychologist	36	33	3
Cho et al. (2002) [11]	50 teenagers	50	NA	NA
Goldman et al. (2014) [24]	28 caregivers	0	0	0
Jiang et al. (2020) [31]	100 children (50 w/ ADHD), unsp. N of parents & doctors	100	42 w/ ADHD, 35 w/o	8 w/ ADHD, 15 w/o
Kang et al. (2007) [32]	27 children (18 w/ ADHD)	27	NA	NA
Mana et al. (2013) [37]	4 children w/o ADHD	4	2	2
Park et al. (2019) [47]	5 children w/ ADHD, unsp. N parents	5	5	0
Smit et al. (2015) [56]	7 adults w/o ADHD, 1 child w/ ADHD, 1 mother, 1 teacher	1	1	0
Sonne et al. (2016a) [58]	16 adults w/o ADHD	0	0	0
Sonne et al. (2016b) [59]	3 children w/ ADHD	3	NA	NA
Sonne et al. (2016c) [60] Sonne et al. (2016d) [62]	11 families (size unspecified), including 13 children w/ ADHD	13	9	4
Sonne et al. (2015) [63]	20 children (11 w/ ADHD)	20	5	3
Weisberg et al. (2014) [70]	6 child-parent pairs	6	4	2
Zuckerman et al. (2015b) [76]	2 children w/ ADHD & their mothers	2	1	1

need arises for a more **active involvement of these actors in designing technologies** that are intended for use by them. One way towards this could be to actively employ Participatory Design (PD) when designing for this population. PD has a long history of involving vulnerable, disadvantaged or marginalised groups of people in the design processes of technologies. However, involving neurodiverse children, such as children with ADHD, in design can give rise to particular challenges that require adaptations to participatory methods [22]. For instance, the amount of required time can increase, as participants might need longer than usual to get to know each other, both with respect to trust establishment as well as (body) language and communication [28]. Nevertheless, the benefits of PD are well-established, and researchers have successfully involved both neurotypical and neurodiverse children towards meaningful design processes. For instance, Benton et al. [5] developed a framework for designing with neurodiverse children, focusing on empowering them by structuring the environment and offering additional support. **Involving more members of a child's care ecosystem in a PD process could also be a way to mitigate some of the challenges of actively involving children with ADHD in the design process**; for instance, including their siblings or best friend could offer additional support. However, only three papers in our corpus employed PD. Tavakoulnia et al. [67] conducted workshops with children with ADHD and their teachers to explore the acceptability of wearables, by sketching prototypes. Cibrian et al. [15] performed PD workshops with children with ADHD and their caregivers towards designing wearable applications supporting their self-regulation. Eriksson et al. [18] employed an iterative PD process with students diagnosed with ADHD, including brainstorming, prototyping, and prototype evaluation, to elicit user requirements in a small focus group setting. Future work should **increase the involvement of the care ecosystem, e.g. by employing PD, involving both children with ADHD and as many stakeholders of their care ecosystem as possible**. Additionally, future work could **perform meta-analyses to explore the effect of the care ecosystem's (increased) involvement on outcomes**.

We also found that the target users of developed systems rarely include multiple actors (i.e. more than one at the same time) of the care ecosystem *(RQ1)*. Accommodating more than one actor of the ecosystem would match closer to a real life situation, where the involvement of the various actors is active and spans layers and contexts, such as a parent having the additional role of a tutor when helping a child struggling with homework. Thus, researchers could **explore technologies where the target users span multiple layers of the care ecosystem, i.e. address various stakeholder groups at the same time. While challenging, it appears to be crucial to not look at technologies as self-contained entities, but to address the inherent interconnectedness between children, ecosystem and technology already in the design process**. Furthermore, our findings with respect to target user groups show that the majority of HCI research does not specify the type of ADHD for which they design (only two papers [31, 32] in our corpus reported ADHD types) *(RQ1)*. Here, the question arises whether or in which cases (e.g. intervention type) future research works in HCI should specify the type(s) of ADHD they design for; namely, to determine whether there is a need to design for specific types, or if there is another way forward. This multidisciplinary question could be the subject of future discussions between ADHD professionals and HCI researchers.

Fostering play & empowerment. A limited number of HCI literature introduces technologies for children with ADHD that focus on play and games (five papers, four distinct games). Their goal is to improve executive functioning. We did not find any papers that focused on designing for ludic play, while only three papers in our corpus considered aspects related to empowerment *(RQ2)*. In particular, two papers (MOBERO system [60, 62]) aim to promote the independence of children within the context of their morning or bedtime routines, and one aims to facilitate acceptance of ADHD [24]. Similar to their neurotypical peers, engaging in playful activities is of the utmost importance for children with ADHD, as play has a defining role in their learning [69] and development process [23, 44]. Furthermore, play facilitates the stimulation of various aspects of functional brain development such as social and communication skills, emotional regulation, and cognitive and physical abilities [35, 39]. However, children with ADHD often have a hard time making friends [29, 30]. These social difficulties, which are very common [29], can lead to feelings of rejection [30], hindering empowerment. For instance, hyperactive and impulsive behaviours, like not waiting one's turn in a game, can contribute to overbearing social behaviour leading to peer aversion [72]. **Designing technologies that aim to facilitate ludic play between children with ADHD and their peers is one example of how HCI researchers could help in that direction**. A pertinent example is the work by Frauenberger et al. [22], who explored social play technologies that aim to scaffold and support co-located play for neurodivergent children. ADHD researchers and designers could benefit from this knowledge and **further explore how to facilitate connectedness and social play between children with ADHD and other groups, and what outcomes that could deliver**. As already discussed by Spiel et al. [64] with respect to technologies for individuals with autism, there is a need for future systems that **not only focus on addressing specific ADHD-related symptoms, but enable children with ADHD to feel more included and accepted, and promote their independence and self-sufficiency**. This would not only empower the children themselves, but could also have a positive effect on their parents' well-being (e.g. by decreasing the frustration and stress levels of parents by increasing the children's autonomy). Therefore, future work could **empower children with ADHD along with their care ecosystem, by designing technologies that give them agency while at the same time facilitating collaboration between them and the various care ecosystem members**.

Engaging with different contexts. We found that the context of use of technologies for children with ADHD is sometimes defined in the sense of physical space, i.e. location, and sometimes in terms of situation. For instance, one study focused on helping children calm down regardless of their location *(RQ2)*. This is partly in-line with Cibrian et al.'s [14] findings regarding the context of use for technological interventions for children with ADHD for self-regulation. In particular, they found that almost half were targeted for use in schools, and 16% for use at home, while the rest did not specify the context. Interestingly, we found an almost equal number of technologies for use at school and at home. However, the environment (comprising both physical and social aspects) can play a defining role in the behaviour of children with ADHD [1]. In particular, children with ADHD may exhibit different behaviour across different contexts, which is actually a prerequisite for an ADHD diagnosis; in more detail, a list of symptoms must impair daily functioning in *two or more settings* to merit a diagnosis [1]. The studies in our corpus did not report on the effect of context on their findings and did not comparatively examine their results under different contexts. In more detail, regarding the location, the majority of the papers studied one context of use (e.g. home *or* school), with the exception of two studies where multiple contexts were specified. Similarly for the situation of use, only one paper specified multiple situations of use [7]. However, the effect of the context was not taken into account in any of the above cases. Given the importance of the environment, **consciously defining the context of use concerning the two identified dimensions of location and situation should be undertaken when designing future systems**. Additionally, future work could **examine the effects of the context of use by evaluating the same technological artefact or intervention under different settings, and exploring how this might impact behaviours and outcomes through comparative studies**. Since children with ADHD can exhibit different behaviours based on the environment, this could potentially lead to trends regarding which type of technological interventions are more suitable and effective, depending on the setting in which they are deployed.

Moving beyond initial validations and establishing reporting standards. Many user studies in our corpus focused on initial design validations or usability evaluations, despite originally presenting a lengthy list of goals of their proposed approaches *(RQ3)*. This is in-line with previous findings from Cibrian et al. [14] who found that technologies supporting self-regulation for children with ADHD are usually suspended in the design and prototyping phases, and from Cibrian et al. [12] who noted this "gap in translation" from design to adoption. Of course, preliminary studies and lab experiments are necessary steps in the design process of technologies, which also applies in the case of technologies for children with ADHD [14]. Based on our findings regarding measures, the majority of papers in our corpus that focused on initial validations (10/16) employed methods such as lab studies (7/10) or interviews (4/10). On the other hand, papers that went on to assess the effect of their systems on ADHD-related symptoms (7/16), which goes beyond an initial validation, mostly conducted field studies (4/7) as well as interviews (4/7). **Therefore, conducting more field studies, e.g. after preliminary lab studies, could be a way towards moving beyond initial validations**. Additionally, there was a lack of consistency among the various studies reported in our corpus with respect to reported data *(RQ3)*. For instance, some papers mention including "the family" in a study without specifying the family members (size, roles and age). Moreover, the list of studies where it is not made clear who participated in the design and development phase is lengthy, as can be seen in Table 1. Further, the age and the number of participating adults were rarely reported. This lack of information can hinder future researchers in the area, as there is not a clear picture of the manner in which previous studies engaged with members of the care ecosystem. This further underlines the need for researchers to consider the care ecosystem throughout their research process, including reporting the results of their studies. Therefore, future work could aim to **establish more consistent reporting standards, as well as delve into more long-term research in specific systems, e.g. by conducting more field-studies, thus moving beyond preliminary evaluation iterations towards more complete systems**.

Our work constitutes a first step towards understanding the design space of technologies for children with ADHD and their care ecosystem. Yet, we recognise that our approach is prone to certain limitations. It has to be noted that we focused on HCI literature, thus excluding some research on children with ADHD due to their publication venues. ADHD is a multidisciplinary subject that spans various research fields, including Psychiatry, Medicine, and Psychology, and reviewing the entire literature available on the subject was beyond the scope or purpose of this review. Nevertheless, this paper constitutes an effort to provide a first step towards understanding where we, as an HCI community, stand, and how we can move forward when designing for children with ADHD. Additionally, our defined inclusion criteria of papers introduces a limitation, as they led to the exclusion of papers that e.g. did not focus on ADHD. For instance, we did not include the work from Mandryk et al. [38], which presents a system that turns regular games into biofeedback games, aiming to promote self-regulation of children with Fetal Alcohol Spectrum Disorder (FASD). The system addresses symptoms of FASD that can be present in ADHD as well; however, it did not meet our inclusion criteria about ADHD being the sole focus of the research, and thus we did not include it in the final corpus. This decision was made in order to ensure that the focus of our review remained on ADHD, especially given the fact that other, often co-morbid conditions (e.g. autism) have attracted more research until now. Finally, it is worth noting the lack of identified papers based on our search criteria for the year 2021. Perhaps a defining factor has been the COVID-19 pandemic, which has restricted access to children as participants for studies. Engaging with both neurotypical and neurodivergent children without being physically present poses various challenges, and researchers might be reluctant to potentially impose additional strain on vulnerable families during this global crisis. Pecor et al. [48] already found that caregivers of children with ADHD and/or autism have been disproportionately affected by the pandemic. Given the importance of the subject and the interest of the HCI community, future work could aim to address aspects of how to conduct studies with neurodivergent children, such as children with ADHD, in times where these have to be conducted remotely.

6 CONCLUSION

This systematic literature review on children with ADHD is based on a sample of 27 out of a total of 377 papers identified. The aim of this paper was to understand how the HCI community has supported children with ADHD, especially considering their care ecosystem. Our analysis resulted in findings in the following categories: (i) the characteristics of the target user group(s) of the papers in our corpus, (ii) the involvement of various care ecosystem stakeholders in the design, development and user study phases, (iii) the methods used by the papers in our corpus, (iv) the context of use of the proposed technologies in terms of location and/or situation where they are deployed, (v) the papers' contribution, the technology type when applicable, and their objective in terms of envisioned support, and (vi) how the proposed approaches were evaluated by the authors in terms of measures and results reported. To stimulate further research, we discuss how to engage multiple stakeholders of the care ecosystem in future approaches. Further, we encourage an increased attention to developing games for children with ADHD which are simply designed to be fun rather than to alleviate certain symptoms, additionally facilitating connectedness and social play. We discuss why and how to engage with different contexts of use, and how to move beyond initial validations. In addition, our analysis showcases the importance of consistent reporting standards in user studies. We hope that our review will inspire further HCI research in technologies for children with ADHD. We aim to pinpoint a variety of starting points to address this most common mental health diagnosis in children in research and design.

7 SPECIAL NOTE ON ETHICS AND CHILDREN

No children participated in this work.

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