University
of Bremen

DESIGNING FOR DIVERSE NEEDS:

Technology-supported Well-being and Empowerment of Children and their Care Ecosystem

submitted by

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To my family and to all the incredible children I
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Declaration

I hereby declare that except where specific reference is made to the work of others, the contents of this dissertation are my original work. This entails both textual as well as graphical content in support of this manuscript. No portion of this work has been submitted in support of an application for another degree or qualification of this or any other university or institution of higher education. I hold the University of Bremen harmless against any third-party claims with regard to copyright violation, breach of confidentiality, defamation and any other third-party right infringement.

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Abstract

In our increasingly digitised society, children are interacting with a range of technologies from a very young age. These interactions can both procure benefits, including new learning opportunities, as well as pose risks, such as increasing social anxiety. Concurrently, many of these technologies are not necessarily designed for children's use (e.g. social media). Therefore, there is a need to investigate both the impact of these interactions on children's well-being, as well as how these technologies are designed. At the same time, as adults often dictate not only children's use of technology, but also the nature of their participation in its design and evaluation, a critical aspect here is that of the power dynamics between them. These power imbalances are particularly pronounced for neurodivergent children, such as those with attention deficit hyperactivity disorder (ADHD), as children's neurodevelopmental diagnoses and adults' perceptions of which technologies can be beneficial can heavily influence children's interactions with technology. Therefore, this thesis argues for the need to create technologies that empower both neurotypical and neurodivergent children by allowing their perspectives to shape the technologies they use, as well as by increasing their agency in interacting with technology in order to support their well-being.

Contributing to the evolving narrative in HCI of designing meaningful interactions, this thesis investigates how to design for both the well-being *and* empowerment of children and their care ecosystem, considering their diverse interests and needs. Children's care ecosystems comprise the stakeholders involved in their everyday experiences, including family, friends, teachers, and therapists. To that end, the work in this thesis actively involves both children and their care ecosystem members in technology design, evaluation, and use. This research particularly focuses on children with ADHD, a group which has been under-explored compared to children with other diagnoses, such as autism, despite ADHD being the most prevalent neurodevelopmental diagnosis in children. Contrary to the majority of prior research, this work explores how to design "beyond symptoms", creating technologies without aiming to address specific symptoms, but rather the interests and needs of ADHD children. Furthermore, the research presented in this dissertation designs a range of such technologies and investigates the interactions of children and of various members of their care ecosystem with them. Therefore, the primary research question (RQ) guiding this thesis is: *How can technologies be designed to empower and support the well-being of both ADHD and neurotypical children and their care ecosystem?*

As a cumulative dissertation, this thesis consists of three parts: Part I elaborates on the motivation, presents background and core concepts, and introduces the research gaps that motivate the three RQs into which the primary RQ is subdivided. Part II includes the six papers that constitute the core of this thesis. Each of these papers addresses one or more of the RQs, and targets different constellations of ADHD and/or neurotypical children and members of their care ecosystem. In this way, various aspects of technologies that aim to empower them and support their well-being are explored, such as emotional expression and reflection. The first two papers contribute to a fundamental conceptual understanding, upon which the

remaining four papers build. Each of these four papers designs a different prototype and investigates its impact on children and their care ecosystem. To that end, different methods are employed, including interview studies, co-design sessions, focus groups, prototype evaluations, user studies, and field studies. Part III offers a comprehensive discussion, reflecting on the research questions answered and highlighting the main implications of this work. The thesis concludes by critically discussing unanswered questions, elaborating on both existing limitations as well as potential for future research, and reflecting on ethical considerations, and ultimately ends with a conclusion summarising this work.

Overall, this thesis contributes to researchers' and designers' understanding of the various strategies and aspects that technologies can employ to empower and support the well-being of both ADHD and neurotypical children and their care ecosystems. Moreover, it presents the design and evaluation of various prototypes that use these aspects while investigating their impact on the well-being and empowerment of children and their care ecosystem. It additionally proposes a new agenda for ADHD technology research that designs "beyond symptoms" and advocates for the active inclusion of multiple care ecosystem stakeholders as users and as technology co-constructors. Finally, this thesis provides a refined understanding surrounding both the individual and collaborative technology-supported emotional expression and reflection processes with which children and their care ecosystem can engage, with the ultimate goal of fostering their well-being.

Zusammenfassung

In unserer zunehmend digitalisierten Gesellschaft interagieren Kinder von klein auf mit einer Vielzahl von Technologien. Dieser Umgang bietet Risiken, wie die Zunahme sozialer Ängste, aber auch Vorteile, darunter neue Lernmöglichkeiten. Gleichzeitig sind viele Technologien aber nicht für die Nutzung durch Kinder konzipiert (z. B. soziale Medien). Aufgrund dessen ist es notwendig, sowohl die Auswirkungen von Technologien auf das Wohlbefinden von Kindern als auch den Entwicklungsprozess dieser Technologien zu betrachten. Da Erwachsene oftmals sowohl den Umgang von Kindern mit Technologien bestimmen, als auch deren Beteiligung im Entwicklungsprozess, entstehen hier kritische Machtverhältnissen zwischen beiden Parteien. Dieses Ungleichgewicht ist besonders ausgeprägt bei neurodivergenten Kindern, wie solchen mit Aufmerksamkeitsdefizit-/Hyperaktivitätsstörung (ADHS). Diese neuroentwicklungsbedingte Diagnose und dessen Wahrnehmung seitens der Erwachsenen, welche Technologien förderlich sind, beeinflussen stark den Umgang der Kinder mit diesen Technologien. Daher argumentiert diese Arbeit für die Notwendigkeit sowohl neurotypische als auch neurodivergente Kinder und deren Perspektiven im Gestaltungsprozess von Technologien zu integrieren, um deren Befähigung und Wohlbefinden zu fördern.

Um einen Beitrag zu den kontinuierlichen Bestrebungen hin zu sinnvollen Interaktionen im Bereich Mensch-Computer-Interaktion (HCI) zu leisten, untersucht diese Dissertation, wie Technologien gestaltet werden können, die Kinder sowohl befähigen als auch deren Wohlbefinden fördern, insbesondere unter Berücksichtigung ihres Betreuungsumfelds und dessen vielfältige Bedürfnisse und Interessen. Dieses Betreuungsumfeld umfasst Personen aus dem Alltag der Kinder, einschließlich Familie, Freunde, Lehrende und Therapierende. Aufgrunddessen bindet diese Arbeit diese Personen aktiv in die Prozesse des Designs, der Evaluierung und der Nutzung der Technologien ein. Dabei konzentriert sich diese Forschung insbesondere auf Kinder mit ADHS, die trotz der am häufigsten vorkommenden neuroentwicklungsbedingten Diagnose, im Vergleich zu Kindern mit anderen Diagnosen, wie Autismus, nur wenig erforscht wurden. Im Gegensatz zum Großteil vorheriger Forschungsarbeiten, die sich auf spezifische Symptome beschränken, untersucht diese Arbeit, wie Technologie „über die Symptome hinaus" gestaltet und Interessen und Bedürfnisse von ADHS-Kindern berücksichtigt werden können. Darüber hinaus entwickeln wir eine Reihe solcher Technologien und erforschen dessen Umgang durch Kinder und Mitgliedern ihres Betreuungsumfelds. Hieraus begründet sich die Hauptforschungsfrage: *Wie können Technologien gestaltet werden, um sowohl ADHS- als auch neurotypische Kinder und deren Betreuungsumfeld zu ermächtigen und deren Wohlbefinden zu fördern?*

Als kumulative Dissertation besteht diese Arbeit aus drei Teilen: Teil I erläutert die Motivation, präsentiert Hintergrundinformationen und Kernkonzepte und führt die Forschungslücken ein. Diese motivieren die drei Forschungsfragen, die die Hauptforschungsfrage weiter unterteilen. Teil II umfasst die sechs Forschungsarbeiten, die den Kern dieser Dissertation bilden. Jede dieser Arbeiten befasst sich mit einer oder mehreren Forschungsfragen und bezieht verschiedene Konstellationen von ADHS- und/oder neurotypischen Kindern und

Mitgliedern ihres Betreuungsumfelds ein. Dies ermöglicht, unterschiedliche Aspekte von Technologien zu erkunden, um deren Befähigung und Wohlbefinden zu unterstützen. Die ersten beiden Arbeiten tragen zu einem grundlegenden konzeptionellen Verständnis bei, auf dem die verbleibenden vier Arbeiten aufbauen. Jede dieser vier Arbeiten entwickelt einen Prototyp und untersucht dessen Auswirkungen auf Kinder und ihr Betreuungsumfeld. Zu diesem Zweck werden verschiedene Methoden angewendet, darunter Interviewstudien, Co-Design-Sitzungen, Fokusgruppen, Prototypenevaluierungen und Feldstudien. Teil III bietet eine umfassende Diskussion, die die bearbeiteten Forschungsfragen reflektiert und die Hauptimplikationen der Ergebnisse hervorhebt. Die Dissertation schließt mit einer kritischen Auseinandersetzung verbliebener Fragen ab, erkundet sowohl bestehende Limitationen als auch zukünftige Forschungsvorhaben und endet schließlich mit einem zusammenfassenden Fazit.

Insgesamt unterstützt diese Dissertation das Verständnis von Forschenden und Designern, wie Technologien verschiedene Strategien und Aspekte nutzen können, um sowohl ADHS- als auch neurotypische Kinder und ihr Betreuungsumfeld zu ermächtigen und deren Wohlbefinden zu fördern. Darüber hinaus stellt sie das Design, die Entwicklung und die Evaluierung verschiedener Prototypen vor, die diese Aspekte umsetzen und deren Auswirkungen auf Kinder untersuchen. Darüber hinaus präsentiert diese Arbeit eine neu aufgestellte Agenda für die ADHS-Technologieforschung, die „über die Symptome hinaus“ gestaltet und für die aktive Einbeziehung des Betreuungsumfelds und der Nutzende als Mitgestalter im Entwicklungsprozess plädiert. Abschließend bietet diese Dissertation ein differenzierteres Verständnis der individuellen und gemeinschaftlichen emotionalen Ausdrucks- und Reflexionsprozesse, mit denen sich Kinder und ihr Betreuungsumfeld beschäftigen können, mit dem ultimativen Ziel, deren Wohlbefinden zu fördern.

Publications Included In This Thesis

This cumulative thesis consists of six papers in the field of Human-Computer Interaction (HCI), of which four are accepted and two are currently under submission. All papers have been authored by me as the first author and main contributor, in cooperation with collaborators. In paper P IV Nadine Wagener and I are joint first authors and main contributors, while I am the one using this publication as a main contribution in my dissertation. Under the supervision and guidance of my advisors, Johannes Schöning, Yvonne Rogers and Jasmin Niess, I overall conceptualised the ideas and formulated the study designs across the research papers included in this thesis. My contributions spanned the development of the study designs, the employed methods, the design and development of prototypes, the execution of the studies and analyses, and the interpretation and discussion of the findings within each publication. Since these papers are collaborative efforts, specific contributions differ per paper. The following list details the publications encompassed by this thesis, highlighting my specific roles and contributions to each.

Throughout this dissertation, the use of first-person singular pronouns "I/me" reflects my personal perspectives, opinions, and the findings unique to this dissertation. In contrast, "we/our" indicates contributions and viewpoints stemming from the collaborative efforts of the broader research team associated with the corresponding publications. For a connection between the publications listed below and the RQs and RGs that each one addresses, Table 3.1 available in chapter 3 provides an overview.

P I **Evropi Stefanidi**, Johannes Schöning, Sebastian S. Feger, Paul Marshall, Yvonne Rogers and Jasmin Niess. "Designing for Care Ecosystems: a Literature Review of Technologies for Children with ADHD". Published in: Proceedings of the 21st Annual ACM Interaction Design and Children Conference. 2022, pp. 13–25.
https://doi.org/10.1145/3501712.3529746

My contribution to this paper was conducting the literature review, including identification, screening, and selection of manuscripts, as well as analysis of the corpus. Interpretation of the results was conducted together with a co-author. I drafted the manuscript, revised it, and submitted it for the final publication.

P II **Evropi Stefanidi**, Johannes Schöning, Yvonne Rogers and Jasmin Niess. "Children with ADHD and their Care Ecosystem: Designing Beyond Symptoms". Published in: Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems. 2023.
https://doi.org/10.1145/3544548.3581216

My contribution to this paper was the study design, and conducting and analysing all the described studies. Interpreting the findings was completed together with a co-author. I drafted the manuscript, revised it, and submitted it for final publication.

P III **Evropi Stefanidi**, Julia Dominiak, Marit Bentvelzen, Paweł W. Woźniak, Johannes Schöning, Yvonne Rogers and Jasmin Niess. "MagiBricks: Fostering Intergenerational Connectedness in Distributed Play with Smart Toy Bricks". Published in: Proceedings of the 22nd Annual ACM Interaction Design and Children Conference. 2023, pp. 239–252
https://doi.org/10.1145/3585088.3589390

My contribution to this paper was the study design, and conducting and analysing the user study. I conceptualised the feedback mechanism together with a co-author. I programmed the feedback mechanism (software). Interpreting the findings was conducted together with a co-author. I drafted the manuscript, revised it, and submitted it for final publication.

P IV **Evropi Stefanidi**, Nadine Wagener, Dustin Augsten, Andy Augsten, Leon Reicherts, Paweł W. Woźniak, Johannes Schöning, Yvonne Rogers and Jasmin Niess. "TeenWorlds: Supporting Emotional Expression for Teenagers with their Parents and Peers through a Collaborative VR Experience". Under submission at the ACM Symposium on Virtual Reality Software and Technology (VRST) 2024.

Nadine Wagener and I are joint first authors of this paper. I am the one including it as a core contribution to my PhD thesis. This work is an extension of the Master Thesis of Andy Augsten and Dustin Augsten, which Nadine Wagener and I supervised. Together with Nadine Wagener, I was the main contributor to the conceptualisation of the study design and to its revisions, to the qualitative analysis, to the interpretation of the data, and to drafting the manuscript. I completed its revisions to reach its currently submitted version, and I submitted the manuscript for consideration at VRST.

P V **Evropi Stefanidi**, Jonathan L. B. Wassmann, Paweł W. Woźniak, Gunnar Spellmeyer, Yvonne Rogers and Jasmin Niess. "MoodGems: Designing for the Well-being of Children with ADHD and their Families at Home". Published in: Proceedings of the 23rd Annual ACM Interaction Design and Children Conference. 2024.
https://doi.org/10.1145/3628516.3655795

This work is an extension of the Bachelor Thesis of Jonathan Wassmann, which I supervised. I contributed to the conceptualisation and the iterative definition of the prototype's features. I created the study design, conducted the study, and analysed the collected data. I interpreted the findings together with two co-authors. I drafted the manuscript, revised it, and submitted it for final publication.

P VI **Evropi Stefanidi**, Nadine Wagener, Ioannis Chatzakis, Paweł W. Woźniak, Stavroula Ntoa, George Margetis, Yvonne Rogers and Jasmin Niess. "Supporting Communication and Well-being with a Multi-Stakeholder Mobile App: Lessons Learned from A Field Study with ADHD Children and their Caregivers". Under submission at the 27th ACM Conference on Computer-Supported Cooperative Work and Social Computing (CSCW) 2024.

My contribution to this paper was the conceptualisation, the study design, and conducting of all studies and activities required for data gathering. I contributed to the design and development of the prototype. Analysing the data was done together with three co-authors, with me being the main contributor. I drafted the manuscript, revised it, and submitted it for consideration at CSCW.

PART I

INTRODUCTION

CHAPTER 1

Motivation

By age four, as high as seventy-five percent of children might have their own mobile devices [276], underscoring the ubiquitous presence of digital devices in children's[1] lives. Today, the influence of technology during childhood has never been more prominent [174]. This was accelerated by the COVID-19 pandemic, which directly affected children's everyday experiences [244], increasing the use of digital devices for social interactions [139], learning [293], and entertainment [609]. This raises critical questions about the implications of children's interactions with technologies, with particular attention to how they impact children's *well-being* and *empowerment*, two key concepts linked to each other [76, 612] and to children's positive development [234]. That is, beyond the frequency of use, it is imperative to explore how engagement with technology affects children, recognising both beneficial and adverse effects [109, 468, 599]. For instance, on the one hand increased screen time – the amount of time spent using devices with screens – can affect children's cognitive and brain development [146, 248], potentially impacting their well-being. Moreover, social media usage can exacerbate anxiety for both children and parents [139], undermining children's sense of empowerment and control. On the other hand, technology interaction can benefit children's education [444] and social skills [458] and can support children's health [439, 581, 640]. Therefore, children's interaction with technology has the potential to deliver *empowering experiences* [491] that support them and their growth, but concurrently, the potential negative repercussions need to be understood and addressed.

At the same time, along with researching the impact of technologies, it is vital to investigate how the technologies that children use are created [142], which in turn brings to the forefront the key consideration of how technologies can be designed not just *for* children, but also *with* them. This is essential in order to give children a voice in technology design and empower them [255, 259, 631]. Human-Computer Interaction (HCI) and Child-Computer Interaction (CCI) researchers have a long tradition of involving both adults and children in the design and development of technologies; children have thus assumed the roles of testers and users, evaluating and using the technologies, as well as of informants and design partners, actively participating in technology design [141, 142]. Various methods have been employed in that respect, including, among others, storyboarding and scenarios [570], playtesting [187], as well as cooperative inquiry, co-design, and participatory design [142]. Constituting participatory approaches for engaging users in the design process, the last three especially aim to actively involve children in the shaping of technologies and have already been widely used with children since the 1990s [142]. These approaches do not only emphasise the fact that empowering children to play an active role in the design process will result in more engaging, useful, and

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[1] In this thesis, by *children*, I refer to those aged under 18 years.

developmentally appropriate technologies [141, 220]. They can also help children to develop design and technical skills [144, 196], and collaboration and communication abilities [144, 196, 219], while promoting critical reflection on the role of technology in their lives [135, 260, 261]. However, despite children's involvement in technology research, adults are the predominant target users for various technologies children use in their everyday lives, ranging from smartphones, to social media or voice assistants [21].

A critical aspect here is that of the power dynamics between adults and children. These relationships, traditionally of the "all-knowing" adult and "all-learning" child, can hinder children from expressing their preferences regarding the technologies they use [142]. This can limit children's options and autonomy to make choices regarding their interaction with technology. The concern here is not about the essential parental strategies for managing screen time and protecting children from technology-related risks. It is rather about how adult and societal perceptions inherently shape children's technology usage, guided by prevailing beliefs about what is beneficial and valuable to them [448]. Therefore, while acknowledging the extensive discourse on the risks associated with children's technology use, this thesis focuses on reimagining the targeted benefits of technology from the perspective of children themselves.

Beyond affecting children's technology use, this power differential between adults and children can be an important obstacle to meaningful and impactful participation in technology design [143]. First, this is because the roles that children are allowed to play in technology design are strongly influenced and determined by the views on childhood and children's skills and cognitive capacities upheld by designers and other adult stakeholders [487]. Moreover, just the presence of adults can influence children's behaviour in participatory design sessions. In Kam et al.'s [279] research with rural children, the young participants were not able to focus and participate in the design activity when their teachers were present as they became tense and nervous. Furthermore, even when children *are* involved in the evaluation of technologies by providing feedback and suggesting changes, "there is a chance that these changes may never get made, since it is ultimately up to adults to make those changes" [142, p.14], and adults may well "[not] agree with feedback" or "decide that the changes are less important" than finalising the product [142]. These aspects showcase the fact that adults usually have "power over" children when it comes to their technology interactions, even when children are actively involved in the design and evaluation of technologies. This suggests that designing for children must consider the relationship between empowerment and power [467].

This imbalance of power between adults and children is even more pronounced for neurodivergent children, whose routines and activities can be rigidly structured by adults and influenced by their neurological conditions. For example, while adherence to structured routines [317, 538] and therapy [435, 558, 576] can be beneficial for symptom management, it can leave children with fewer opportunities to exercise choice and autonomy in their daily lives, with literature detailing how neurodivergent individual's autonomy can be compromised by expectations of their caregivers [297, 370]. From a technology design perspective, while many approaches have striven for inclusion and diversity [41, 179, 513, 541], there are still shortcomings of and challenges associated with involving not only neurotypical but also neurodivergent children in technology design and evaluation [179, 181, 541, 542], including but not limited to the power dynamics between (neurodivergent) children and adults [179, 541, 542].

In this context, it is important to understand the nuances between the concepts *power-to* and *power-over* [15, 123, 467, 491]. Power-to is employed in this setting to refer to a child's ability to act independently or accomplish something, while power-over involves their influence on their environment and relationships [467, 491]. Currently, technology for children predominantly focuses on power-to [491], helping them navigate challenges independently (e.g. multi-sensory interactive maps for visually impaired children [66] or educational games for children in India [278]). Especially for neurodivergent children, such as those with ADHD, these approaches can assist them with various aspects of everyday life, for instance by providing structure in children's routines [536, 647], thus supporting their parents as well [534, 536]. However, children frequently experience a deficit in power-over, i.e. the power to steer their own circumstances and interactions, such as having limited control over their daily activities, choices in education or the ability to express and enact personal preferences. In particular, they usually have to conform to routines and expectations established by adults, which can narrow the scope of autonomous decision-making or, in the context of technologies, limit their agency over technology use or negatively influence their participation in the design and evaluation processes [143, 487]. Such constraints not only affect their immediate choices but can also impact their overall well-being, as when one's autonomy is restricted, and their empowerment is compromised [254, 393], this can have a negative impact on one's well-being [472, 507]. Empowerment, in this sense, does not just enable children to accomplish tasks but also allows them to have a say in their actions and decisions [254]. *Well-being in childhood can be tied to the sense of being empowered. When children have opportunities to make choices and exercise control over their daily lives, it can lead to enhanced self-esteem, better problem-solving skills, and greater resilience - qualities that contribute to healthier, more positive development [234].*

Therefore, this thesis advocates that in creating technologies for children, it is crucial to balance power-to with adequate opportunities for power-over. For instance, power-to can be exemplified by providing children with educational apps that enhance their learning abilities and foster creativity, representing the power to develop skills and knowledge (see the "skills and education" categorisation of empowerment in HCI by Schneider et al. [491]). Conversely, power-over can be demonstrated by giving children control over their user settings and content choices within these apps, thereby nurturing their capacity to influence their world and make autonomous decisions, for example through *combining* providing "empowering experiences" and "empowerment through design process" [491], which this thesis proposes. This balance could support children's growth into empowered individuals with increased well-being. This is in line with previous work that emphasises that engaging children in the technology design process, especially in the case of neurodivergent participants, necessitates a thoughtful exploration of strategies to amplify their voices and increase their autonomy and agency, thereby empowering them in their everyday lives and technology interactions [41, 178, 180, 182, 384, 426, 513, 580]. This approach requires a deliberate focus on creating environments and tools that not only respect but also reflect their unique perspectives, ensuring that technology development is inclusive and supportive of their needs and aspirations.

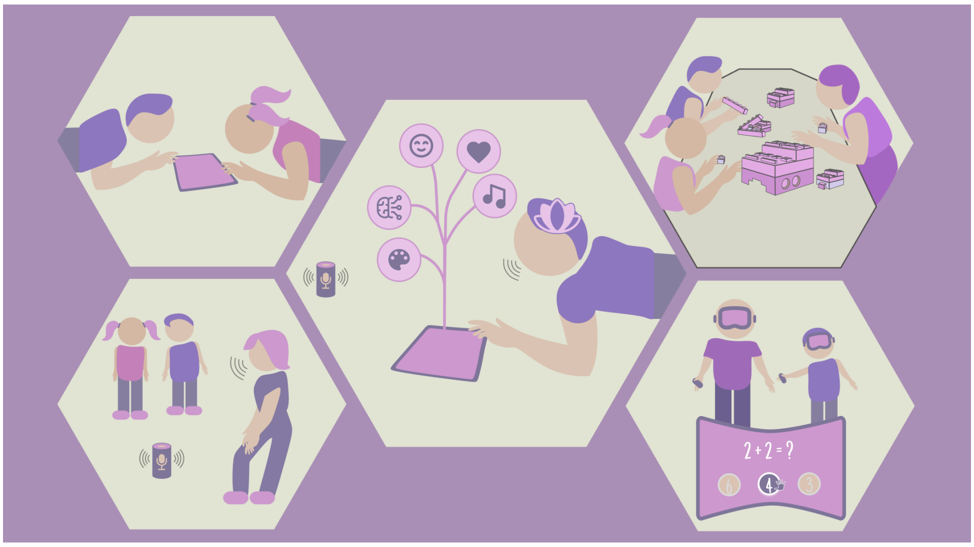

Fig. 1.1 This figure illustrates the various interactions between children and different members of their care ecosystem, including friends, parents and siblings, and other caregivers (for example, teachers or therapists). It also shows the range of technologies that children might interact with, such as VR, mobile devices, voice assistants, and smart toys, covering a range of applications from educational software to games and digital health tools. It thus depicts the complexity of the relationships among children, their care ecosystem members, and a range of technologies which can be used in both individual and collaborative settings thereby shaping children's experiences with technology and influencing their well-being.

To that end, the present thesis explores the design and development of technologies for both neurotypical and neurodivergent (particularly ADHD) children that empower them, both by including them in the design process [491], as well as by delivering empowering experiences [491], with the overall goal to support their well-being. The work presented in this thesis is positioned in the field of HCI, with a strong emphasis on CCI. Tsvyatkova and Storni [571] write that "as a research discipline within HCI", CCI "explores the design of systems that reflect the nature of children's growth and cognitive development, and the opportunity for children's involvement in the design process through developing their own technology in collaboration with researchers and designers". Read and Bekker [448] outline the key differences that set CCI apart from HCI, highlighting the pivotal role and involvement of adult participants in children's interactions with technology, as well as how "cultural and societal assumptions about technology and children (...) determine what is good for children and what has value" [448, p.1]. This links directly to the aforementioned power imbalances between children and adults pertaining to both the design and evaluation *and* the use of technologies by children, and the need to explore how to empower children in that respect.

This thesis engages with both of these aspects, as it explores the design of technologies with and for children *and* their care ecosystem while seeking to understand how to design driven by children's desires and needs. In particular, it takes a special focus on how to design with and for children's care ecosystems (i.e. the stakeholders involved in children's everyday experiences such as family, teachers, peers and therapists), seeing that they strongly influence children's health and well-being [494]. This work argues for their active inclusion, alongside children, in the design, development, and evaluation of technologies, and explores the impact of technologies that aim to support the well-being of both groups. Figure 1.1 presents a visualisation that seeks to depict the complex role of children's care ecosystems in their well-being and technology use, which is investigated in this thesis.

This thesis particularly focuses on children with attention deficit hyperactivity disorder (ADHD), as it is the most prevalent neurodevelopmental diagnosis for children [125, 470, 639], and it has been relatively under-researched by HCI and CCI scholars in comparison to other diagnoses, such as autism. In doing so, this research investigates how to satisfy *diverse needs* of different stakeholders, referring to both the varying needs and interests of neurotypical and ADHD children as well as those of their care ecosystem. Overall, this thesis delivers a variety of contributions, proposing how to design technologies *for* and *with* ADHD and neurotypical children and their care ecosystems that can support their overall well-being and empower them. Those include both artefact contributions by designing and developing such technologies, as well as empirical contributions by investigating their impact on a range of behaviours such as emotional expression, reflection, and interpersonal interactions, all of which affect the empowerment and well-being of children and their care ecosystems.

The role of HCI in this endeavour is pivotal, as it offers a comprehensive framework for understanding and addressing the complexities of designing for children's empowerment and well-being, embracing experience and meaning-making [622]. By investigating how to support them in that respect, this research recognises children's agency and autonomy in shaping their experiences and interactions with technology, aiming to deliver meaningful experiences with technologies [396]. This links to the paradigm of *Entanglement HCI* by Frauenberger [177], who argued that "designing technology means creating hybrid things with ambiguous boundaries and proposed programs of actions that seek to reconfigure agency and power with moral responsibility" [177, p.22]. Relating to this, and acknowledging the power that we as researchers and designers wield, this thesis emphasises the importance of living up to the responsibility that comes with it, pinpointing ways to consider and actively involve children's needs and interests in the design process. The overarching goal of this thesis is to contribute to this evolving narrative, by exploring how to design technology so that it can be a tool for enhancing children's autonomy, decision-making, and ultimately, their well-being, by finding ways to satisfy their diverse needs and those of their care ecosystem.

1.1 Thesis Overview

This thesis addresses the above goal by actively engaging with children with ADHD and neurotypical children, parents, teachers, and therapists. Employing a variety of methods, including interview studies, co-design sessions, focus groups, prototype evaluations, user studies and field studies, this research involves the various care ecosystem stakeholders in building a conceptual basis towards the design of well-being technologies for these stakeholders (see P I and P II), and subsequently engages them in studies with a range of technological prototypes that seek to empower them and support their well-being. Those prototypes include a tangible smart toy (see P III), a VR application (see P IV), physical situated displays (see P V), and a mobile application (see P VI).

Following common practices for a cumulative thesis, this dissertation is split into three main parts: Introduction, Publications, and Discussion. Preceding the Introduction, the full list of publications that form this thesis is presented, detailing my specific contributions to each publication.

The Introduction establishes the basis of this work and consists of four chapters. The first and present chapter begins with the motivation for this research, introducing key concepts that are relevant to this thesis. The second chapter elaborates on relevant background and terminology that is needed to contextualise and understand this work, including definitions of the core concepts that are employed throughout this dissertation and their connections to each other. The third chapter presents the research questions that this thesis addresses, based on research gaps that are described using both previous literature as well as gradually building on findings from the studies of this thesis.

The second part includes the six publications comprising this thesis. Each paper is introduced including its digital object identifier (DOI), thereby linking the work to the official online version of each publisher. For better readability, each paper has been integrated into the format of this thesis. The second part includes two additional chapters, Transition I and Transition II, facilitating the transition from the conceptual papers (P I and P II) to the ones that present the designs of and studies with the four proposed technologies of this dissertation (P III, P IV, P V, and P VI).

The third and final part of this thesis presents a general Discussion. First, it discusses how the papers included in this thesis address the research questions presented in chapter 3. I then discuss how the findings of this dissertation translate to specific insights and their implications future research along two specific domains, each of which comprises a separate chapter. The first regards insights from applying the proposed "designing beyond symptoms" strategy and the second from engaging in a care ecosystem-based approach in technology design, evaluation, and use. Subsequently, this thesis contributes a model that conceptualises the findings of this research around how technology can support well-being and empowerment for children and their care ecosystem. Following that is a chapter that discusses questions that remain unanswered at the point of completion of this thesis, engaging in reflection about both limitations and possible future steps, as well as ethical considerations. This thesis ends with a conclusion, summarising the work conducted in this thesis.

CHAPTER 2

Background & Terminology

This chapter presents relevant background that is necessary to contextualise the research conducted during this PhD, including important terminology and concepts that are employed in this thesis. For each of the concepts, their working definitions in this thesis are explicitly marked. Moreover, this chapter selectively highlights a few relevant prototypes and conceptual frameworks developed in prior research, illustrating the use of these core concepts in HCI research. These examples are chosen to underscore the design choices that have shaped this dissertation. For an in-depth review of the related work that informs each specific paper, and especially for details on interactive technologies that have been developed addressing the various concepts, please refer to the related work sections in the respective publications included in this thesis.

Below, I first present the concept of neurodiversity, elaborating on one specific neurodevelopmental condition that this thesis particularly explores: ADHD. I then introduce the term *care ecosystem*, which is used throughout this thesis. Following this, I engage with the concepts central to this thesis: well-being, empowerment, power (and particularly power-to and power-over), autonomy, agency, reflection, and emotional expression, discussing their various definitions and correlations. Finally, the chapter is concluded by summarising the concepts, detailing their working definitions in the context of this thesis and how they connect to each other, thus relating them to the goals of this thesis (i.e. support well-being and empowerment for children and their care ecosystem). For additional conceptual clarity, Table 2.1 presents an overview of the above, while each concept is also elaborated upon in detail in the sections below.

2.1 Neurodiversity

> The term “neurodiversity” refers to a divergence from the norms that usually define individuals as neurotypical, expressing a variety in the human brain activity [543].

It should be noted that no single person can be diverse and, subsequently, no single person can be neurodiverse; instead, neurodiversity relates to a multitude of brain differences, similar to biodiversity [543]. Along these lines, in this thesis, I use the terms neurodiversity to describe these variations and neurodivergent to describe people.

There has been an increasing interest in neurodiversity by the HCI community, particularly in building a systematic understanding of technologies for neurodivergent populations. This interest is reflected in literature reviews on neurodiversity, both within HCI and CCI. For instance, Börjesson et al. [55] performed a systematic literature review on the involvement of

Table 2.1 Overview of the core concepts employed in this thesis, their working definitions (shortened for presentation clarity, please refer to the pertinent sections of this chapter for an elaboration on how this thesis employs each concept), and established connections to each other.

Concept	**Thesis Working Definition**	**Links to Other Concepts**
Well-being	It consists of emotional, psychological, and social components [290, 291], integrating both hedonic and eudaimonic dimensions [472].	This thesis deconstructs well-being to the following positively linked components: empowerment [76, 612], autonomy [92, 472], agency [8, 507], reflection [67, 231, 341, 454, 525], and emotional expression [421].
Empowerment	Providing necessary resources, opportunities, and capabilities to exert control over one's life and take actions, encompassing both affording "power-to" and "power-over" [467].	Links to well-being [76, 612], autonomy [466], agency [254, 347], and reflection [393].
Power-to	"The ability to do something" [15], "creating new possibilities" [467].	Links to empowerment (as it is a notion of empowerment) [467].
Power-over	Having control over one's decisions [254], and "bringing people who are outside the decision-making process into it" [467].	Links to empowerment (as it is a notion of empowerment) [467].
Autonomy	The ability to make decisions and act independently, being associated with individual freedom and self-determination [472].	Links to well-being [92, 472], agency [39, 121], and empowerment [466].
Agency	The capacity to act and make choices in pursuit of one's goals [508], while also acknowledging the social and cultural contexts [26, 200, 644] that shape those choices.	Links to well-being [8, 507], autonomy [39, 121], and empowerment [254, 347].
Reflection	The process of introspection where individuals review and analyse their thoughts, emotions, and behaviours [210], including both reflection-on and -in-action [492].	Links to well-being [67, 231, 341, 454, 525], and empowerment due to the link of both reflection and well-being with increased self-esteem [393, 503].
Emotional expression	Any type of communication (verbal, visual, or other) of one's inner states towards the outside, in an individual capacity or by sharing that with others.	Links to well-being [421].

developmentally diverse children in design. They found that children with high-functioning autism are the ones most frequently engaged in technology design, with other groups of neurodivergent children often playing more passive roles, for example being observed throughout the design and evaluation phases of technologies. Moreover, they showed that when designing for neurodivergent children, adults assume the roles of users, proxies, experts and/or facilitators, playing a more prevalent role compared to designing for neurotypical children. Their results highlight the importance of active participation of caregivers, teachers, and therapists when designing with neurodivergent children.

Another example is the work by Spiel et al. [542], who reviewed the purposes of HCI technologies for children with autism and how these discursively conceptualise their agency. They identified an existing 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. [34] systematically reviewed 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. [343] 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, research on "cognitive disorders" – such as ADHD – accounted for less than 10% of the papers.

The research conducted in this thesis focuses on both neurotypical children as well as children with ADHD, motivated by its prevalence as a diagnosis [125, 470, 639] and the comparatively rather limited number of research works in HCI surrounding the subject [343]. The various studies included in this thesis have involved both neurotypical children, ADHD[1] children, and children with other neurodevelopmental diagnoses (co-morbidities of ADHD), such as autism, which is one of the most common co-morbid conditions to ADHD [555].

2.1.1 Attention Deficit Hyperactivity Disorder (ADHD) & Technologies

ADHD is recognised as the most common neurodevelopmental condition in children [125, 639]. ADHD individuals may exhibit variations in attention, activity level, and impulse control when compared to peers of the same age [110]. ADHD is categorised into three types: predominantly inattentive, hyperactive-impulsive or combined [19, 212], depending on which of these characteristics is prevalent. It has been associated with academic underachievement, bedtime resistance, disruptive behaviours, and social difficulties, such as issues in peer interaction [163, 537, 604]. As a result, families of ADHD children typically experience added stress and family frustrations [565], which is often underscored by ADHD's high heritability [162], making it likely that parents of ADHD children need to regulate themselves in addition to supporting the regulation of their children. This can become particularly challenging since ADHD individuals often struggle with self-regulation and with emotion-regulation [35, 452, 514].

Children with ADHD frequently encounter communication barriers within their care ecosystems [456]. For instance, additional time and strategies are required for care coordina-

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[1] In order to show respect for the different views and preferences communities and ADHD people have expressed regarding the use of person-first language, and in line with prior work (e.g. [523, 544]), this thesis uses both "ADHD children" and "children with ADHD".

tion [456]. Moreover, difficulties in emotion regulation can hinder ADHD children's ability to express and share their feelings, affecting their relationships and communication with their care ecosystem members [85, 159, 307, 309]. Additionally, discrepancies in approaches and motivations between families and therapists can result in unclear treatment goals and a lack of shared understanding within a child's care ecosystem [456].

Traditional treatments for ADHD include mainly psychosocial treatments, medication treatment with stimulants (mostly methylphenidate) and their combination [435, 558, 576]. Specifically, psychosocial treatments for ADHD focus on the parents, the teacher, and the child, with variants of (cognitive) behavioural therapy [576], which emphasises the crucial role of these caregivers. The National Institute of Health and Care Excellence [395], for instance, recommends parent training and educational programs as the primary treatments for ADHD, advising that medication should be considered as a secondary option. Parent training programs, such as "The Incredible Years" [603], have been effective in mitigating symptoms of ADHD according to parent reports. These programs typically emphasise five key strategies: encouraging play and positive interactions, rewarding desirable behaviour, setting clear expectations, enforcing calm and consistent consequences for misbehaviour, and structuring the child's day to minimise stress [373]. At the same time, while medications like methylphenidate have been shown to improve ADHD symptoms, general behaviour, and quality of life as reported by teachers and parents [556], their use is not without concerns. These include side effects such as sleep disturbances [556] as well as dysphoria and potential delays in growth [163]. Moreover, medications tend to alleviate symptoms temporarily without addressing the underlying causes, leading to a resurgence of symptoms once the medication is discontinued [87]. Additionally, there is no substantial evidence to suggest that ADHD medications enhance academic performance [87].

Various interactive technologies have been designed to support children with ADHD and their care ecosystem by addressing ADHD-related challenges. These include mobile and tablet applications [428, 523, 536], smartwatches and wearables [106, 137, 523], as well as tangible systems [532, 606, 645, 647]. Prominent examples of technologies supporting children with ADHD and their families include ParentGuardian by Pina et al. [428], a mobile and tablet system that monitors the stress of parents of children with ADHD in order to deliver reminders of behavioural strategies to follow. In particular, it includes both "heat of the moment" strategies for moments of duress as well as reflective strategies, which can be practised at any time. Based on a two-week deployment study, this work showed that cues which are delivered in situ can remind parents to implement these strategies in times of need, but also raised questions regarding how to prompt parents in idle moments to proactively reflect on behavioural strategies. On a similar note, focusing on morning and bedtime routines, MOBERO by Sonne et al. [536] is a smartphone-based system that seeks to support families in establishing healthy routines. In a field study with families of ADHD children, the system was found to significantly improve children's independence and reduce parents' frustration levels. Additionally, the use of MOBERO was associated with a 16.5% reduction in core ADHD symptoms and an 8.3% improvement in the child's sleep habits, both measured by standardised questionnaires. While the above systems focused specifically on the home context, CoolTaco by Silva et al. [523] is a smartwatch and smartphone system that aims to support ADHD children and their families to collaborate in creating tasks, gain points for achieving them, and allow children to redeem rewards. Due to its inherent portable nature, it enables them to self- and co-regulate across multiple contexts (e.g. at school and at home). The above systems were all evaluated with their end users, i.e. ADHD children and/or their families, and were found to have positive effects on the ADHD-related aspects that they sought to address, such as improved organisation and time management [647], fewer conflicts with parents [647], and help with providing pervasive regulation support to children [523].

These studies have shown the potential benefits of designing technologies to enhance certain cognitive and social behaviours for ADHD children. Nevertheless, there are many un(der)-explored opportunities and challenges to design further technologies that can support ADHD children's well-being and that of their care ecosystems [535]. Furthermore, while there is a growing discourse advocating for the design of technologies that extend beyond solely addressing symptoms for neurodivergent populations, much of that research has focused on children with autism [543, 544]. Therefore, there is a need, firstly, to improve our understanding of how HCI researchers have supported ADHD children and their care ecosystem as well as their roles in the design and evaluation of technologies, and secondly, to chart the impact of embedding such technologies with ADHD children and their care ecosystems in real-life contexts. The work reported in this thesis seeks to address those aforementioned aspects. Given this thesis' particular focus on children's care ecosystems, the following section engages with the term and elaborates on its use and significance in this work.

2.2 Children's Care Ecosystems

> In this thesis, the term *care ecosystem* is employed to describe all the people that are involved and play a key role in children's everyday experiences, including parents, siblings, grandparents (and other family members), peers[2], as well as teachers and potential therapists. Moreover, this thesis uses the term care ecosystem and care ecosystem members to refer to the different stakeholders that comprise children's care ecosystems, while the term (care) ecosystem stakeholders is used to also include the child itself in that group.

This emphasis on these key stakeholders aligns with Bronfenbrenner's Ecological Systems Theory [61], which suggests that an individual's development is shaped by various interconnected environmental layers, ranging from the immediate family setting to broader cultural systems. Within this framework, the first layer is the "microsystem", including family, school, friends, and neighbours, which is the most influential level and directly impacts the child's development and well-being.

The concept of a care ecosystem is extensively discussed across various studies. Cigarini et al. [107] examined the roles within a mental health care ecosystem, comprising health and

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[2] The terms "friends" and "peers" are used interchangeably in this thesis to denote similarly aged children who have a relationship such as a friendship, depending on whether the intended focus is on the nature of their relationship or on the fact that they belong to the same age group.

social sector professionals, alongside both formal and informal caregivers and the patient's family and friends. Formal caregivers refer to paid professionals, while informal caregivers are close acquaintances, including family, friends, and neighbours who provide unpaid assistance [328]. Weisz et al. [607] outlined a multi-layered mental health ecosystem specifically for clinically referred youths, incorporating their families, caregivers, and health practitioners. Amir et al. [11] described a comprehensive care ecosystem for children with complex medical needs, incorporating a wide array of medical experts, parents, and community-based support networks. Furthermore, the term is also prevalent in autism studies, for example in clinical settings [314], whereas other researchers in this field have used the term "social support network" [47] and explored its impact on the subjective well-being of mothers of children with autism. To the best of our knowledge, the term care ecosystem has not been explicitly used with regards to children with ADHD before the first publication included in this thesis, while it is a recognised term within the broader mental health context [107, 607]. Nevertheless, variations can be found in literature, both in the area of ADHD and in general family health; for instance, Cibrian et al. [105] refer to the social actors surrounding the child as its caregivers (a term which, however, does not encompass peers).

This thesis argues that exploring the role of the various stakeholders involved in children's everyday experiences could provide a more comprehensive overview and valuable insights to consider when designing technologies, both for children with ADHD and neurotypical children. In line with this, previous HCI research highlights the significance of accounting for the entire "use ecology" in which technologies are deployed [529], which includes both the social and spatial aspects of the environment in which technology is integrated. This perspective resonates with the arguments presented by Forlizzi [175], who called for a transition from a user-centred design paradigm to a stakeholder-centred one. Therefore, in the context of technologies for (ADHD) children, it is crucial to build a comprehensive understanding of how technology can be integrated and function within children's care ecosystems. In particular, it is important to consider children's care ecosystems in technology design and not *only* focus on the child, due to the vital role that they play in children's everyday experiences. These support networks strongly influence children's quality of life, social activity, and success in school environments [227, 427], and can offer motivational and emotional scaffolding [105]. This comprehensive approach is also supported by Schor [494, p.413], who stated that "children's health and well-being is directly related to their families' ability to provide their essential physical, emotional, and social needs", further underscoring the influential role of children's caregivers. Additionally, investigating and integrating the needs and interests of both children and their care ecosystems when designing a technology could potentially lead to technologies that are more acceptable to both groups, which is crucial given the active role that parents, for example, play in the technologies and content that children get to use [448].

Since a core aim of this thesis is to explore how to design technologies that support the *well-being* of children and their care ecosystem, the following section engages and deconstructs this term, along with other concepts that connect to it, namely empowerment, which is another design goal of this thesis, as well as autonomy, agency, reflection, and emotional expression.

2.3 Core Concepts

This section engages with core concepts for this thesis: well-being and empowerment, as two key goals that this research aims to achieve when creating technologies, in addition to autonomy and agency, reflection, and emotional expression, as crucial concepts that connect to the two key goals as well as to each other. Below, I elaborate on their working definitions in this thesis and discuss their correlations.

2.3.1 Well-being

Well-being is a complex construct that concerns optimal experience and functioning [472]. Numerous scholars have engaged with the concept and various – sometimes contesting – definitions exist. Many scholars have approached the definition of well-being by outlining its various dimensions. In that respect, a number of research works suggest that well-being is most accurately understood as a complex phenomenon encompassing elements of both *hedonic* (pleasure-based) and *eudaimonic* (meaning and self-realisation based) views of well-being [472]. In particular, according to this distinction, the hedonic approach to well-being defines it in terms of attaining pleasure and avoiding pain; the eudaimonic approach focuses on meaning, self-realisation, and self-growth. Another related perspective is that of *subjective* well-being [134], referring to one's cognitive and affective evaluations of life satisfaction. On the other hand, Ryff and Keyes [475] described *psychological* well-being as distinct from subjective and presented a multidimensional approach to measure it. This method evaluates six unique aspects of human actualisation: autonomy, personal growth, self-acceptance, life purpose, mastery, and positive relatedness. These six constructs define psychological well-being both theoretically and operationally and detail the factors that enhance emotional and physical health [476]. Thus, psychological well-being as proposed by Ryff [474] corresponds more closely to the eudaimonic dimension described above. Subjective well-being has links to both the hedonic and the eudaimonic dimensions, as it incorporates subjectively assessing one's emotional states or overall life satisfaction [134], which at the same time can include meaningful engagement and personal challenges, aspects that are connected to eudaimonic well-being [472].

Other approaches deconstruct well-being into specific components. In that respect, Keyes [290, 291] linked well-being and *mental health*, outlining three components of mental health: *emotional* well-being, *psychological* well-being and *social* well-being. According to this, emotional well-being encompasses happiness, life interest, and satisfaction; psychological well-being involves positive self-perception, effective daily life management, healthy relationships, and life satisfaction; and social well-being pertains to contributing to society, feeling integrated within a community, believing in societal improvement, and understanding societal functions. As yet another definition of well-being, the PERMA model by Seligman [500, 501], which is widely acknowledged in the literature, posits that well-being is founded on five fundamental pillars: positive emotion, engagement, relationships, meaning, and accomplishment. It thus forms a fundamental theory of positive psychology, aiming to achieve a scientific understanding of the factors that enable individuals and communities to flourish [502]. Focusing on definitions of children's well-being specifically, Pollard and Lee's [437] systematic review identified five distinct domains of child well-being: physical, psychological, cognitive, social, and economic. “The social domain includes only sociological perspectives. Psychosocial perspectives fall within the psychological domain. The psychological domain includes indicators that pertain to emotions, mental health, or mental illness, while the cognitive domain includes those indicators that are considered intellectual or school-related in nature” [437, p.64].

Overall, the plethora of concepts and theoretical models engaging with the concept of well-being share some overlapping constructs, yet they each delineate, attribute, and conceptualise these constructs distinctly. Moreover, apart from the different approaches and perspectives to well-being, numerous researchers have explored the various concepts that are positively correlated to well-being, among others: empowerment [76, 612], autonomy [92, 472], agency [8, 507], reflection [67, 231, 341, 454, 525], and emotional expression[421]. In light of the above, this thesis sees well-being, along with empowerment as the goals and explores how to design technologies in order to achieve the support of the several related concepts elaborated in the subsequent sections, i.e. autonomy, agency, reflection, and emotional expression, which all positively correlate to well-being as detailed above. **Specifically, this thesis deconstructs the concept of well-being to components that are positively linked to it and seeks to design for those, in order to support the overall well-being of children and their care ecosystem.**

> Grounded in the concepts correlated with well-being explored in this thesis, the most appropriate definition of well-being for this research aligns with Keyes' [290, 291] conceptualisation, encompassing emotional, psychological, and social dimensions.

Also, since well-being in childhood is closely associated with a sense of empowerment, this research particularly highlights the link between well-being and empowerment through opportunities to exert control and choices, enhancing self-esteem and resilience [234].

Please refer to Table 2.1 for an overview of these core concepts that this thesis employs and their connections. Furthermore, the research presented in this thesis designs with neurodivergent needs and desires in mind, focusing on the case of ADHD children, thus touching upon the satisfaction aspect of the hedonic definition of well-being and on the meaning aspect of the eudaimonic definition.

The sections below elaborate on these concepts that are positively linked to well-being, providing definitions for them and detailing their relationship not just to the construct of well-being, but also to each other. Exploring these concepts and especially their links to well-being is in line with the overarching aim of this thesis, i.e. to explore how to design technologies that empower and support the well-being of both ADHD and neurotypical children and their care ecosystem.

2.3.2 Empowerment & Power

The concept of empowerment, which has been interwoven with well-being since its introduction in the late 1960s [76], inspired by the seminal work of Paulo Freire [184, 342], originally aimed to ensure the well-being of marginalised groups by enabling them to take part in decision-making processes that affected them [612]. Since then, its meaning has evolved and multiple articulations have emerged. In any case, this initial aim directly links to the ever-increasing focus of HCI researchers and designers on prioritising inclusivity and user-centric approaches, to empower (marginalised) groups to exert influence over the technological systems that impact their lives, and in the context of this thesis, to empower both neurotypical and ADHD children through their interactions with technology.

Going back to the concept's definitions, according to the Oxford Learner's Dictionary, empowerment is "the act of giving somebody more control over their own life or the situation they are in" [409]. While there is no single definition, with Robert Adams [4] pointing to the limitations of any single definition of empowerment, the majority of the definitions engage with the terms of *control* and *power*. This is also reflected in Ibrahim and Alkire's [254] overview of different definitions and concepts of empowerment ranging from 1991 to 2006. For instance, according to Rowlands "empowerment is more than participation in decision-making; it must also include the processes that lead people to perceive themselves as able and entitled to make decisions" [467, p.14]; while Malena [346] states that "to 'empower' simply means to 'enable' or 'give power to"'.

Overall, the concept of empowerment is related to terms such as agency, autonomy, self-determination and self-confidence, among others [393]. Notably, Ibrahim and Alkire [254] argue that empowerment is an expansion of *agency*. Similarly, Maholtra [347, p.72-73] writes about empowerment: "among the various concepts and terms we encountered in the literature on empowerment, 'agency' probably comes closest to capturing what the majority of writers see as the essence of empowerment". Concurrently, liberal feminist scholars Rowland-Serdar and Schwartz-Shea connect empowerment to autonomy, arguing that "autonomy, the struggle for choice of response, is the bridge between the powerlessness of dependency and the empowerment of self" [466, p.617] Therefore, given the connections between agency and empowerment, as well as autonomy and empowerment, and considering that agency and autonomy are often used interchangeably due to their conceptual similarity [39, 121], agency and autonomy also form core concepts in the context of this thesis. Consequently, they are thoroughly examined in the subsequent section.

Before diving deeper into empowerment and engaging with the concepts of power-to and power-over, as well as discussing empowerment in the context of HCI research, the working definition of empowerment in this research is provided. In particular, this thesis addresses empowerment as a separate notion to agency, contrary to Ibrahim and Alkire's [254] definition, despite recognising the connections between them.

> Instead, in this thesis empowerment is described as equipping individuals with the necessary resources, opportunities, and capabilities to exert control over their lives and be able to take actions, encompassing empowering individuals by affording them both "power-to" and "power-over" [467]. It entails transferring control and power to individuals, ensuring they have not only the means but also the self-perception of being capable of making decisions and initiating actions, therefore aligning with Rowlands' [467] definition.

This suggests that technologies *can* be designed to foster empowerment, serving as the means that encourages and enables users to feel more capable and in control. Furthermore, this thesis delves into the concepts of power-to and power-over, exploring how these forms of power can be granted to children and their care ecosystem through their engagement with technology. These aspects are further explored in the subsequent subsection.

Power-to and Power-over. Empowerment contains the word *power*. Rowlands [467] argues that the confusion around the concept of empowerment arises due to this root concept, i.e. power, being itself disputed, having been the subject of debate across the social sciences (e.g. [25, 176, 232, 339]). For instance, while some definitions focus on power as one individual making another do "something against their will", other frameworks for understanding power are neutral, i.e. not commenting on the distribution of power, while others conceptualise power as a process, not involving domination but rather being generative [467]. Rowlands [467, p.13] engages with those different definitions and concludes that power can take many different forms: power-to (creating new possibilities); power-over (controlling power); power-with (acting in a group); and power from within (enhancing self-respect). This thesis particularly focuses on the concepts of power-to and power-over (further elaborated upon below), which have already been conceptualised as possible ways that HCI technologies can empower users [491].

Before delving into those two notions of power, I briefly elaborate on the concepts of power-with and power from within, to provide a comprehensive understanding of the concept of power. Based on Rowlands [467, p.13], power-with encompasses "a sense of the whole being greater than the sum of the individuals, especially when a group tackles a problem together". On the other hand, power from within [467, p.13] regards "the spiritual strength and uniqueness that resides in each one of us and makes us truly human. Its basis is self-acceptance and self-respect which extend, in turn, to respect and acceptance of others as equals". Below, I engage with the notions of power-to and power-over, which apply in the context of this thesis in the following manner. First, this research explores how to design technologies that empower children by affording them power-to, e.g. by providing them with the means to express their emotions (see papers P II, P IV, P V, and P VI). Moreover, it also designs with the goal to afford them power-over, e.g. by allowing them to exert control over the sharing of their data when using technologies (see papers P V, and P VI), or to feel empowered to take the leading role in their interactions with their caregiver (see paper P III).

Similar to how different definitions for empowerment exist, power-to and power-over also have different articulations. Ibrahim and Alkire [254] developed indicators to measure individual agency and empowerment and associated power-to with choice, both in decision-making as well as domain-specific autonomy, and power-over with control over one's personal decisions. This notion of power has also been reflected in the works by Hobbes [241] and Arendt [15]. Hobbes defines power as a person's "present means [...] to obtain some future apparent Good". Similarly, for Arendt "power is a something – anything – which makes or renders somebody able to do, capable of doing something. Power is capacity, potential, ability, or wherewithal". Arendt explicitly distinguishes power from authority, strength, force, and violence.

> Therefore this thesis conceptualises power-to based on Arendt's [15] definition, as "the ability to do something", "creating new possibilities" as per Rowlands [467].

On the other hand, power-over can be understood as a "controlling power, which may be responded to with compliance, resistance, or manipulation", or as "bringing people who are outside the decision-making process into it" [467, p.13]. Weber notably articulates power as "the probability that one actor within a social relationship will be in a position to carry out his own will despite resistance" [602]. Similarly, Dahl presents his "intuitive idea of power", wherein "A has power over B to the extent that he can get B to do something that B would not otherwise do" [123]. Notably, Dahl excludes the concept of force from his definition, which aligns more closely with this thesis.

> This thesis employs power-over encompassing the following aspects: first, Ibrahim and Alkire's [254] definition of having control over one's decisions, referring to the extent to which the individual has control over everyday activities, without including any aspects of force, in line with Dahl [123]; and second, Rowlands' [467] aspect of "bringing people who are outside the decision-making process into it".

The second aspect, in particular, is directly linked to the active involvement of both neurotypical and ADHD children in the design and evaluation processes of the various explored technologies in the context of this thesis. Below, the concept of empowerment is discussed in the context of HCI research.

Empowerment in HCI. Various calls have been made in the HCI community for technology that empowers people [27, 352, 464, 517]. Previous work has attempted to clarify the different articulations of empowerment and create an understanding of the term within HCI research, via creating conceptual frameworks to categorise it [296, 491, 578]. For instance, Kinnula et al. [296] focused on children's empowerment, and proposed a framework outlining functional, educational, democratic, mainstream, and critical empowerment. As another example, Schneider et al. [491] reviewed how empowerment has been used within CHI[3] publications, and derived a framework to analyse notions of empowerment in HCI research. They demonstrated that the lines of research on empowerment within HCI can be categorised as follows: i) empowering experiences, ii) skills and education, iii) self-enhancement, iv) holistic approaches, v) empowerment through the design process, vi) technology for development, and vii) protective technology. To illustrate, in the context of empowering children with ADHD, assistive technologies that train executive functioning or attention time on learning tasks could empower them by developing their skills and education. For instance, Zuckerman et al.'s [647] TangiPlan system of tangible objects and a tablet application aimed to train ADHD children's executive functioning, in order to support them and their parents during morning

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[3] The ACM Conference on Human Factors in Computing Systems (CHI) conference is generally considered the most prestigious in the field of HCI.

routines. In the above example, the concept of power applied is power-to, as the proposed technology could empower ADHD children by enhancing their executive function skills.

In Schneider et al.'s [491] review of empowerment in HCI, the concept of power-over was predominantly associated with technologies targeting adults, particularly in community-based contexts (e.g. [155, 252, 563]) and technologies for development (e.g. [520, 564, 634]); only one HCI publication [616] was found to empower children (and in particular teenagers) employing the concept of power-over. In that case, Wisniewski et al. [616] aimed to increase teenagers' online risk awareness by asking them to reflect and report on their encounters with online risks. Thus, they empowered teenagers to protect themselves so that they can more effectively manage their online risk experiences and benefit from online engagement. This aspect of "protective technology" [491] is thus an example of how to empower by employing the concept of power-over, "addressing the power imbalance between technology users...and [technology] providers" [491, p.7]. Below, the work conducted in the context of this thesis is contextualised based on those two aforementioned frameworks, i.e. by Schneider et al. [491] and Kinnula et al. [296].

This thesis employs the notion of empowerment by providing *empowering experiences* based on the categorisation by Schneider et al. [491]. According to this notion, "technology allows users to experience feelings that are associated with power and powerfulness, such as sense of agency, control, and privacy" [491, p.5]. Moreover, this work can also be categorised in the notion of *empowerment through the design process*, wherein "users are empowered by having their voice heard and being put into the centre of the design process" [491, p.6]. Based on this, employing participatory approaches and placing the user in the centre of the design process can lead to empowerment in itself [30]. Furthermore, with respect to the framework discussed by Kinnula et al. [296], this thesis addresses the following views of empowerment: mainstream, as children take part in design actions initiated by others, democratic, as children's decision power in technology design is increased, and functional, as this work aims to contribute to the life conditions of children.

This thesis proposes that combining empowerment through the design process and providing empowering experiences can result in children both having power-to and power-over. This extends these concepts, applying them in the domain of children's interaction with technologies. In particular, this thesis expands on the notion of power-to by empowering children to have the ability to perform actions (e.g. emotional expression, reflection) that support their well-being; it also extends the concept of power-over by empowering children to have the ability to actively decide and have control their actions, i.e. the types of technologies they use as well as how they wish to use those technologies.

2.3.3 Autonomy & Agency

Autonomy and *agency* are also positively linked to well-being [8, 92, 472, 507] and to empowerment [254, 347, 466]. and are complex concepts, as they are often used interchangeably [39, 121], while they have distinct, albeit deeply entangled, meanings [121]. Their complexity and often synonymous use is also echoed in the findings of Bennett et al.'s [39, p.1] literature review of how HCI research understands the two concepts, which “are used to describe a wide range of phenomena pertaining to sense-of-control, material independence, and identity”.

Regarding autonomy, the Oxford Learner’s Dictionary defines it as “the ability to act and make decisions without being controlled by anyone else”, and provides “independence” as its synonym [408]. Combining both notions, Mosby’s Medical, Nursing and Allied Health Dictionary [203] states that autonomy is “the quality of having the ability to function independently”. Autonomy is considered a crucial part of an individual’s development, signifying the ability to make choices based on one’s own values and principles rather than being influenced or controlled by external forces [156, 157, 473]. It is often associated with the concept of *self-determination* [472]. In particular, self-determination theory proposes that autonomy is one of three fundamental, universal psychological needs, along with relatedness and competence, and that their expression is associated with psychological health and flourishing (eudaimonia) [472]. Autonomy in this context refers to the ability to pursue goals that are authentically related to the needs of the self. Furthermore, autonomy is linked to empowerment [466]. Research in a variety of cultures has indicated that individuals’ well-being (subjectively and objectively measured) is associated with their perceived ability to pursue goals held to be important to them [472]. As an example of a relevant research finding, Chirkov and Ryan [92] showed that Russian adolescents generally perceive less autonomy support from their teachers compared to their American peers, likely reflecting differences in cultural norms. However, in both groups, lower levels of perceived autonomy support were associated with decreased well-being (both subjective and other forms) [92].

Agency, on the other hand, refers to “the ability to take action or to choose what action to take” (according to the Cambridge Dictionary [78]). Sen [508, p.203] defines agency as “what a person is free to do and achieve in pursuit of whatever goals or values he or she regards as important”. According to Sen [507, p.51], agency is intrinsically valued: “Acting freely and being able to choose are, in this view, directly conducive to well-being”. In the field of sociology and psychology, agency is often discussed in the context of the structure versus agency debate, where structure refers to the limiting or constraining factors in a society (like social class, religion, gender, ethnicity, customs, etc.), and agency is the individual’s capacity to act independently of those structures [26, 200, 644]. Ibrahim and Alkire [254] argue that empowerment is an expansion of agency, while Kabeer [277] describes agency as related to the ability of an individual to set their own goals and act upon them. Increasing agency in one domain can lead to beneficial ripple effects on agency in other domains, and potentially on other aspects of well-being [8].

> Therefore, based on the above, the key distinction between the two concepts and working definition that this thesis adopts for each one is that autonomy refers to the ability to make decisions and act independently, being associated with individual freedom and self-determination [472], without external influence or control [156, 157, 473]; while agency refers to the capacity to act and make choices in pursuit of one’s goals [277], while also acknowledging the social and cultural contexts that shape those choices [26, 200, 644].

This thesis employs both autonomy and agency as concepts that technologies should aim to promote, in the effort to empower children and support their well-being. Given the aforementioned distinction between the terms and the employed definitions of power-to and power-over, this dissertation connects autonomy to the notion of power-to, being able to act independently e.g. to accomplish something, and agency to the notion of power-over, having control over one's own decisions and actions.

2.3.4 Reflection

Another core concept in this thesis that has been positively linked to well-being [231, 341, 454], is that of reflection[4].

> While no single definition exists, in this thesis *reflection* is used to denote the process of introspection where individuals review and analyse their thoughts, emotions, and behaviours, as per Grant et al. [210].

Based on Schön [492], reflection involves comprehending and contemplating possible actions, as well as understanding one's role in those actions. In particular, Schön's [492] foundational work distinguishes reflection as *reflection-in-action* or *reflection-on-action*, a framing which has been prevalent in HCI research [33, 525]. Reflection-in-action occurs *during* the action, in real-time [492]. In contrast, reflection-on-action is a retrospective process, conducted *after* the event has concluded. It involves reconstructing the experience based on memory, enabling individuals to analyse past events and derive insights. The work that comprises this thesis aims to support both *reflection-on-action* and *in-action*. In particular, the technologies designed and investigated in papers P II, P IV, P V, and P VI include both the aspect of reflecting in the moment, i.e. in-action, in the sense of users being able to log and reflect on their current states and emotions, as well as after an action, i.e. on-action, as the users can choose to use the described technologies to log and reflect at past events.

Below, different outcomes that have been associated with reflection are detailed. Finally, this subsection concludes with a quick venture into how HCI researchers have approached and employed the concept (for more related work and detailed explorations on interactive systems that aim to foster reflection, please refer to the publications included in this thesis).

Outcomes Linked to Reflection. Reflection can benefit well-being and personal growth [67, 231, 341, 454, 525]. It is also connected to insight and self-awareness, defined as understanding oneself on a conscious level, and recognising one's inner states [454], concepts that are directly linked to reflection: Harrington and Loffredo [230] found a positive relationship between self-awareness and psychological well-being, and in a subsequent work [231] they demonstrated that reflection, and in particular insight, is linked to improved well-being, both psychological and subjective. Moreover, reflection has been shown to improve not only self-awareness but also self-esteem [503], concepts that are linked to empowerment [393]. This further underscores the aforementioned connections among reflection, empowerment, and well-being.

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[4] Or self-reflection; this thesis predominantly uses the shorter form "reflection".

Drawing on the above, this thesis argues that by designing for empowerment for neurotypical and neurodivergent children, and for reflection, their well-being can be supported.

Furthermore, reflection can benefit empathy [270], defined as the ability to understand and share another person's feelings, thoughts, and perspectives [28, 120, 197, 418]. In particular, reflection is positively correlated with perspective-taking and empathic concern [270]. Overall, positive reflection can improve one's mood and the ability to enjoy life and helps people maintain relationships, work through past events, and develop self-identity [341]. Even reflecting on negative experiences can have health benefits [420].

Still, a distinction must be made between reflection on (negative experiences) and *rumination* [569], describing the repetitive negative thought and emotion cycles that can result from reflective thoughts [569], which comprises a counterpoint to the beneficial activity of reflection [569]. For instance, dwelling on negative thoughts and emotions can lead to increased stress [198]. This process can negatively impact perspective-taking and empathy [270] as well as well-being [231]. Rumination has also been discussed in HCI research, introduced by Niess et al. [398] in the context of fitness-tracking, and subsequently discussed by Eikey et al. [152]. In general, reflection has become a recurring theme in HCI research [44, 171]; thus, a brief report on how HCI researchers have conceptualised and employed reflection is presented below.

Designing for Reflection in HCI. Given the many benefits that have been espoused about reflection, an increasing number of researchers have been exploring technology-mediated reflection and how to design for it (e.g. [42, 44, 257, 429, 479, 480, 485]). Furthermore, previous research has demonstrated that technology-mediated reflection can support well-being [44, 257]. However, engaging in meaningful reflection can be challenging and often does not occur automatically, but needs to be encouraged from the outside [525]. Therefore, a number of HCI researchers have sought to provide a more comprehensive understanding of how to design to foster users' reflection.

For instance, Fleck and Fitzpatrick [171] proposed a structured framework for designing for reflection, which categorises its outcomes, presenting five levels of reflection from R0 to R4, each indicating a deeper level of understanding [171]. These levels range from "R0: Description", where users merely revisit or describe events, to "R4: Critical Reflection", which involves considering broader social and ethical implications. Intermediate levels include "R1: Reflective Description", which includes limited analysis but no changed perspective, and "R2: Dialogic Reflection", where new perspectives or approaches are explored. "R3: Transformative Reflection" includes revisiting an event or knowledge to change one's actions, leading to a change in practice or understanding. This framework not only helps in assessing how deeply and effectively reflection occurs in individuals but also in guiding the design of technology to support reflective processes. Fleck and Fitzpatrick [171] also provide guidelines that resonate with Slovak's [525] direction for reflection-oriented design, emphasising the integration of reflective practices into technological solutions to facilitate deeper understanding and cognitive change.

As another example, Bentvelzen et al. [44] investigated reflection-related constructs in HCI, identifying awareness, engagement, learning, behaviour change, and empowerment, among others, as integral to reflection. They identified key design resources that researchers can employ to design for reflection, including employing a temporal perspective, conversation, comparison, and discovery. They also developed the Technology-Supported Reflection Inventory (TSRI) [42], to assess a system's support for reflection.

In collaborative settings, Marcu et al. [353, 354] examined *collaborative reflection* within health teams of children, highlighting its role in improving team efficiency and effectiveness. They defined reflection as the interpretation of behaviour through data analysis, emphasising its importance in enhancing the documentation and communication processes within care teams. This thesis employs and extends the concept of "collaborative" reflection, building on Marcu et al. [354]'s work. In particular, this work explores collaborative reflection in the context of collaborative collection and/or review and communication around shared data, in the form of logging and sharing experiences and emotions by both children and their care ecosystem, as detailed in papers P II, P IV, P V and P VI.

Regarding related work on interactive systems and artefacts that seek to foster reflection for their users, a few examples are presented below, to showcase the wide range of HCI systems that employ the concept. HCI researchers have designed systems to support reflection, for symptom tracking for multiple sclerosis [23], stress management [481], and reflection on everyday experiences [257]. With respect to children and families, research efforts have, for instance, targeted children's physical well-being together with their families by fostering reflection on health data in the context of physical exercise [480] and sleep [429].

Regarding neurodivergent children, particularly those with ADHD, research relating to reflection has primarily focused on managing symptoms through self-regulation of behaviour and emotions, which includes skills like self-monitoring, goal setting, and emotional management [390, 452]. While self-regulation is an important aspect for children with ADHD, Loke et al. [335] identified the lack of digital tools that support learning on how to improve emotional self-regulation, and to that end, co-designed a reflective storytelling activity with therapists, leading to a framework for supporting reflective experiences for children with emotional trauma. Similarly, Cibrian et al. [106] engaged in participatory design with children with ADHD, their parents, and teachers towards considerations for designing wearable applications supporting the self-regulation of children with ADHD. Further, Doan et al. [137] developed CoolCraig, a mobile app designed for both children with ADHD and their caregivers to co-regulate behaviours and emotions using a smartwatch and smartphone app. However, there is still much opportunity to design technological artefacts that employ reflection as a means to improve the overall well-being of children with ADHD and their care ecosystem [535].

Building on previous research that examines technology-mediated reflection with the goal of supporting (children and caregiver) well-being, this thesis designs and investigates the impact of technologies that foster reflection as a way to support empowerment and well-being for children (both neurotypical and with ADHD) and their care ecosystems. This thesis engages in that endeavour without only focusing on addressing ADHD-related symptoms, but rather by exploring how to design technologies that support the diverse and varying needs of children and their care ecosystem.

2.3.5 Emotional Expression

Emotional expression communicates inner emotional states towards the outside [217]. It is a multifaceted phenomenon, encompassing everything from unconscious reactions, such as nonverbal cues (facial expressions), short utterances of awe or surprise, and verbal expressions such as naming emotions, to complex behaviour, such as visualising emotions by writing or drawing [217]. This process of expressing emotions has a number of important benefits. For example, expressing negative emotions can help with gaining control, regulating emotional responses, and adjusting actions [289], thus being an emotion regulation strategy. This can result in cognitive change, which in turn can increase well-being [421].

Moreover, sharing how we feel can build new relationships and intensify and strengthen existing ones [209]. Yet, the expectation of the sharer when disclosing emotions must be met by an empathetic behaviour from the listener [421], making empathy integral to effective emotional expression. This underscores the importance of mutual understanding in the communication of emotions and states between individuals. In particular, empathetic communication and mutual understanding are vital components of healthy interpersonal relationships and well-being, particularly in the context of children's care ecosystems [62, 208, 376, 557, 627]. However, neurodivergent children often encounter communication barriers within their care ecosystems [456], due to the fact that they are often confronted with additional challenges and stress compared to families with neurotypical children [565]. Therefore, there is a need to investigate how technologies could help them overcome those communication barriers, supporting their empathy and emotional expression.

Thus, HCI researchers have explored how to support emotional expression in a range of settings. For example, VR has prominently been used in a number of projects that are intended to promote emotional expression [506, 592, 594]. For instance, previous work has employed VR for autonomous expression, showing how this approach of visualising emotions can increase positive affect [592], or has combined visual emotional expression with verbal aspects via guided reflection on past challenges, demonstrating how this can help with resolving negative emotions [594]. In the context of having more than one user engage in emotional expression and sharing, Semsioglu [506] investigated collaborative experiences in a multi-user setup when representing positive and negative emotions by creating “emotion islands” in VR, showing how this can foster communication. Kitson et al. [300] conducted explorative co-design workshops with teenagers to investigate how VR could support them with positive emotion regulation. However, exploring how to use different types of technologies for supporting emotional expression via different modalities, including visual, textual, and verbal expression, for children, and especially for ADHD children, and their care ecosystem, remains underexplored.

> This thesis explores the design of technologies that allow children to freely express their emotions and experiences, defined as any type of communication (verbal, visual, or other) of their inner states towards the outside, in line with Gross' definition of emotional expression [217], in an individual capacity or by sharing that with others, in this case, with members of their care ecosystem.

In this way, this research investigates technologies that facilitate different forms of emotional expression, with the overall aim of supporting children's well-being. Concurrently, this thesis demonstrates how technology-supported emotional expression can support the well-being of children and their care ecosystem, based on the working definition of this dissertation of *emotional* well-being, *psychological* well-being and *social* well-being [290, 291].

2.4 Summary

This chapter first presented the term neurodiversity and introduced this thesis' particular focus on ADHD as a neurodevelopmental diagnosis for children, demonstrating the research interest of the HCI and CCI communities in designing technologies for them and pointing to current practices as well as gaps in the domain. Then, the use of the term care ecosystem employed throughout this thesis was introduced. Subsequently, key concepts that are integral to this thesis were discussed. I started with well-being and explained how the concept, which forms a goal of the technologies this thesis explores, is connected to the concepts presented in the following sections: empowerment, which is another goal of the technologies designed in this thesis, as well as autonomy and agency, reflection, and emotional expression. First, regarding empowerment, I elaborated on the notions of power-to and power-over and explained how this thesis proposes to afford children both power-to and power-over, by combining "empowerment through the design process" and providing "empowering experiences". I also presented a brief account of the use of the concept in HCI research. These aforementioned concepts were then connected with those of autonomy and agency, briefly outlining their different notions, as well as with the concept of reflection, discussing existing research approaches and relating these concepts back to the goals of this thesis, underlining their connections with both empowerment and well-being. Finally, I defined emotional expression and explained how it is employed in this thesis and briefly presented HCI and CCI research work around it.

The investigation of these core concepts that this chapter engaged in shows that there are many aspects that can be considered when aiming to improve the well-being of children and their care ecosystem through their interactions with technologies, ranging from emotional expression and reflection, to supporting children's agency and affording them power-over their decisions and environment. Especially given the connections between these core concepts, it is important to consider how they relate to each other in a given context. To show how these complex interrelations have been addressed in the publications that comprise this dissertation, an example is presented below of how these concepts were employed in one of the papers, namely in the study with MagiBricks (P III). In particular, in the context of supporting children's play with their grandparents reported in paper P III, where the focus is on facili-

Table 2.2 Overview of the core concepts that the technologies included in this thesis explicitly addressed in their design and the corresponding papers. Please note that the papers' findings can show links to other concepts, which are not depicted in this Table. Please also note that empowerment and well-being are addressed in all the papers of this thesis, being the main goals of this research, and are therefore highlighted separately.

Concept	Papers
Empowerment	P I, P II, P III, P IV, P V, P VI
Well-being	P I, P II, P III, P IV, P V, P VI
Agency	P III, P IV, P V, P VI
Autonomy	P IV, P V, P VI
Emotional expression	P IV, P V, P VI
Power-over	P V, P VI
Power-to	P V, P VI
Reflection	P IV, P V, P VI

tating intergenerational playful interactions in distributed settings through a smart toy, the core concepts that were considered were well-being, empowerment, and agency. The reason for exploring these concepts in the context of grandparent-grandchild playful interactions was that empowerment and agency not only link to each other [254] but also to the power dynamics between older caregivers and younger children. Therefore, our aim was to study how an augmented version of an otherwise regular and familiar toy that allows for mutual awareness and control would impact the traditional roles of "all-knowing" adults and "all-learning" children [142]. Indeed, our findings showed that playing with the smart toy we developed empowered children and supported their agency by allowing them to have mutual awareness and control during playtime, enabling them to take leading roles in their interactions with their grandparents. Connecting this to the other key goal of fostering well-being, we aimed to engage children and their grandparents in playtime that supported their communication and feelings of connection to each other, thus supporting: i) their psychological well-being by nurturing their relationship, ii) their emotional well-being, by delivering an engaging and satisfactory activity, and iii) their social well-being, since playing with the developed smart toy together increased their feelings of connectedness and belonging. Similar to the above example, different constellations of the core concepts were employed in the design of the other prototypes, corresponding to specific papers of this thesis. Table 2.2 provides an overview of this, while Table 2.1 presents the connections between these core concepts. Finally, the Discussion available in the third part of this thesis specifically details how the features of these prototypes supported well-being and empowerment.

Overall, this thesis builds on and extends previous HCI and CCI research that seeks to empower children and support their well-being, which is an inherent interest of these communities [285, 325, 578]. To that end, this research actively includes both children (neurotypical and with ADHD) and their care ecosystem in the design and evaluation process but also as end users of technologies, delivering technologies that can be used by multiple care ecosystem stakeholders, both individually and collaboratively, thus extending previous approaches. Additionally, this thesis explores under-researched but important aspects, including designing based on neurodivergent interests, and in that respect, proposing "designing beyond symptoms" for ADHD children and their care ecosystems. Finally, it investigates the longitudinal impact of technologies designed to support the overall well-being of both neurotypical and ADHD children and their care ecosystem, discussing the real-life impact and (ethical) considerations when integrating such technologies that bring the ecosystem together in real-life settings.

CHAPTER 3

Research Questions & Methodology

This thesis investigates how to design technologies for and with children, neurotypical and with ADHD, and their care ecosystems (e.g. families, therapists) that can empower them and support their well-being. The work presented is interdisciplinary, situated at the intersection of HCI, CCI, and family informatics research. First, it aims to explore how to design technologies that support the needs and interests of both children and their care ecosystem. Second, it explores how to design such technologies by actively involving both ADHD and neurotypical children, and members of their care ecosystem. In that respect, this research particularly considers the power dynamics between children and their caregivers, with the goal to afford children both power-to and power-over. Thus, the primary research question (RQ) to be addressed by this thesis is:

> **Primary RQ:** ***How can technologies be designed to empower and support the well-being of both ADHD and neurotypical children and their care ecosystem?***

In order to answer this primary RQ, a user-centred design process [403] was followed (Figure 3.1). This involved understanding the user, then designing for them, and finally building and evaluating the prototypes. It is important to note that, although these steps appear sequential, the process was inherently iterative. This iterative process resulted in a deeper understanding following each study conducted in the context of this PhD, enriching the subsequent system's design and features. This reflects the thesis's wider aim to investigate various technologies that empower and support children and their care ecosystem, rather than focusing on a single technology or design. The three main stages of this thesis' process are visualised in Figure 3.1, corresponding to a different research question each: RQ1, RQ2, or RQ3, which, taken together, address the primary RQ introduced above. Concurrently, a participatory and inclusive approach was adopted for this thesis, where ADHD children, neurotypical children, parents, teachers, and therapists were involved throughout, in the form of interviews, focus groups, co-design sessions, prototype evaluations, user studies, and field studies.

Next, the three research questions are described, along with their motivations based on specific research gaps (RGs), and the methods used to address them in more detail.

3.1 RQ1 Formulation

Although approximately three-quarters of research in CCI does not focus on specific characteristics among children, e.g. physical or neurological diagnoses, according to a recent literature review published in the domain [325], there has been growing interest in HCI and CCI in researching how to support and design for neurodivergent children. This is evidenced

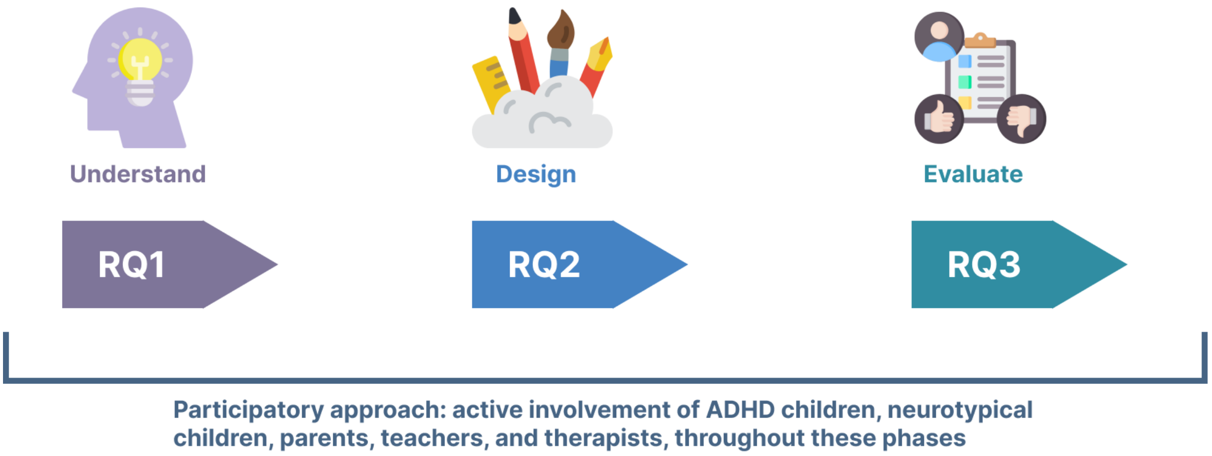

Fig. 3.1 A visualisation of the relationship between the three research questions addressed in this thesis, structured in three phases: understand, design, and evaluate.

by the proliferation of literature reviews on the topic (e.g. [55, 102, 103, 542]). Overall, autism has been one of the most frequently addressed neurodevelopmental diagnoses [325] (e.g. [29, 160, 249]). In contrast, despite ADHD being the most common neurodevelopmental condition in children [125, 470, 639], there has been considerably less research conducted about technologies to support ADHD children and their caregivers, which was a key motivator for this thesis. Examining the role that both children and adults take in the design of technologies has been identified as an important topic in CCI [325]. In particular, active participation of caregivers, teachers, and therapists is important when designing for children in general [325], with literature detailing the significance of involving these groups in the design process for neurodivergent children in particular [55]. Furthermore, it is crucial to investigate how these roles influence children's and their care ecosystem's lived experiences with technologies and how the support that current technologies provide corresponds to their everyday experiences and needs, in order to build a systematic understanding of the opportunities and challenges involved when designing for their overall well-being. However, there is a lack of systematic knowledge around technologies that have been designed and developed to support children with ADHD and their caregivers, and of their roles in that process, as well as how this maps to their lived experiences with technology use (*RG 1*). (For an overview of the RGs this thesis addresses please see Table 3.1).

Based on the above, the following RQ was formulated:

RQ1: *What is the role of children with ADHD and their care ecosystem in the design and evaluation of technologies for them and how does this map to their lived experiences and needs?*

In order to start addressing **RQ1**, i.e. investigate the roles of ADHD children and their care ecosystem in the creation of technologies in HCI, a systematic literature review was initially conducted (see paper P I). We systematically analysed existing HCI literature on technologies for children with ADHD, specifically focusing on the role and involvement of ADHD children and their care ecosystem. From this comprehensive analysis, we formulated an inclusive design agenda for ADHD children and their care ecosystem.

To address the second part of **RQ1**, an interview study was then conducted, involving ADHD children, parents, therapists, and teachers. This is the study that comprises the first step in paper P II, visualised in Figure PII.2. This interview study investigated the lived experiences and roles of children with ADHD and their care ecosystem, as well as the role of technology in their everyday lives. Conducting an interview study was an important first step in that process, in order to obtain an in-depth understanding of ADHD children and their care ecosystems' lived experiences, drawing on the findings identified in the literature review. The remaining three studies (step 2 to 4 in Figure PII.2) reported in P II correspond to **RQ2**, and are elaborated upon in the section below.

3.2 RQ2 Formulation

Our systematic literature review (paper P I) uncovered a number of opportunities where further research could be conducted. The next two research questions were formulated to directly address these opportunities. First, much of the existing research has only involved children with ADHD and their care ecosystem in the design, development, and evaluation of technologies in a limited way (*RG 2)*. In particular, few studies consistently involved both ADHD children and their care ecosystem members throughout their design and evaluation processes. Second, there has been little research conducted that has considered the wider remit of all the various stakeholders involved or technologies that have been designed to support collaborative use (*RG 3)*. To illustrate, there is a lack of technologies that can be used by both ADHD and neurotypical children together with their family *and* other members of their care ecosystem, such as their teachers or therapists. This means that there are few collaborative technologies that have multiple groups within the children's care ecosystem as their target users. Third, most technologies have focused on addressing symptoms and diagnosis, rather than designing technologies that but are rather driven by ADHD children's interests or prioritising empowerment and playful interactions (*RG* 4). Thus, there is a need to redress this balance, to not only design technologies for specific symptoms for neurodivergent individuals, such as ADHD children, but also driven by their interests, needs, and desires [542–544]. This involves "establishing their agency" in defining technologies that are appropriate for them [542]. In the domain of technologies for children with autism, Spiel et al.'s [542] review showed that these technologies do not address their needs, but rather embody the expectations of a neurotypical society. While Spiel et al. [542] focused on autism, this thesis explores this challenge in the context of children with ADHD, highlighting the intrinsic link between establishing agency and fostering autonomy for ADHD children. In particular, this thesis investigates how to design technologies for ADHD *and* neurotypical children that *empower* them by affording them both "power-to", creating "new possibilities" [467] and "power-over", by allowing them to control their decisions [254] and shape technology design [467].

Based on the above, the second RQ was formulated:

RQ2: *How can technologies be designed to empower ADHD and neurotypical children and their care ecosystem, by affording them both power-to and power-over?*

In order to begin addressing **RQ2**, a series of qualitative studies were conducted (see paper P II for the pertinent publication, and in particular steps 2, 3, and 4 in Figure PII.2 for a visualisation). These studies investigated how to *design beyond symptoms* with ADHD children and their care ecosystem, thus directly addressing RG 4. The series of studies included, apart from the interview study that corresponded to RQ1, a pilot co-design session, an interview, co-design sessions and a focus group, involving the various care ecosystem stakeholders in these steps. This multi-step, multi-stakeholder approach was chosen to actively involve both children and their care ecosystem and ensure their perspectives are considered, particularly through the co-design workshops for the children. The aforementioned process contributed insights into how technologies can be designed in a way that empowers both neurotypical children and children with ADHD, both by providing "empowering experiences" while also providing "empowerment through design process" [491], thus contributing to addressing RQ2. It should be noted that all publications comprising this cumulative thesis address RG 2 and RG 3, by actively involving both children and at least one other care ecosystem member, and by investigating technologies that include collaborative aspects of use within the care ecosystem.

Moreover, as part of addressing **RQ2**, and in particular exploring technologies that more broadly empower children and their care ecosystem by delivering empowering experiences, this thesis contributes the design, development, and evaluation of MagiBricks. This is a smart toy system that allows children to play with members of their care ecosystem in distributed settings. Our aim in building this was to support playful interactions and communication among children and members of their care ecosystem. In the context of the publication P III included in this thesis, we engaged children with an important member of their care ecosystem: grandparents, given the importance of a close grandparent-grandchild relationship for mental health [265, 469] and the benefits of their playful interactions to their social communication and well-being [114, 305, 306, 358, 453]. This study showed how such a smart toy, and particularly the mutual awareness and feedback it allowed for, empowered even younger children to take leading roles in their playful interactions with their grandparents while fostering connectedness.

3.3 RQ3 Formulation

Based on the work conducted in the context of paper P II, the following aspects were found to be important with regard to how to support the well-being of children and their care ecosystem: i) communication and interpersonal interactions among children and their care ecosystem, ii) emotional expression, and iii) reflection. This concurs with previous research that has demonstrated the importance of those aspects with regards to well-being, e.g. of communication and interpersonal interactions [62, 208, 209, 376, 557, 627], emotional expression [421], and reflection [67, 231, 341, 454, 525]. However, there is limited knowledge on how technologies can employ emotional expression, reflection as a means to support communication and well-being of both neurotypical and ADHD children and their care ecosystem (*RG 5).*

The findings from our literature review indicate that the types of technologies that children engage with increasingly vary, ranging from mobile and tablet to virtual reality (VR) applications – for children entering preadolescence[1] – with the widespread integration of VR in the consumer market, as well as smart toys and other tangibles. Each of these types of technologies provides different affordances and potential benefits in the setting of designing technologies that children and their care ecosystem use. Mobile and tablet applications are easily accessible and can ensure portability and use across different contexts (e.g. home, school, therapy settings); VR technologies can create controllable, immersive and distraction-free spaces [336] which can evoke visceral emotional responses through a sense of "being there", called presence [461]; tangible systems are known to support collaborative play and social communication [338, 356, 584], and can foster reflection [122]. Similar to how individuals within a child's care ecosystem might have distinct needs and interests from the other ecosystem members, it is important to consider how various types of technologies can support the different needs and interests of both neurotypical and neurodivergent children. Thus, this thesis aims to explore how a range of technologies can empower children and their care ecosystem and support their well-being in different ways – and particularly to identify them and investigate their impact. Additionally, this thesis investigates how to design technologies that allow both individual as well as collaborative/joint use by children and their care ecosystem members. Especially the collaborative use aspect directly addresses RG 3, as well as the aspect of supporting communication of RG 5, through joint interactions with technologies. This is also in line with previous work that has underlined the importance of mutual activities and joint time together for both parents and their children [50, 239], and particularly work that has explored joint media engagement, i.e. the collaborative interactions of children and their caregivers with technologies (e.g. [49, 238, 480, 596, 632, 633]).

Based on the above, the final RQ that this thesis seeks to address is:

RQ3: *How can different technologies that allow individual and/or collaborative emotional expression and reflection support the well-being of ADHD and neurotypical children, and their care ecosystem?*

Addressing both **RQ2** and **RQ3**, this thesis engages in the following. First, it contributes a qualitative study with TeenWorlds, a VR multiplayer application that allows teenagers to emotionally express, both visually and verbally, together with members of their care ecosystem, namely their parents or peers (see P IV). Moreover, a study was conducted where the MoodGems prototype was iteratively designed and evaluated. MoodGems is a set of modular, portable, situated displays that allow children to log and reflect on their emotions and routines, and select whether to share those with their family (see P V). Finally, a final series of studies were conducted, including the iterative design, development, and longitudinal evaluation via a field study of REMEMO, a mobile application, tailored to each care ecosystem member (children, parents, teachers, therapists). The findings show how such a technology design can impact the communication and well-being of the care ecosystem stakeholders and, in particular, how it supports children's agency and empowerment (see P VI). Publications P V

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[1] Despite small variations, the majority of VR headsets state that their users should be at least 12 or 13 years old, e.g. https://www.meta.com/quest/safety-center/.

and P VI thus address RG 4, while publications P IV, P V and P VI address RG 5 (see Table 3.1). Thus, by exploring how to design for technology-supported emotional expression and reflection, in both individual and collaborative settings, this thesis addresses the primary RQ of how to design technologies that *empower and support the well-being* of children in their care ecosystem.

Overall, by investigating technologies that support *both* well-being *and* empowerment for children and their care ecosystems, this thesis explores the relationship between them [76, 612]. This is in line with the "designing beyond symptoms" (see RG 4)) approach of this dissertation, which seeks to support overall well-being *by empowering* ADHD and neurotypical children to both shape technology design (empowerment through the design process [491]) as well as by delivering empowering experiences [491] in their engagement with technologies.

3.4 A Note on Methods & Epistemology

Overall, this thesis employs a variety of methods in order to address the multi-faceted RQs. Those include both qualitative and mixed methods, as well as participatory approaches such as co-design, and finally, prototype evaluations, user studies, and field studies of the designed technologies. Qualitative data analysis methods were used for the analysis of the data collected in these various studies in order to gain deep insights into the experiences and needs of both neurotypical and ADHD children within their care ecosystems, using thematic analysis [51]. This approach allows for a nuanced understanding and rich data collection. This methodological approach is supported by the seminal works of Martens [375] and Creswell [116], emphasising the value of qualitative research for exploring complex phenomena within their contexts. The mixed-methods approach, blending quantitative surveys with qualitative observations was used to provide a comprehensive view of the studies where quantitative data was additionally collected, e.g. through standardised questionnaires. Greene et al. [211] and Creswell et al. [117] also highlight the strengths of using mixed methods to achieve both breadth and depth of understanding. Moreover, by engaging directly with children (both neurotypical and with ADHD) and their care ecosystems, participatory approaches such as co-design sessions were instrumental in the iterative and inclusive development of the technologies presented in this thesis. Sanders and Stappers [482] also emphasise the value of using participatory approaches in creating more inclusive technologies and supporting "collective creativity", validating this approach. In line with this, participatory approaches to the design *and* evaluation of technologies that have children as their target users have been used widely already since the 1990s [142]. To assess the real-world applicability and impact of a designed technology, the approach of conducting a field deployment, also known as "in-the-wild" evaluations and studies, was adopted. This method provides authentic insights into users' interaction with technology in-situ, outside controlled environments, which enabled RQ3 to be addressed. Rogers et al. [465] discuss the emergence of these studies in HCI to understand how technology fits into users' lives, supporting this evaluative approach.

In this thesis, both an interpretivist and a (social) constructivist approach were used to address the multifaceted nature of our research questions. The interpretivist stance allows for a deep understanding of the subjective experiences, needs, and perspectives of children (both neurotypical and with ADHD) and their care ecosystems, by “understand[ing] phenomena from the meaning that the participants assign to them” [407, p.5], emphasising the value of the lived experiences of children and their care ecosystem in informing technology design. Through qualitative methods such as interviews and observations conducted as part of our user studies, the nuanced dynamics within care ecosystems and how these influence and are influenced by technology were interpreted. Simultaneously, this dissertation adopted a social constructivist approach, to actively involve the children and their care ecosystems in the design process. Social constructivism is often combined with interpretivism (see Mertens [375]). This stance acknowledges the importance of social interactions and different contexts in the co-construction of knowledge and solutions, empowering children to shape the technologies that affect their well-being, by participating in both their design and their evaluation. In using the participatory methodology of co-design, a collaborative creation process was enabled, ensuring the technologies developed were rooted in the actual needs and aspirations of both children and their care ecosystem. Thus, this work attempts to understand the complex world of lived experience from the point of view of those who inhabit it [496], relying “as much as possible on the participants’ views of the situation” [116, p.20] and as researchers, looking “for the complexity of views” [116, p.20] of the participants experiences and how these shape technology design and use.

Concurrently, this thesis acknowledges the foundations of positivism, which emphasises objective measurements and the empirical validation of hypotheses through quantitative methods [118, 498]. Drawing from these principles, this work has incorporated mixed methods that provide empirical validation of our findings [269], thereby extending its methodological framework to include a postpositivist stance. Unlike strict positivism, which often assumes a completely objective reality, postpositivism accepts that while striving for objectivity, our observations can be influenced by our perspectives [115]. Thus, while employing empirical observations and quantitative analyses, this thesis also recognises the inherent limitations and biases in such measures. This nuanced approach aligns with postpositivist philosophy, which pragmatically blends empirical rigour with an acknowledgement of the subjective elements inherent in human-computer interaction research [115].

By integrating these stances, the thesis not only captures a rich understanding of the participants’ worlds but also engages them in creating meaningful, empowering technological solutions. This multifaceted epistemological approach is essential for the comprehensive exploration of how technology can empower and support the well-being of children and their care ecosystems, reflecting both their lived experiences and their active participation in the technology creation process. Overall, this highlights our commitment to understanding the nuanced, subjective experiences of our participants, alongside the collaborative, co-constructive processes emphasised by social constructivism, and supported by the empirical rigour of postpositivism.

Before moving forward, I make the following clarification. The research presented in this thesis addresses both specific neurodivergent populations, i.e. children with ADHD, as well as neurotypical children. Additionally, it addresses different age groups, i.e. children (both younger children and teenagers), adults, and older adults. This thesis does not aim to propose one unique solution towards supporting these diverse user groups, but rather to i) show how their needs and interests can be explored and satisfied in technology design through the methodology employed in this thesis, and ii) identify specific features of technologies that have the potential to support the well-being and empower children (both with and without ADHD) and their care ecosystems.

Table 3.1 Research gaps, questions, and corresponding papers in this thesis that address them.

Research Gaps	Research Questions	Papers
RG1: Lack of systematic knowledge around technologies that have been designed and developed by the HCI community to support children with ADHD and their caregivers, and of their roles in that process, as well as how this maps to their lived experiences with technology use.	**RQ1:** *What is the role of children with ADHD and their care ecosystem in the design and evaluation of technologies for them and how does this map to their lived experiences and needs?*	P I, P II
RG2: Children with ADHD and their care ecosystem are not sufficiently involved in the design, development, and evaluation of technologies.	**RQ2:** *How can technologies be designed to empower ADHD and neurotypical children and their care ecosystem, by affording them both power-to and power-over?*	P II, P IV, P V, P VI
RG3: The majority of existing work does not address multiple target groups (neurotypical and neurodivergent children and multiple members of their care ecosystem) nor allows collaborative use.		P II, P III, P IV, P V, P VI
RG4: Lack of technologies that do not solely focus on addressing symptoms but are rather driven by ADHD children's interests.		P II, P V, P VI
RG5: Limited knowledge of how the concepts of emotional expression and reflection can be employed in the design of different technologies as a means to support communication and well-being of both neurotypical and ADHD children and their care ecosystem.	**RQ3:** *How can different technologies that allow individual and/or collaborative emotional expression and reflection support the well-being of ADHD and neurotypical children, and their care ecosystem?*	P IV, P V, P VI

PART II

PUBLICATIONS

Transition I

The first two papers included in this thesis form the conceptual understanding that guides the rest of the work. In that way, paper P I and the interview study reported in paper P II address the *Understand* aspect of Figure 3.1 (RQ1), while the remaining studies reported in paper P II begin to address the *Design* aspect of Figure 3.1 (RQ2). The specific care ecosystem stakeholders that are involved in these two publications are ADHD children, neurotypical children, parents, siblings, teachers, and therapists.

As a whole, papers P I and P II contribute to our understanding of how ADHD children and their care ecosystem have been involved in technology design, evaluation, and use, how their complex roles affect their relationships and their interactions with technologies in everyday settings, with paper P II taking this understanding a step further and actively engaging with the care ecosystem stakeholders in order to investigate how technologies can empower them.

PUBLICATION P I

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

The contents of this chapter originally appeared in: **Evropi Stefanidi**, Johannes Schöning, Sebastian S. Feger, Paul Marshall, Yvonne Rogers, and Jasmin Niess. 2022. Designing for Care Ecosystems: a Literature Review of Technologies for Children with ADHD. In Proceedings of the 21st Annual ACM Interaction Design and Children Conference (IDC ’22). Association for Computing Machinery, New York, NY, USA, 13–25.
https://doi.org/10.1145/3501712.3529746

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.

Contributions

This systematic review of HCI literature on the topic of technologies for ADHD children contributes the following. First, a systematic analysis charting the state-of-the-art in HCI literature focusing on children with ADHD, considering the role of their care ecosystem. Second, identification of current trends and gaps that suggest how the field should move forward. Finally, considerations for designing future systems that empower and promote the well-being of children with ADHD and their care ecosystem.

PI.1 Introduction

Attention deficit hyperactivity disorder (ADHD) [621] is the most prevalent mental health diagnosis in children [470, 639]. ADHD has an occurrence of approximately 5% worldwide [436], a number which exhibits significant variability. Children with ADHD exhibit symptoms across two broad areas: inattention and hyperactivity/impulsivity [19]. 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. [428] 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. [536] aimed to support families of children with ADHD to establish effective morning and bedtime routines. Zuckerman et al. [648] 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 [34], 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 [34]. 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 [105]. 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. [107] 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 [328]. Weisz et al. [607] 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. [11] 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 [314]. 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 [107, 607]. Nevertheless, variations can be found in ADHD literature; for instance, Cibrian et al. [105] 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 [529], referring to the inclusion of the sociality and spatiality of the environment where technologies are integrated [529]. The importance of considering all stakeholders rather than a single user was also discussed by Forlizzi [175], 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 [105], and who strongly influence quality of life, social activity, and success in school environments [227, 427].

Specific guidelines for design sessions with developmentally diverse children in general have often highlighted the need to actively involve caregivers, teachers and therapists [55]. 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 [532]). Moreover, we reveal trends regarding the engagement of the care ecosystem in the design, development and user study phases of the proposed systems.

We found 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 [105, 227, 427]. 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.

PI.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, and present related work on technology design for individuals with ADHD.

PI.2.1 Attention deficit hyperactivity disorder (ADHD)

ADHD is categorised into three types: predominantly inattentive (ADHD-I), hyperactive-impulsive (ADHD-HI), or combined presentation (ADHD-C) [212], 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 [163, 537].

To date, standard treatment for ADHD includes mainly psychosocial treatments (behavioural or cognitive-behavioural), medication treatment with stimulants (mostly methylphenidate), and their combination [435, 558, 576]. For example, psychosocial treatments for ADHD focus on the parents, the teacher, and the child, with variants of (cognitive) behavioural therapy [576], 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) [359]. For children with ADHD, this approach can often help improve behaviour and self-control [359].

PI.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 [543]. 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. [55] 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. [542], 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. [34] 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. [343] 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.

PI.2.3 Technology Design for People with ADHD

Sonne et al.'s [535] 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. [535] 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. [102] 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. [102] classify interactive technology research based on the role of technology in the following domains: i) diagnosis and assessment of ADHD, ii) training cognition and

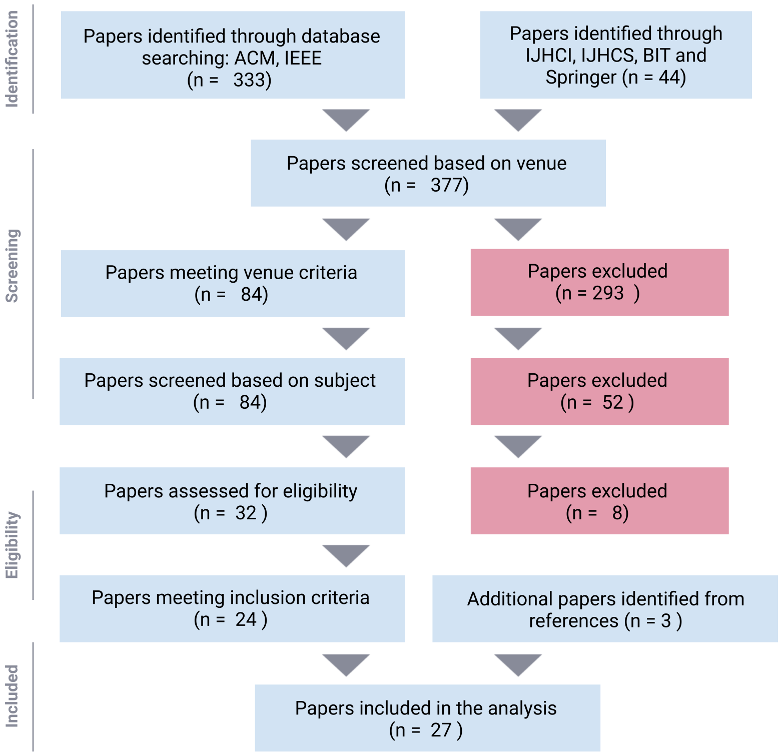

Fig. PI.2 Adapted PRISMA statement, structured in four phases: (i) identification, (ii) screening, (iii) eligibility, and (iv) inclusion of papers.

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. [103] 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. [535] and Cibrian et al. [102] 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 [105, 227, 427]. Additionally, Cibrian et al.'s [103] 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.

PI.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 [381], structured in four main phases: (i) identification, (ii) screening, (iii) eligibility, and (iv) inclusion of papers (see Figure PI.2).

PI.3.1 Literature Selection

All studies published in the top twenty HCI journals and conferences based on the Google Scholar Ranking [207] were analysed, similar to other literature reviews published within the HCI community (e.g. [80, 226]). 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 PI.3). 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

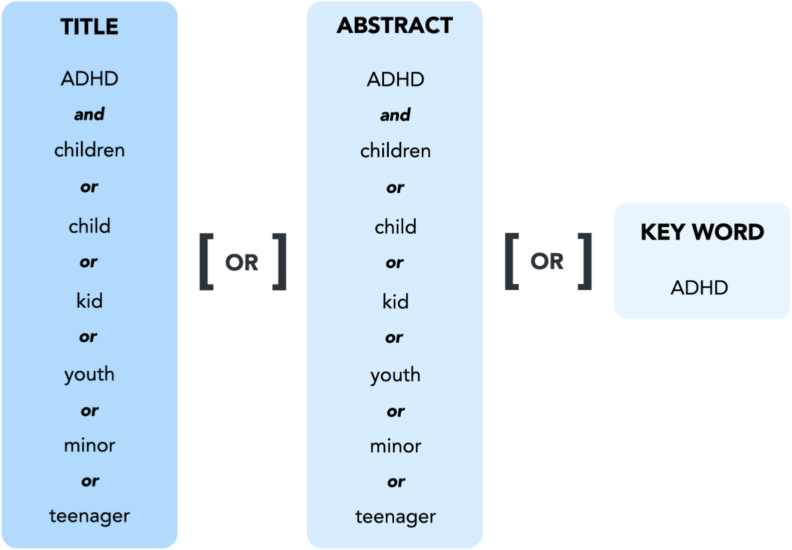

Fig. PI.3 Visualisation of our search query.

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 [619], 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.

PI.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.

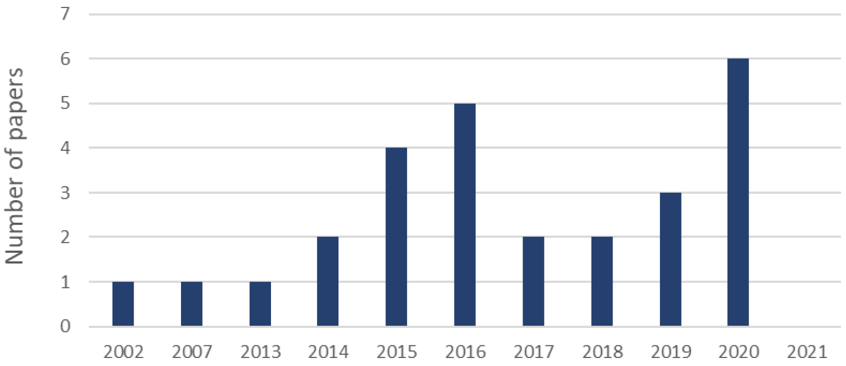

Fig. PI.4 Number of papers according to year of publication.

Table PI.2 The applicable coding categories for each paper in our corpus.

Category	**Codes & respective papers**
Target group	Children with ADHD [18, 72, 86, 91, 93, 106, 158, 350, 367, 412, 528, 532, 533, 537, 562, 606, 645, 647], Children with ADHD-I and -C [281], Children with ADHD-HI and -C [267], Children with ADHD and their families [411, 534, 536], Children with ADHD and their caregivers [137, 535], Caregivers of children with ADHD [204], Not clear/not specified [380]
Involved in design & development	Children with ADHD [72, 106, 137, 158, 534, 537, 562, 606, 645, 647], Experts [18, 72, 91, 267, 411, 412, 532–534, 536, 537, 606, 645, 647], Parents of children with ADHD [411, 534, 536, 606, 645, 647], Caregivers [106, 137, 412, 537, 562], Children not diagnosed with ADHD [412], Not clear/not specified [86, 93, 204, 281, 350, 367, 528], Not applicable [380, 535]
Involved in user studies	Children with ADHD [72, 86, 267, 281, 412, 528, 533, 534, 536, 537, 606, 647], Experts [18, 86, 267], Parents of children with ADHD [72, 267, 412, 534, 536, 606, 647], Caregivers [86, 204, 528], Adults not diagnosed with ADHD [204, 528, 532], Children not diagnosed with ADHD [93, 350, 537], Future evaluation plans [91, 367], No study reported [106, 137, 158, 411, 562, 645], Not applicable [380, 535]

Methods	User requirement elicitation [158, 411, 537, 606, 645, 647], Focus group [106, 158], Brainstorming [158], Prototyping [158, 532, 562, 606], Workshop [106, 137, 562], Questionnaire [412, 534, 647], Personas & scenarios [137], Lab study [18, 86, 91, 204, 267, 350, 528, 532, 533, 536], Field study [72, 93, 281, 528, 536, 647], Post-experience interviews [86, 267, 412, 528, 533, 534, 536, 647]
Context of use: situation	Execution of morning routines [606, 645, 647], Execution of morning & bedtime routines [534, 536], Execution of daily home routine [411], Understanding ADHD [204], Going to sleep [535], Calming down [532, 533], Assistance in healthcare, school, and socialisation contexts [562], Self-regulation (e.g. mood, reflection, emotion) [106, 137, 367, 562], Neurofeedback therapy [18], Learning (e.g. mathematics instruction, e-learning, in school) [91, 281, 350, 537], Regaining Attention [537], Controlling impulsive speaking [528], ADHD assessment [267, 380], Multiple contexts specified [72], Not clear/not specified [86, 93, 412]
Context of use: location	Home [411, 534–536, 606, 645, 647], School/classroom [281, 367, 380, 528, 537], Multiple contexts specified (e.g. home, shower, school, clinic) [72, 158], Online learning environment [91], Not specified [18, 86, 93, 106, 137, 204, 267, 350, 412, 532, 533, 562]

Contribution type	Design guidelines, considerations or insights [86, 106, 532, 534, 535, 537, 562, 606, 645], System, tool or algorithm [18, 72, 91, 93, 137, 158, 204, 267, 281, 350, 367, 380, 411, 412, 528, 532–537, 606, 647]
Technology type	Tangible [606, 645, 647], Mobile [137, 411, 532–534, 536], Biofeedback [93, 532, 533], 3D-printing [267], Brain-Computer Interface [18, 412], Wearables [106, 137, 158, 267, 528, 537, 562], Voice-bot [411], Neurofeedback [18, 367], PC software [204, 281, 350], Touch screen [267], Tablet [72], Machine Learning Model [91, 380], Haptic Feedback [158], Virtual Reality [93]
Objective	Executive functioning [606], Calming down by breath control [532, 533], Morning routines [645, 647], Morning & bedtime routines [534, 536], Avoid blurting [528], Self-regulation (behaviour, emotions) [106, 137, 367], Daily routine tasks [411], Social motivation [18], Adherence to therapy [18], ADHD assessment [267, 380], Improve or regain attention and time on task [93, 281, 350, 412, 537], Conceptualise and tell time [158], Detect or predict attention [91, 350], Foster understanding of ADHD [204], Support therapeutic work [86], Reading ability [412], Improve behaviour inhibition [412], Sleep assistance [535], Improve learnability [72]

Measures	Effects on ADHD-related states & traits [93, 412, 528, 534, 536, 537, 647],
	System usability [72, 86], Intermediate evaluation [18, 204, 267, 281, 350, 528, 532, 537, 606],
	General perception (feedback, satisfaction, acceptance) [86, 528, 533, 647]

PI.4 Results

The following section presents the results of our analysis, structured according to our research questions. For an overview of categories and associated codes see Table PI.2, as well as Table PI.3 and Figures PI.9, PI.10 for user study data.

PI.4.1 Distribution per Year, Venue and Region

Figure PI.4 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 PI.5) and Table PI.3, 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 PI.6. 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.

PI.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 [105, 227, 427]. 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

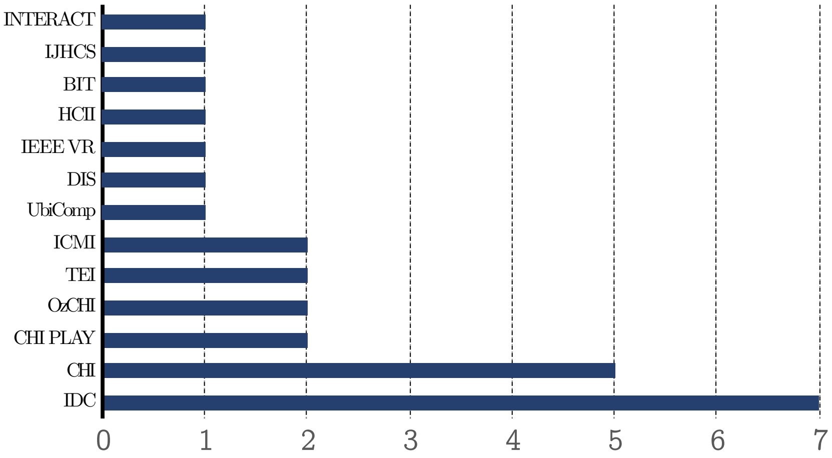

Fig. PI.5 Distribution of papers across venues.

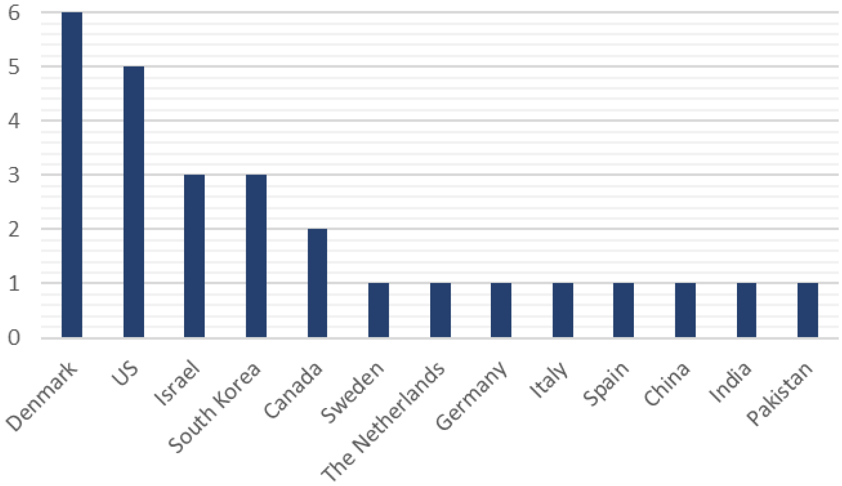

Fig. PI.6 Geographical distribution of the papers.

combined [281], or the hyperactive/impulsive and combined presentations of ADHD [267]. Further, one paper [204] did not target children with ADHD but rather people surrounding them, aiming to promote understanding of the condition, and one paper [380] 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 [463]. 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

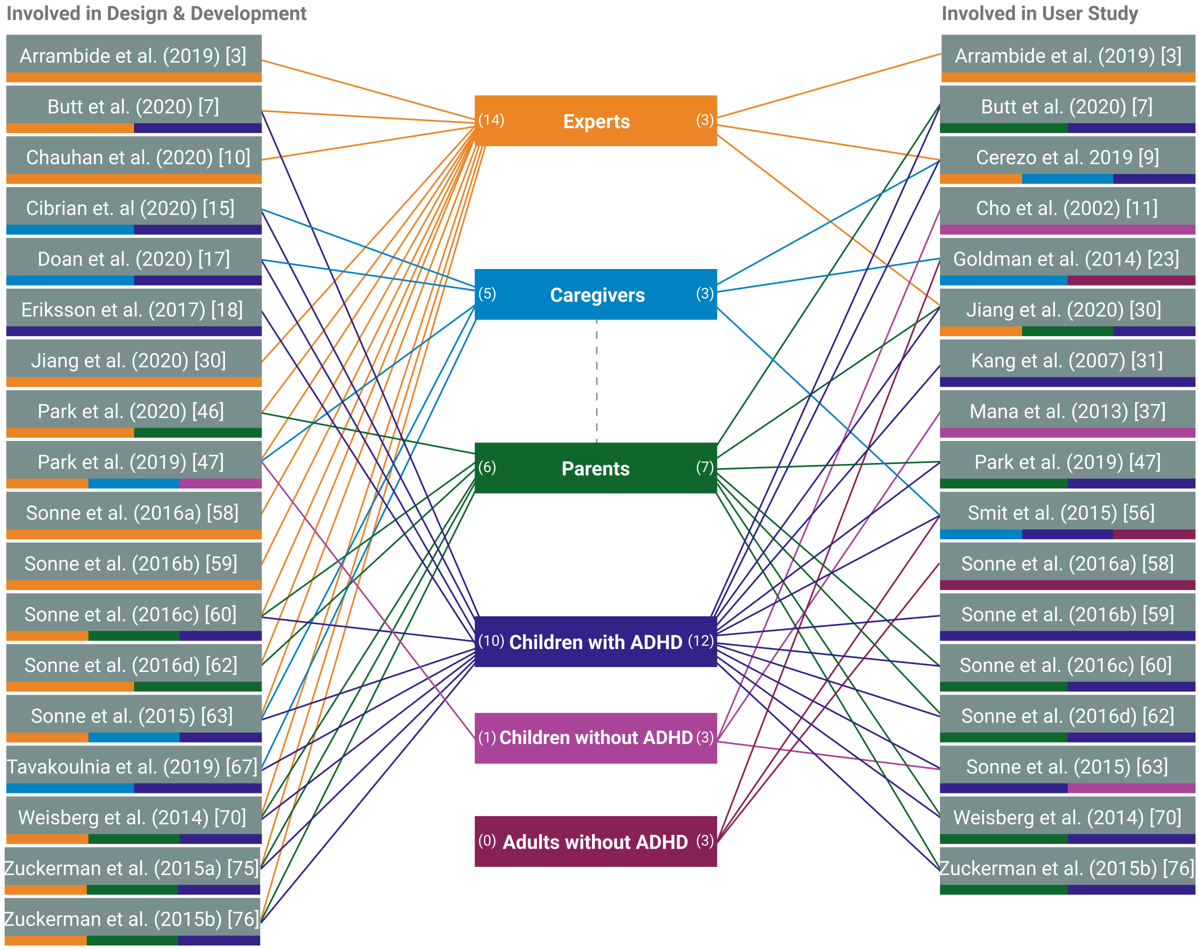

Fig. PI.7 Stakeholders involved in the design, development and user study phases.

reported in the papers (second and third row of Table PI.2). 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 PI.7 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. [18], who used experts), others used completely different groups in the two phases (e.g. Sonne et al. [532], 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.

PI.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 PI.2. To illustrate, Sonne et al. [532], 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 PI.2). 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 [532, 534, 535, 537, 606]. As can be seen in Table PI.2, 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. [532] 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.

PI.4.4 Methods, User Study Data, and Measures

Understanding the methods the papers in our corpus used, how they conducted their studies, and what they measured 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 [158], and one other reported creating

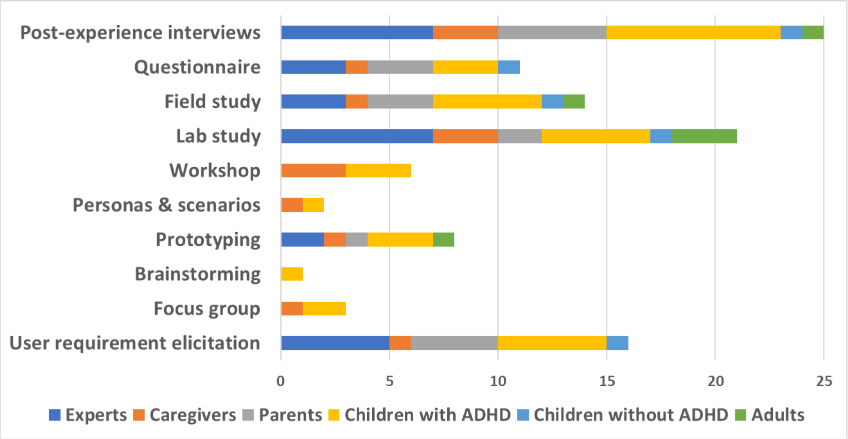

Fig. PI.8 Number of stakeholders from each group involved in each of the identified methods.

personas and scenarios [137]. Interesting correlations can be drawn from Figure PI.8. 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 either experts, adults without ADHD, or children without ADHD. The most commonly used method involving children with ADHD 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 PI.3 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. [72] did not specify the number of parents, while Cerezo et al. [86] did not mention the number of participating educators. Sonne et al. [534, 536] mention "the family" as participants, without specifying its size or structure. We report on participants for the two papers by Sonne et al. [534, 536] together, as this work by Sonne et al. [534] is a follow-up of another paper by Sonne et al. [536]. However, it should be noted that the follow-up study [534] 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 PI.3). For instance, Sonne et al. [537] 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. [562] 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 PI.9, 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

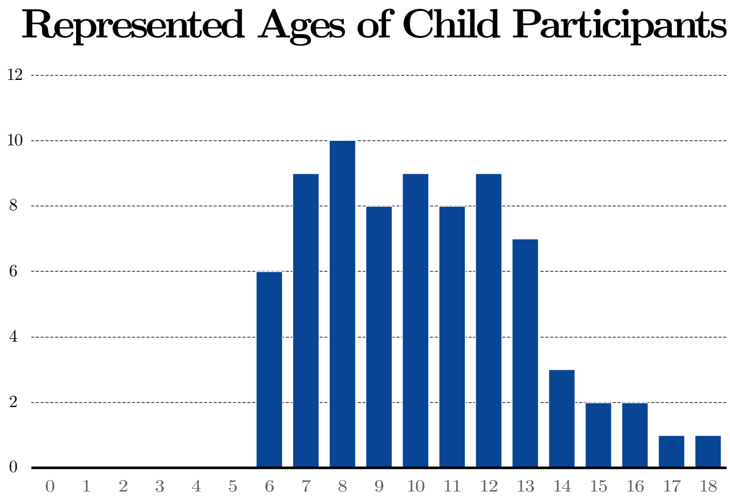

Fig. PI.9 Number of papers for each age.

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 PI.10). In particular, the user study from Park et al. [411] is described as future work, and in Sonne et al. [535] 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 (last row in Table PI.2).

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. [537] and Smit et al. [528] 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. [528] 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. [86] was coded as both evaluating system usability and users' general perception to their tangible tabletop activities with children with ADHD. They showed

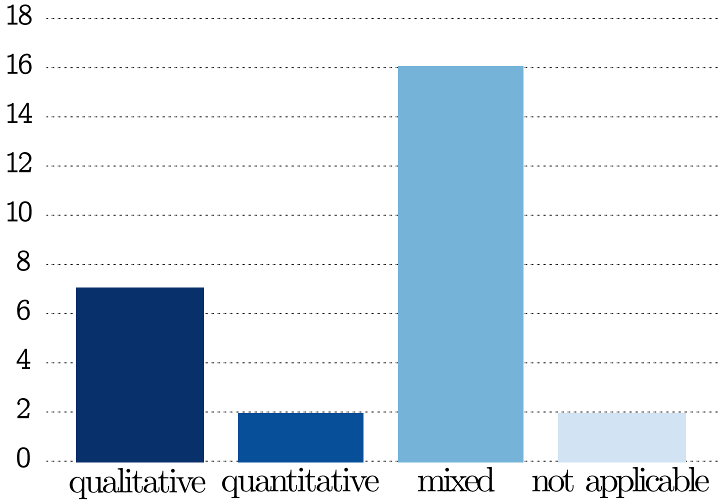

Fig. PI.10 The types of the studies reported in our corpus.

that the activities and interactions seem to be usable for children with ADHD, who interacted 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.

PI.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.

PI.5.1 Engaging (with) children with ADHD and their the care ecosystem.

Despite the defining role of the care ecosystem [105, 227, 427] and the known importance of involving relevant stakeholders in IDC research (e.g. parents [325], 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 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 and with this population. PD has a long history of involving vulnerable, disadvantaged or marginalised groups 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

Table PI.3 User study participants: reporting trends.

Paper	Participants	Children	Boys	Girls
Arrambide et al. (2019) [18]	5 neuropsychologists	0	0	0
Butt et al. (2020) [72]	5 children w/ ADHD, unsp. N parents	5	3	2
Cerezo et al. 2019 [86]	unsp. N educators, 1 system expert, 1 psychologist	36	33	3
Cho et al. (2002) [93]	50 teenagers	50	NA	NA
Goldman et al. (2014) [204]	28 caregivers	0	0	0
Jiang et al. (2020) [267]	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) [281]	27 children (18 w/ ADHD)	27	NA	NA
Mana et al. (2013) [350]	4 children w/o ADHD	4	2	2
Park et al. (2019) [412]	5 children w/ ADHD, unsp. N parents	5	5	0
Smit et al. (2015) [528]	7 adults w/o ADHD, 1 child w/ ADHD, 1 mother, 1 teacher	1	1	0
Sonne et al. (2016a) [532]	16 adults w/o ADHD	0	0	0
Sonne et al. (2016b) [533]	3 children w/ ADHD	3	NA	NA
Sonne et al. (2016c) [534] Sonne et al. (2016d) [536]	11 families (size unspecified), including 13 children w/ ADHD	13	9	4
Sonne et al. (2015) [537]	20 children (11 w/ ADHD)	20	5	3
Weisberg et al. (2014) [606]	6 child-parent pairs	6	4	2
Zuckerman et al. (2015b) [647]	2 children w/ ADHD & their mothers	2	1	1

to participatory methods [181]. 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 [243]. Nevertheless, the benefits of PD are well-established, and researchers have successfully involved both neurotypical and neurodiverse children towards meaningful design processes [325]. For instance, Benton et al. [41] 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. [562] conducted workshops with children with ADHD and their teachers to explore the acceptability of wearables, by sketching prototypes. Cibrian et al. [106] performed PD workshops with children with ADHD and their caregivers towards designing wearable applications supporting their self-regulation. Eriksson et al. [158] 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 [267, 281] in our corpus reported ADHD types) *(RQ1)*. Here, the question arises whether or in which cases (e.g. intervention type) future research 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.

PI.5.2 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 [534, 536]) aim to promote the independence of children within the context of their morning or bedtime routines, and one aims to facilitate acceptance of ADHD [204]. 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 [588] and development process [201, 402]. Furthermore, play facilitates the stimulation of various aspects of functional brain development such as social and communication skills, emotion regulation, and cognitive and physical abilities [331, 358]. However, children with ADHD often have a hard time making friends [250, 251]. These social difficulties, which are very common [250], can lead to feelings of rejection [251], 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 [611]. **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. [181], 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. [542] 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**.

PI.5.3 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 [103] 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 [19]. 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 [19]. 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 [72]. 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.

PI.5.4 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. [103] 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. [102] 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 [103]. 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 PI.2. 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. [351], 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. [419] 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 when these have to be conducted remotely.

PI.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.

PUBLICATION P II

Children with ADHD and their Care Ecosystem: Designing Beyond Symptoms

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Abstract

Designing for children with ADHD has been of increasing interest to the HCI community. However, current approaches do not adequately involve all relevant stakeholders, and primarily focus on addressing symptoms, following a medical model of disability that is extrinsic to neurodivergent interests. To address this, we employed a multi-step, multi-stakeholder approach (N=31). First, we conducted 1) interviews with children with ADHD and their care ecosystem followed by 2) a co-design pilot with one child with ADHD and his therapists and an interview with a UX designer and an occupational therapist. We then employed 3) co-design sessions with neurotypical children and children with ADHD, and 4) a focus group with their therapists. We identified communication and reflection as key concepts for empowering and promoting the well-being of children with ADHD and their care ecosystem. We contribute design implications for future systems aiming to promote the overall well-being of this population.

Contributions

This paper, consisting of a series of studies with children with ADHD and their care ecosystem, contributes the following. First, a multi-step, multi-stakeholder approach for designing beyond symptoms for and with children with ADHD and their care ecosystem. Second, the identification of key concepts that technologies could target to foster the well-being of children with ADHD and their care ecosystem through empowering them: communication for collaboration, and free expression and reflection on experiences and emotions. Finally, design implications for technologies that aim to foster the overall well-being of children with ADHD and their care ecosystem, without focusing (only) on diagnosing or addressing symptoms.

Fig. PII.1 (Left) Example of the material used in a co-design session taking place in the therapy centre. (Middle) Design of one participant (AC5). (Right) Designs of two participants (AC3 and AC4) including the materials they used.

PII.1 Introduction

Attention deficit hyperactivity disorder (ADHD) [621] is the prevailing mental health diagnosis in children [470, 639]. In particular, approximately 5% of children worldwide are diagnosed with ADHD [436]. ADHD is categorised into three types: predominantly inattentive, hyperactive-impulsive, or combined presentation [19, 212], depending on which of these characteristics is prevalent. ADHD has been associated with academic underachievement, bedtime resistance, disruptive behaviours, poor self-regulation of emotions, and social difficulties, such as issues in interacting with peers [163, 537, 604]. This can lead to negative outcomes for both individuals with ADHD as well as their care ecosystems (i.e. actors who play a role in their lives, e.g. parents, teachers, therapists [549]) and society.

Over the years, the HCI community has shown an increasing interest in designing and developing technologies for neurodivergent populations [549], with autism spectrum disorder (ASD) being one of the most frequently addressed conditions (e.g. [29, 160, 249]). In recent years, a newly increased interest in the HCI community can be observed in supporting children with ADHD [549]. Research has demonstrated how technologies can support well-being, for example via fostering empowerment [65, 578, 612] or reflection [525]. The majority of existing approaches focus on empowering children with ADHD and supporting their well-being by addressing specific symptoms, driven by the medical model of disability [542, 543, 549]. For instance, HCI researchers have developed interactive technologies that aim to train executive functions [606, 647], or self-regulation of their behaviour and emotions [106, 137, 367], or establishing effective morning and bedtime routines for increased child independence and lowered parental frustration [536].

However, there is a need to also design technologies that are driven by the interests, needs, and desires of neurodivergent individuals [542, 543, 549], without only focusing on addressing specific symptoms, but rather "establishing their agency" [542]. For instance, Spiel et al. [542] emphasised the need to acknowledge neurodivergent children's agency in defining technologies that are appropriate for them. Hereinafter, we employ the definition of agency by the Cambridge Dictionary as "the ability to take action or to choose what action to take". Therefore, there is a need for future systems that strive to empower children with ADHD and their care ecosystem without (solely) focusing on addressing ADHD-related symptoms [549]. This is in line with Spiel et al. [543] who argued that current HCI research, in particular regarding games, "fails" neurodivergent populations in that it tends to focus on educational and medical settings. It is thus driven by factors that are extrinsic to neurodivergent interests [543]. At the same time, there is a need to actively involve both children with ADHD and the various care ecosystem stakeholders in the design, development, and evaluation of technologies that are intended for use by them, a practice which has not sufficiently been followed so far [549]. Actively involving the care ecosystem of children with ADHD includes engagement of stakeholders such as family and teachers, but also of ADHD professionals, such as therapists and special educators. All these stakeholders play an active part in the everyday lives of children with ADHD, influencing not only their medical health, but also their overall well-being. Therefore, including them is important to collaboratively explore how to design for well-being and empowerment beyond symptoms. The importance of actively involving the care ecosystem stakeholders has already been emphasised by specific guidelines for design sessions with developmentally diverse children [55]. Therefore, we set out to explore how we can design "beyond symptoms", for the overall well-being of both children with ADHD and their care ecosystem. In this work, we seek to address the following research question:

(RQ): How can we design technologies that foster the overall well-being of children with ADHD and their care ecosystem, by actively involving them in the process?

To that end, we adopted a multi-step, multi-stakeholder approach that actively engaged both children with ADHD and the following stakeholder groups of their care ecosystem: parents, therapists, and teachers. We first conducted an interview study with six children with ADHD, six ADHD professionals, five teachers, and four parents of children with ADHD. Our aim was to draw insights from their lived experiences, relationships, and the role of technologies in their lives. Based on the interview findings, we came up with key concepts that technologies aiming to improve the overall well-being of this population should foster. These concepts were iteratively refined and enhanced by the subsequent steps of our approach.

As a next step, we conducted a pilot co-design activity including one boy with ADHD and two of his therapists, followed by an interview with an occupational therapist and a UX designer. This further refined the key concepts we had previously identified, and informed the structure and content of a co-design activity that we conducted with both children with and without an ADHD diagnosis. In particular, we performed co-design sessions with five children with ADHD as well as six neurotypical children, leading to an initial set of design considerations. Finally, a focus group with three therapists of children with ADHD led to enhanced and refined design implications.

This paper derives design implications for technologies that aim to foster the overall well-being of children with ADHD and their care ecosystem. We present our method and findings from each step of our process, informing future research in the domain of (collaborative) reflection for empowering children and their care ecosystem and fostering their well-being. Therefore, this paper contributes the following: i) a multi-step, multi-stakeholder approach for designing beyond symptoms for and with children with ADHD and their care ecosystem, ii) identification of key concepts that technologies could target to foster the well-being of children with ADHD and their care ecosystem through empowering them: communication for collaboration, and free expression and reflection on experiences and emotions, and iii) design implications for technologies that aim to foster the overall well-being of children with ADHD and their care ecosystem, without focusing (only) on diagnosing or addressing symptoms.

PII.2 Background & Related Work

This section presents relevant background, knowledge, and previous work on technologies designed for children with ADHD and their care ecosystem. We then engage with literature on reflection and empowerment, focusing on works published within HCI, to contextualise our use of the terms within this work as key concepts for well-being. Finally, we present other approaches that have included multiple stakeholders in their methods, demonstrating that previous work in the domain has not actively involved both children, therapists, teachers, and parents throughout their design approaches.

PII.2.1 Attention Deficit Hyperactivity Disorder (ADHD)

The HCI community has exhibited increasing interest in research for children with ADHD. Various interactive systems and assistive technologies have been developed in recent years, aiming to assist either children with ADHD or members of their care ecosystem. For instance, Sonne et al. [532] developed a tangible respiration game for children with ADHD, aiming to help them stay focused during breathing exercises by combining them with a video game. Pina et al. [428] developed a system that monitors the stress of parents of children with ADHD, in order to deliver reminders of behavioural strategies to follow. In particular, it includes both "heat of the moment" strategies, for moments of duress, as well as reflective strategies, which can be practised at any time. Sonne et al. [536] developed a smartphone-based system that aims to support families in establishing healthy morning and bedtime routines, with the goal to assist children with ADHD in becoming independent and lowering the parents' frustration levels.

Apart from designing assistive technologies, the research interest in designing for individuals with ADHD can be observed in various reviews published on the subject. Sonne et al. [535] mapped the design space of assistive technologies for children with ADHD in 2016 and proposed a framework including two dimensions: technology and ADHD symptom, as well as a set of design strategies. They thus pinpointed unexplored opportunities in the domain. In 2020, Cibrian et al. [102]'s book reviewed available technologies for individuals with ADHD, focusing on the technological advancements in the domain and classifying existing technology in seven domains, including diagnosis and assessment, social and emotional skills, and supporting behaviour management and self-regulation among others. Moreover, Cibrian et al. [103] recently reviewed technological interventions that specifically regard the self-regulation of behaviours and emotions of children with ADHD. Their findings included the contexts within which such technologies are deployed (home, school, clinic, lab-based). They highlighted how these interventions can offer a "safe space" for children with ADHD to practice behaviour and receive feedback. In 2021, Stefanidi et al. [549] performed a review of

HCI papers focusing on children with ADHD, identifying current trends, opportunities, as well as gaps. Their main findings included a lack of technologies that focus on empowerment and ludic play for children with ADHD, as well as shortcomings with respect to the engagement of both children with ADHD and their care ecosystem throughout the design, development and evaluation phases of current technologies.

As Stefanidi et al. [549] outlined, current approaches mainly focus on addressing ADHD-related symptoms. There is therefore a lack of technologies that focus on improving the overall well-being of children with ADHD without focusing on symptoms or treatment, but rather with the goal of empowering them. Hence, the question arises as to what extent it is necessary to consider aspects that go beyond specific artefacts designed for children with ADHD or their parents. In particular, exploring the lived experiences of children with ADHD and the different stakeholders involved in them could provide a broader perspective on the role technology can play.

PII.2.2 Empowerment

Various calls have been made in the HCI community for technology that empowers people [27, 352, 464, 517]. The term empowerment, which has been interwoven with well-being since its introduction in the 1960s and 1970s [76], originally aimed to ensure the well-being of marginalised groups by enabling them to take part in decision-making processes that affected them [612]. Since then, its meaning has evolved and multiple articulations have emerged, which previous work have tried to clarify by finding an understanding via creating conceptual frameworks to categorise it [296, 491, 578]. Schneider et al. [491] reviewed reviewed how empowerment has been used within CHI papers, and derived a framework to analyse notions of empowerment in HCI research. They found that the lines of research on empowerment within HCI can be categorised as follows: i) empowering experiences, ii) skills and education, iii) self-enhancement, iv) holistic approaches, v) empowerment through the design process, vi) technology for development, and vii) protective technology. To illustrate, in the context of empowering children with ADHD, assistive technologies that train executive functioning or attention time on learning tasks could empower them by developing their skills and education. Kinnula et al. [296] focused on children's empowerment, and proposed a framework outlining functional, educational, democratic, mainstream, and critical empowerment. In the context of this work, we adopt the notion of empowerment by providing "empowering experiences", based on the categorisation by Schneider et al. [491]. According to this notion, empowerment refers to users' autonomy or self-esteem. Moreover, our work can also be categorised in the notion of "empowerment through design process", wherein "users are empowered by having their voice heard and being put into the centre of the design process" [491]. Based on this, employing participatory design methods and placing the user in the centre of the design process can lead to empowerment in itself [30]. With respect to the framework discussed by Kinnula et al. [296] et al., our work addresses the following views of empowerment: mainstream, as children take part in design actions initiated by others, democratic, as children's decision power in technology design is increased, and functional, as we aim to contribute to the life conditions of children with ADHD.

PII.2.3 Reflection

Reflection has been increasingly associated with well-being [44]; it has important benefits for psychological well-being and personal growth [67, 341] and it has been shown to improve self-awareness and self-esteem [503], concepts that are linked to empowerment. Positive reflection improves mood and ability to enjoy life, helps people maintain relationships, work through past events, and develop self-identity [341]. Even reflecting on negative experiences can have health benefits [420]. Still, a distinction must be made between positive reflection on negative experiences and "rumination", introduced by Niess et al. [398] in the context of fitness-tracking and subsequently discussed by Eikey et al. [152]. Rumination describes the negative thought and emotion cycles that can result from reflective thoughts.

Moreover, research has already demonstrated that technology-mediated reflection can improve well-being [257]. However, there is a lack of conceptual agreement within the HCI field regarding reflection, with a variety of definitions currently in use [44], for instance "reflection-in-action" and "reflection-on-action" by Schön [492] or transformative reflection in the context of social-emotional learning which cannot be simply triggered by data and requires careful scaffolding [525]. Bentvelzen et al. [44] explored constructs associated with reflection and found that the concepts of awareness, engagement, learning, behaviour change, and empowerment, are related to reflection within HCI literature. Further, they introduced the Technology-Supported Refection Inventory (TSRI) [42], which is a scale that evaluates how effectively a system supports refection. In collaborative settings, Marcu et al. [353, 354] explored "collaborative reflection" in the informal processes of documentation and communication in health teams of children with behavioural needs. They suggested that care teams could improve their efficiency and effectiveness by supporting the process of collaborative reflection. Their use of the term reflection refers to interpreting behaviour based on collected data. In the context of this work, we employ Schön [492]'s notion of reflection-on-action and reflection-in-action, as well as the aspects of reflection on past events and reminiscing with the goal of well-being discussed by Isaacs et al. [257]. We also build on Marcu et al. [354]'s work, exploring collaborative reflection in the context of collaborative collection and sharing of data in the form of logging and sharing posts about experiences.

An increasing number of systems designed by HCI researchers aim to support reflection, e.g. for symptom tracking for multiple sclerosis [23], stress management [481], and reflection on everyday experiences [257]. The concept of reflection for children has also been explored within HCI research in varying contexts. Ataguba [20] explored life logs as a form of personal reflection in the context of long-distance parent-child relationships. Torsi et al. [568] engaged 9-11 year-olds in reflection-in-action in the context of promoting their reflection on environmental sustainability by using recycled materials to create computational tools. Chu et al. [100] designed a smartwatch application that allowed elementary school students to record reflections related to specific science topics throughout the course of their everyday lives. However, research on technological artefacts that enable reflection for children remains limited.

Regarding neurodivergent children, the majority of research relating to reflection has addressed symptom-related challenges, and in particular the self-regulation of behaviour or emotions. Self-regulation as a skill involves self-monitoring, goal setting, reflective thinking, decision making, self-evaluation, and management of emotions arising as a result of behaviour change [390, 452]. As such, self-regulation is an important aspect for children with ADHD. Loke et al. [335] identified the lack of digital tools that support learning on how to improve emotional self-regulation, which involves reflection and behaviour change for children with serious emotional behaviour problems. They conducted co-design sessions of a reflective storytelling activity with therapists and developed a framework containing key elements for a reflective experience. Doan et al. [137] developed CoolCraig, a mobile application supporting the co-regulation of behaviours and emotions of children with ADHD. Its interface included a smartwatch for the children and a smartphone application for their caregivers. However, we can observe a lack of technological artefacts that use reflection as a means to improve the overall well-being of children with ADHD and their care ecosystem, without primarily focusing on addressing symptoms. Previously, Spiel et al. [543] had discussed the need for future systems that do not focus on addressing symptoms of neurodivergent populations, such as people with ASD, but rather enable them to feel included, accepted, and promote their independence and self-sufficiency.

PII.2.4 Engaging Multiple Stakeholders

HCI research has outlined the importance of considering the "use ecology" in which technologies are used [529], meaning the social and spatial aspects of the environment in which technologies are deployed [529]. Forlizzi [175] argued for a shift from user-centred to stakeholder-centred design, pointing out the need to consider all stakeholders rather than a single user. Particularly with regard to neurodivergent children, guidelines exist that point to the need to actively involve caregivers, teachers and therapists in the design of technologies [55]. Moreover, Benton et al. [41] presented a participatory design framework for involving neurodivergent children in the design process, and highlighted the need to engage both children with ADHD and "the adults that work with them". However, recent research [549] uncovered shortcomings in the engagement of both children with ADHD and their care ecosystem in the design, development, and studies of current technologies.

Below we present examples of approaches within HCI literature that engage at least some care ecosystem stakeholders and/or children with ADHD, highlighting the phases (design and development, user study or evaluation) in which each stakeholder group (children, family, teachers, therapists) was involved. Cibrian et al. [106] engaged children with ADHD, parents, and teachers in the design phase, conducting participatory design workshops with them towards considerations for designing wearable applications supporting the self-regulation of children with ADHD. Loke et al. [335] also followed a multi-stakeholder approach in their co-design of a reflective storytelling activity for children with serious emotional behaviour issues. In particular, they included both therapists, as well as a single child-parent pair in their design process, in which the child was diagnosed with ASD, ADHD, and anxiety. Weisberg et al. [606] followed a user-centred design process for designing an assistive technology with the goal to improve the executive functioning of children with ADHD. They involved educational psychologists and a psychiatrist, as well as six child-parent pairs, conducting interviews with them. For their user study of a paper prototype, they included three child-parent pairs. Sonne et al.'s [536] work on an assistive technology aimed at improving morning and bedtime routines for families of children with ADHD involved parents of children with ADHD and eight ADHD domain professionals in their design process. In their user study, they involved 11 families, including 13 children with ADHD. Richards et al. [456] did not engage with children with ADHD, but with clinicians, educators, and home caregivers of children with behavioural needs in general. They described how the ability to develop a shared understanding of care goals and progress influences care coordination, which in turn affects the ability of the caregivers to support the health and well-being of a child.

The above examples show that even though some approaches have engaged different stakeholders, as Stefanidi et al. [549] highlighted, current works within HCI literature for technologies for ADHD do not sufficiently involve neither children with ADHD nor their care ecosystem stakeholders throughout their approaches. For instance, none of the above examples include both children and their therapists in both the design & development and the user study phases. In our approach, we actively include both children with ADHD and the key care ecosystem stakeholder categories in a multi-step design process. Moreover, we make not only design decisions, but also methodological decisions based on iterative discussions and feedback from relevant stakeholders. For instance, our co-design activity for eliciting design implications was not only informed by existing literature but was structured based on discussions and feedback from a co-design pilot session with a boy with ADHD, his two therapists, as well as the interview with an occupational therapist and a UX designer. Therefore, we deliver a holistic approach that considers both children with ADHD and their care ecosystem at every step of the process.

PII.3 Method

In order to answer our RQ of how we can design for the overall well-being of children with ADHD and their care ecosystem by actively involving them, we followed a multi-step process. The following sections describe each step of this process in detail, including: step 1) the interview study with children with ADHD and the key stakeholder groups of their care ecosystem, step 2) the co-design pilot with a child with ADHD and his therapists and the experts interview with a therapist and a UX designer, step 3) the co-design sessions with children with ADHD as well as neurotypical children, and step 4) the focus group with therapists. This multi-step process continuously informed and refined the final design implications, and each step of the process served as a basis for the ones that followed. This process is visualised in Figure PII.2, including each of the four steps, the participants involved, and the outcomes of the step.

Ethics approval was obtained by the Ethics Committee of the University of St. Gallen (HSG-EC-20220302), and all adult participants provided written informed consent. Children's parents provided written consent for the participation of their children and children were also verbally asked to provide their assent that they wanted to participate before each session. Consent and participant information forms were tailored separately to ADHD therapists, teachers, parents and children (with or without an ADHD diagnosis). Participants were recruited by contacting ADHD professionals and treatment centres and through snowball sampling. The

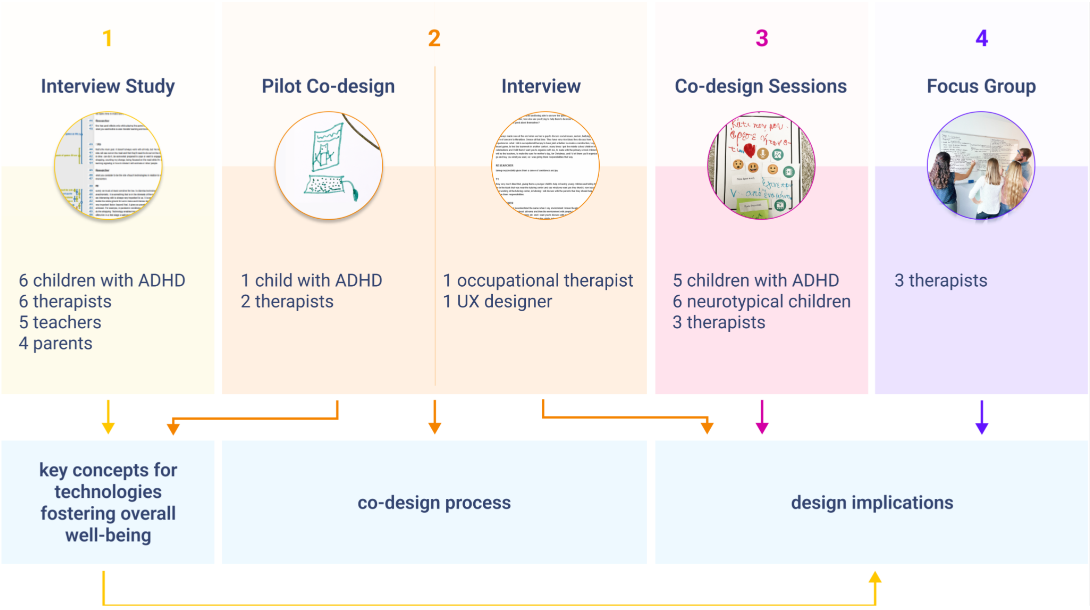

Fig. PII.2 Overview of the process we followed, structured in four steps, and the resulting outcomes of each step.

participants took part on a voluntary basis. All children participants received a board game as a token of appreciation for attendance. Information about the participants who took part in the four steps described in this work is presented in Table PII.1. Hereinafter, we will refer to the participants as follows: to the children with ADHD as AC1-AC6, to the children without an ADHD diagnosis as NC1-NC6, to the therapists (experts) as E1-E9, to the teachers as T1-T5, and to the parents as P1-P4. It should be noted that E7 is the therapist of AC1, AC3, AC4, and AC5, E8 of AC2, and E9 of AC6. Also, P4 is the parent of AC1, and AC3 and AC4 are siblings. The following sections describe our multi-step process in detail (Figure PII.2).

PII.4 Step 1: Interview Study

Given the inherent complexity of designing for this population, the need arises for a deeper understanding of their lived experiences. Therefore, in order to explore how to design for their overall well-being, we conducted semi-structured interviews with children with ADHD and key stakeholder groups of their care ecosystem. We strove to explore relationships, roles, challenges between the different stakeholders of the care ecosystem, what they enjoy, their environment, and technologies.

PII.4.1 Participants

We recruited N = 21 interview participants. In particular, we interviewed six children with ADHD aged 7-10 (M = 9, SD = 1.4), and fifteen adults aged 29-62 (M = 38, SD = 9.8), consisting of six ADHD professionals (three occupational therapists, one psychologist, one psychotherapist, and one speech pathologist), five teachers of children with ADHD, and four parents of children with ADHD. More information about the interview participants is visible on Table PII.1 (see participants marked in column Step 1). Since many participants were involved in multiple

Table PII.1 Demographics of participants (total N = 31) and the steps where they were involved. Step 1: Interview study. Step 2: Co-design pilot and interview. Step 3: Co-design sessions. Step 4: Focus group. AC1-AC6: children with ADHD, NC1-NC6: neurotypical children, E1-E9: therapists (experts), T1-T5: teachers, P1-P4: parents.

Participant	Step 1	Step 2	Step 3	Step 4	Description	Gender	Age	Country of residence
E1	■				occupational therapist	male	36	Greece
E2	■				occupational therapist	female	31	Greece
E3	■	■			occupational therapist	female	57	Greece
E4	■				psychologist	male	38	UK
E5	■				psychotherapist	female	56	UK
E6	■				speech pathologist	male	38	Greece
E7		■	■	■	child & family psychologist	female	26	Greece
E8			■	■	psychologist	female	28	Greece
E9		■	■	■	psychotherapist	male	33	Greece
T1	■				special educator	female	37	Greece
T2	■				special educator	female	30	Greece
T3	■				special educator	female	47	Germany
T4	■				special educator	male	34	UK
T5	■				private tutor	female	29	Greece
P1	■				mother of boy with ADHD-HI and boy with ADHD-I	female	41	Greece
P2	■				mother of girl with ADHD-I	female	44	Greece
P3	■				mother of boy with ADHD-C	female	62	The Netherlands
P4	■				mother of boy with ADHD-C	female	40	Greece
U1		■			UX designer	female	43	Greece
AC1	■	■			ADHD-C, no medication	male	7	Greece
AC2	■		■		ADHD-C and Asperger, no medication	male	8	Greece
AC3	■		■		ADHD-C and HFA, no medication	female	10	Greece
AC4	■		■		ADHD-C and HFA, no medication	male	7	Greece
AC5	■		■		ADHD-I, no medication	female	10	Greece
AC6	■		■		ADHD-C, medication	male	10	Greece
NC1			■		neurotypical child	female	10	Greece
NC2			■		neurotypical child	male	13	Greece
NC3			■		neurotypical child	female	10	Greece
NC4			■		neurotypical child	male	11	Greece
NC5			■		neurotypical child	male	7	Greece
NC6			■		neurotypical child	female	8	Greece

steps of our approach, in each of the following sections we only briefly mention the participants who took part and refer to this Table PII.1, where it is visible who participated in each step.

PII.4.2 Interview Protocol & Analysis

For the adult participants, the semi-structured interviews were conducted via video conferencing software, and lasted between 31 minutes and 1 hour and 5 minutes each (11 hours and 49 minutes total time of recordings, M = 49 minutes, SD = 10.7 minutes). For the children participants, the interviews were conducted in person, at the therapy centre where they attended sessions with their therapists. Each child interview lasted between 7 and 15 minutes (54 minutes total time of recordings, M = 8 minutes, SD = 3 minutes). At each session, the attending therapist was present, along with the researcher conducting the interview. While the interviews with adult participants provided us with rich information regarding relationships, challenges, and the role of the environment and technologies, the interviews with children participants, albeit significantly shorter, served as additional insights. In particular, they verified certain aspects that were already brought up in the adult interviews, e.g. about activities they enjoyed as well as those they did not. For both adults and children, at the beginning of each interview, the interviewer welcomed the participants, and informed them about the structure of the interview and the context of the study. Participants had the opportunity to ask any questions they had and were provided with consent forms to sign. In the case of children participants, both the legal guardian and the child were informed of the process and had to give their written consent and verbal assent respectively. For all participants, the interviewer collected demographic data and then proceeded with some introductory questions, followed by questions on participants' daily routines and challenges, the role of the environment on children's behaviour, the role of their care ecosystem, playful activities and what they enjoy, and their experience with technologies. These questions were used as prompts rather than as solid questions to be asked in a specific order or manner. Furthermore, as this is a sensitive topic, we had taken precautions to phrase our questions openly to ensure that participants can guide the conversation in a direction that is comfortable for them. All interviews were audio recorded for later transcription and analysis, with the consent of the participants.

All 21 interviews were transcribed verbatim, 16 of them were translated from Greek to English. Two researchers analysed the interviews by performing open coding in an iterative process, using the MaxQDA software. After an initial round of open-coding, two authors applied thematic analysis by using affinity diagramming in line with Blandford et al. [51] to uncover emerging themes. We identified three themes from the data: *Care Ecosystem and Environment*, *Balancing Perceptions of Technology*, and *Paths and Obstacles to Empowerment*.

PII.4.3 Interview Findings

In this section, we present the three themes we constructed based on the analysis of the interviews with children with ADHD and their care ecosystem: *Care Ecosystem and Environment*, *Balancing Perceptions of Technology*, and *Paths and Obstacles to Empowerment*. We provide a detailed description of the themes and illustrate them with excerpts of the interview data.

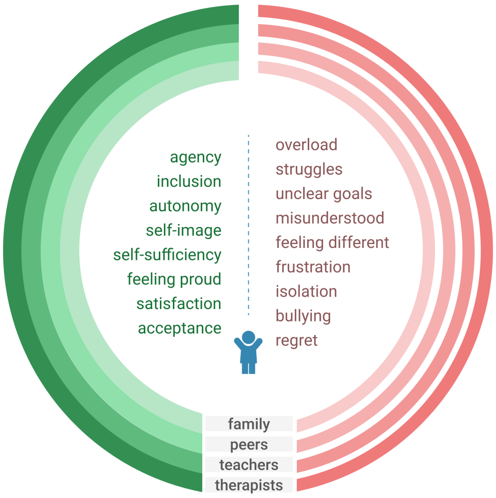

Fig. PII.3 A visualisation of our findings regarding the layers of the care ecosystem of children with ADHD. The left part of the figure demonstrates the positive outcomes when the care ecosystem layers come together, communicate and efficiently collaborate, which can lead to empowerment. On the other hand, the right part of the figure shows the negative outcomes of poor communication and unclear goals. Gaps in communication, translating to barriers in collaboration, are visualised by the white gaps between the ecosystem layers on the right part. For instance, communication without barriers (visualised by the connected green stripes on the left semicircle) between the family and the therapists can lead to clear goals and shared understanding between them, which in turn can help the child feel proud when completing the goals and accepted by both the family and the therapists. On the other hand, the reverse situation (red separated stripes showing the gaps in communication) can lead to overload, unclear goals, and frustration for the child .

Care Ecosystem and Environment. The interviews allowed us to build an understanding of the roles and interconnections between the different members of the care ecosystem of children with ADHD PII.3. We place the child in the middle, and "paint" the surrounding layers of the care ecosystem and how the connections between them relate to their and the child's well-being. Our interviews demonstrated the important role that each layer plays in defining the child's experience, and additionally how the environment in which the child finds itself in can have a direct influence on its behaviour. *"It is of infinite importance how [the actors of the care ecosystem] actually interact and what relationships exist within that environment" (E2)*. Our interviews also demonstrated a strong relationship between the environment and the behaviour of a child with ADHD, showing how the first affected the second. In particular, the environment plays a crucial role *"in terms of semantics"*, for instance *"what the school environment means for a child, what their home means" (E1)*, and also because of *"the different stimuli that the child receives in different environments" (E2)*. The analysis of the interviews also showed that the roles of the care ecosystem members can span multiple layers. For instance, parents often take on multiple roles, including those of the teacher or "therapist". This often resulted in parents having limited time to engage in playful interactions with their children, which some children recognised; for instance *"Mum doesn't want to play something with me, [she] doesn't have time" (AC2)*. Instead, we observed mothers taking on the role of a "private tutor", actively assisting children with tasks such as homework or getting them to calm down in stressful situations, acting as a support system in different contexts. However, the support system of families can be wider than the parents, including siblings and grandparents, who need to have a *"shared vision and deal with things the same way (P1)."*

Our analysis particularly highlighted the importance of communication for effective collaboration between the different layers of the ecosystem, and how it can have a crucial effect on their and the child's well-being and everyday experiences: *"When there's a good partnership of family, child and therapist, miracles happen there" (T1).* We found that aligned goals across all contexts are crucial, not only for goal achievement, but also as a way to avoid negative experiences and feelings. This is evident by the side effects of poor cooperation between parents and therapists, which result in the child exhibiting *"a complete different behaviour in therapy than they have at home" (E2).* The following participant quote describes this aspect:

> *"The child is sort of like, do you know pinball machines, so that child is ricocheting around basically, in different environments. And it gets a different experience every time it lands from one side to another. So home, school, extracurricular activities, that child doesn't get a joined up, equal experience of how they're treated. So everywhere they go, they're treated differently. And so it's like this constant need to be understood and being misunderstood, being missed, basically" (E5).*

This is in line with previous work that emphasised the need for creating a shared understanding in care coordination for children with "behavioural needs" [456]. Our findings shed light on which implications this has for children with ADHD and their care ecosystem, and extends previous knowledge by outlining the multi-faceted roles of caregivers and the role of the environment within the picture.

Balancing Perceptions of Technology. Another theme that we identified focuses on the different perceptions of technology. In particular, caregivers regarded technology as a means of potentially "addictive" entertainment for children, e.g. in the form of social media or video games, or as a successful and useful intervention media; a *"very big ally" (E2).* Positive perceptions regarding technology included evident improvement in ADHD-related symptoms and enhanced motivation by the child to participate. *"I saw that the attention span was much better, but also there was motivation to try even harder than other methods" (E1). "There was a very big difference in [the child's] concentration and his hyperactivity [after the neurofeedback treatment]" (P1).* This disagreement amongst parents, children, and research on the extent to which children should engage with technology has been established in general [54, 445] and with respect to neurodivergent children, e.g. with ASD [316]. For example, some parents think their children's technology use is positive since it supports child development [138, 459], while others suggest it has negative implications for their physical activity [459]. Building on this, our interviews also uncovered a different dimension of these mixed perceptions for children with ADHD: the possibility that games utilised in the context of therapy could lose their appeal on children. In particular, despite the importance and usefulness of using technologies in interventions to address ADHD-related symptoms, analysis of the interviews demonstrated that children often felt like activities and games played in therapy, even digital ones, became *"more like a chore at one point" (P1).* This further underlines the need for technologies that on the one hand do not fall into the "addictive video game" category, but on the other support children's well-being without solely focusing on addressing symptoms or solely being used within the context of therapy. This is tied to the third theme we identified, that focuses on empowerment.

Paths and Obstacles to Empowerment. The term empowerment was often mentioned in the interviews, especially by the therapists and educators. Our interviews highlighted the importance of empowerment and showed ways that it manifests in the case of children with ADHD. We identified manifestations of empowerment in the interviews in the following forms: i) having fun, receiving satisfaction and feeling happy, ii) self-image (self-confidence, self-esteem), iii) self-sufficiency, agency, autonomy, independence, iv) feeling safe, accepted, included, and v) feeling proud. The interviews helped us identify both paths and obstacles to empowerment, visualised in Figure PII.3, which connects this aspect to the other two identified themes. In particular, efficient communication among the various care ecosystem layers and with the child leading to collaboration and shared, clear goals, can be a path to empowerment (left side of Figure PII.3), including positive outcomes such as satisfaction, inclusion and increased self-esteem. For instance, *"setting common goals together [...] helps [both children and the parents] have a better picture and a satisfaction in seeing that they achieve them" (T2).* On the other hand, gaps and issues in communication create collaboration barriers and constitute obstacles to empowerment. Therefore, Figure PII.3 provides an overview of possible ways to empowerment and of obstacles to empowerment and their negative outcomes, thus helping to better conceptualise the term within the context of this population. Participants described multiple situations of negative experiences and feelings connected to undesirable outcomes. These negative experiences are often coupled with a *"stream of interventions"*, so that the child *"always feels as being in emergency mode"*, and often *"gets tired of the overloaded schedule"* (T4). This focus on interventions and symptoms, following the medical model of disability, is discussed in Spiel et al.'s work [543], who argue that current HCI work is driven by factors extrinsic to neurodivergent interests. Nevertheless, technologies have great potential to empower children with ADHD, as *"it is something that they like, it gives them satisfaction and builds the whole ground for us to make each child feel good in each intervention. That alone makes it a very important factor. Beyond that, it gives us possibilities that in other circumstances could not be achieved" (T2).*

Having identified these themes, it becomes clear that **a key concept for fostering the overall well-being of children with ADHD and their care ecosystem is to empower them by facilitating and supporting efficient communication and collaboration among them**.

PII.5 Step 2: Co-design Pilot & Expert Interviews

The next step in our method was employing co-design, with the ultimate aim to foster the children's agency and allow them to draw a technology that they would like to have in their lives. Co-design refers to proactively involving non-designers in the design process, in this case including end-users and stakeholders affected by the design [362]. Before conducting a series of co-design sessions, and in line with our vision of involving children with ADHD and their care ecosystem in every step of the process, we wanted to explore how the co-design sessions should look like. We therefore conducted a co-design pilot with a seven-year-old boy and his two therapists at the therapy centre. We drew from previous work that employed co-design processes with children of similar ages, such as drawing and using collages similar to Aarts et al. [3]. Many of the children we interviewed had also stated that *"drawing is [their] favourite activity" (AC5).* We decided to employ storytelling as a means of expression, since research shows it is an appropriate design method for children [527]. This was followed by a semi-structured group interview involving an occupational therapist and a UX designer. This process refined the content and structure of the co-design activity and resulted in further design implications. Participants AC1, E7 and E9 took part in the pilot co-design session, and E3 and U1 participated in the group interview (see participants marked in column Step 2 in Table PII.1).

PII.5.1 Process & Analysis

After following the same process regarding greeting and consent forms described in Step 1 (see section PII.4), the researcher engaged in a short, casual conversation with AC1, so as to re-establish rapport, and help the child feel more comfortable. The researcher and the child then engaged in a short discussion about the child's likes and dislikes, and the child was asked to "draw the story" about the activities he did the previous day and illustrate them on a DIN A2 piece of paper. He could draw, paint, and collage various paper snippets, including cartoon-like sketches of different activities, objects, and smileys. This session was subsequently discussed in a semi-structured group interview with E3 and U1. The two-hour interview took place online via video conferencing software, where findings of the interview study and the pilot co-design were discussed. Both the pilot co-design session and the interview were audio recorded with the participants' consent, were transcribed verbatim, and translated from Greek to English for analysis. Two authors analysed the interviews by performing open coding, using the MaxQDA software. The findings from Step 2 are presented below.

PII.5.2 Findings

Here, we describe the main implications that resulted from the pilot co-design session with AC1, followed by the interview with E3 and U1. They span two dimensions: i) implications that regard the content and structure of the co-design activity, and ii) general design implications for technologies that foster well-being.

Firstly, AC1 enjoyed the activity, and particularly explaining and illustrating his daily activities as a story. He described what he liked and did not like in his day, and used appropriate smileys *"to make [his] story whole" (AC1).* The importance of giving children the means to express themselves in this way was highlighted by E3:

> *"Every child does things in their everyday lives that gives them meaning. It is important for a child to be able to define what has meaning for them, to reflect, to declare it, to keep it."*

E3 proceeded to link the act of reflecting with empowering children to express themselves in this way via technology, emphasising how *"[a technology for] enabling a child to depict their thoughts while reflecting on an event would be “wow”" (E3).* **Therefore, we identified reflection as a possible vehicle towards empowerment in this context.** However, *"the way children are asked to describe their "story" of events that happened matters. If you ask a child why they did not sleep well the previous night, and they try to justify it with other actions or events of the day, that could be forcing them to make connections, and is not necessarily leading to reflection" (E3).* Therefore, to explore how reflection could be used as a means to well-being, we decided to integrate it within the co-design activity. The activity was designed to include stages from Gibb's [199] reflective cycle, and in particular to guide the child to answer the questions: what happened, when it occurred, who was there, what was the outcome, and to additionally describe their feelings about it. Specifically regarding feelings, E3 suggested that *"the co-design activity should be less activity-driven and more feeling-driven. For instance, instead of asking the children to describe what activities they did recently, they could be asked to tell the story about something that recently happened which they enjoyed. They can then elaborate on it, and articulate the exact feelings they had about it, for instance happiness or surprise."* Further insights for the content of the co-design activity from U1 included that it should allow children to "draw" the technological artefact on a "paper-based tablet". This would *"allow them to quickly get into the concept that it's a technology and make them excited given the appeal of playing on a tablet for children" (U1).* Finally, both U1 and E3 suggested that the co-design be conducted with both children with and without an ADHD diagnosis, as this would *"solidify the findings".*

Based on the findings of our interview study (Step 1 - section PII.4), and the pilot co-design and interview with experts (Step 2 - section PII.5), we formulated a co-design activity, to conduct with both children with and without an ADHD diagnosis. The key concepts for technologies fostering the overall well-being of children with ADHD and their care ecosystem were also refined to include the aspect of expressing experiences and feelings and reflecting upon them as a vehicle towards empowerment and well-being.

PII.6 Step 3: Co-design Sessions

The formulated co-design activity was conducted with five children with ADHD as well as six children without an ADHD diagnosis, following the suggestion of U1 and E3 to additionally recruit neurotypical children. Including neurotypical children in the design process was also in line with our vision to include as many stakeholder groups of the care ecosystem of a child with ADHD as possible, which can include neurotypical children. Our goal was to explore how children would envision and interact with a technology that allows them to tell a story about a recent past event and their perceived emotions about it (reflection aspect) and share it with other members of the care ecosystem (communication aspect). Before conducting the first co-design session, we consulted with therapists E7-E9. We presented the final structure of the co-design activity to them for any additional feedback. Having the detailed description of the co-design activity at hand, the therapists made an informed selection of children they were treating who they deemed appropriate to contact for participating in the study. Originally, eight families were contacted, of which five responded positively and participated in the co-design sessions.

In particular, children AC2-AC6 participated in the co-design sessions, along with E7-E9, who were present during the co-design activity. It should be noted that AC3 and AC4 who are siblings participated in the co-design session together, each making their own "design". Moreover, the co-design activity was carried out with six neurotypical children, NC1-NC6. The neurotypical children participants were recruited using the extended network of the authors and snowball sampling strategy. More information is presented in Table PII.1 (see participants marked in column Step 3). The co-design activity with AC2-AC6 took place at the therapy centre, while the sessions with NC1-NC6 were conducted at a location that was convenient to the participants, either their own homes or the house of a contact person of the authors.

PII.6.1 Process & Analysis

The same process regarding welcoming participants and consent forms described in Step 1 (see section PII.4) was followed, after which the researcher engaged in a short, casual conversation with each child to re-establish rapport and help the child feel more comfortable. The researcher explained once again the process they would follow, and that *"they needed the help of the child to design a cool technology for them"* that the child itself could make it *"in any way they wanted"*. The researcher and the child then engaged in a short discussion about what the child enjoys doing. Following this, the researcher instructed the child to imagine an application where they could input what they like and what they do not like about things or events that have happened. This would allow them to be able to "keep" all those things and be able to look at them later. The researcher then asked the children if they would like to help with making this application and drawing what it would look like.

The children were provided with a variety of materials in order to equip the application with "something that recently happened and they liked". The materials that children had at their disposal for the activity was the following (see Figure PII.1): paper "tablets", different coloured crayons, pens, pencils and markers, post-it notes, and glue. They were also provided with paper icons which they could glue upon their designs. The icons represented various type of media: videos, images, and recordings, as well as smileys portraying different feelings: happiness, sadness, surprise, anger, disgust and love. The smileys were pre-selected based on a discussion with E7, E8 and E9 about which feelings should be included in the activity. Finally, participants were also provided with paper snippets baring the following prompts: "Something that happened and I liked was", "When did this happen", "Who was there", "Where did this happen", "Why did you like it". All children could read the prompts by themselves, without external help from the researcher or their therapist. We used these scaffolding questions to facilitate storytelling as suggested by Loke et al. [335].

Participants made designs using the materials described above, in which they told a story about "something that happened that they liked", explained their feelings about it, and answered the reflective questions described above. At each stage, children could use any of the available icons described above. During the sessions, the researcher was not taking any notes but was fully present and engaging with the children [335]. After the design activity,

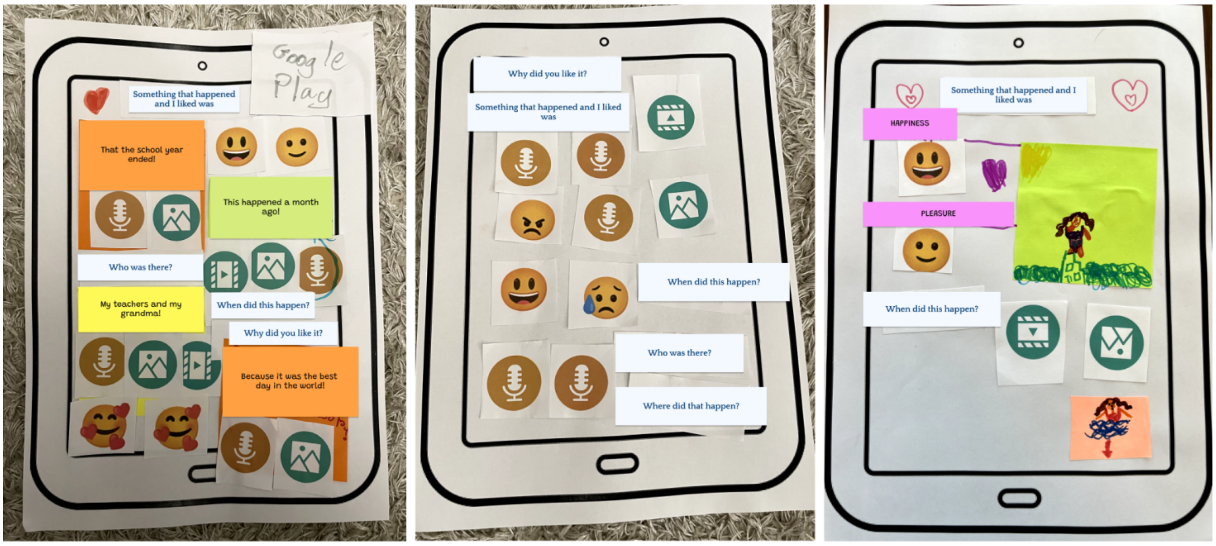

Fig. PII.4 Example designs from the co-design sessions (with handwritten texts translated from Greek to English). From left to right: AC3, AC2, NC6. Variations in the use of text, recordings, images, and videos can be observed, additionally including drawings to depict the events children were describing.

children were asked questions to infer their opinions and experience. In particular, they were asked if they would use this application, what kind of things they would like to input in such an application, if they would share those things with others, if they would change or add something, and what they liked and disliked about the application. The sessions were audio recorded with the participants' consent, transcribed non-verbatim, and translated from Greek to English for analysis. Two researchers analysed the interviews by performing open coding, using the MaxQDA software. The findings from Step 3 are presented below.

PII.6.2 Co-design Session Findings

Here, we summarise our findings from the co-design sessions. As an example of the children's designs, Figure PII.4 shows the designs of AC3, AC2, and NC6 (translations in English of the children's handwritten text superimposed). The supplementary material includes all eleven designs of children participants crafted in this step.

Overall, the process and the technology concept appealed to all participants, and they were very engaged with it. For instance, the majority of the children, both with and without an ADHD diagnosis, got so immersed in the application concept, that they would pretend to tap on the recording button once they glued it on the paper tablet, and say out loud what they would like the application to record. This is also reflected in the comment of one of the therapists, who voiced positive surprise about the behaviour of a usually particularly active child who participated in the co-design activities without any issues: *"I think I have never seen you so calm and focused!" (E9 to AC6)*. For AC2-AC6, the previously conducted interviews with the same researcher present seemed to have acted as a warm up activity, making them feel more comfortable and potentially acting as a scaffold to the co-design activity, as they had already discussed with the researcher activities they enjoy doing.

Both groups of children (with and without an ADHD diagnosis) liked the idea of being able to log and *"keep the things that happened" (NC1)*. They would *"use the app to see what [they] did and liked, in order to do it again" (NC1, NC3)*. Regarding when they would use such a technology, they *"would use it when [they] had something important to log. [They] would have [their] memories in it so that [they] could go back to it afterwards" (NC3)*. Others said they would use it "at least a couple of times a week", when something important happens (NC1, NC4, AC3, AC4, AC6), while others "sometimes" (NC3, AC5). All participants also said that they would not need any specific incentive to use it, but would like to use it anyway.

> *"I would not have it as a game. I would have it as a means, I would use it to be able to express myself more freely." (AC6)*

This further underlined the value that the children found in a technology that would allow them to express what they liked and be able to reflect upon it. With respect to the way that they could "tell their story", all children found the guiding questions helpful, as *"it helps [them] keep the basic important content" (NC1)*. They also enjoyed the ability to be able to express themselves with multiple media types (text, recording, image, video), with each child using a variety of the media they preferred. AC5 and NC6 additionally drew pictures about the experience they were describing. All children stated they would like to share the "posts" they would make in such an application, e.g. with their parents, teachers or therapists. In more detail, AC2 mentioned he would like to share his post with his mother, AC3 to her friends, cousins, and *"actually all the people [I] know!"*, AC5 *"to [her] teacher, to [her] mum, to [her] dad, and to [name of E7]"* and AC6 to everyone, but *"mostly [his] friends"*. AC4 however specified he would *"only want to show it to [his] sister"*. From the six neurotypical children, NC1, NC2, and NC3 specified they would share their posts with friends, parents, and teachers. On the other hand, NC4 would prefer to share his posts with his cousins, friends, and siblings, but "maybe not with teachers". Participants did not mention specific types of posts they would or would not want to share, rather focusing on the types of posts they would like to create in general, as described above.

Participants particularly liked the ability to *"add the feelings that belonged to the experience with the icons" (NC6)*. We observed that the only feeling that was not used from the available icons was disgust, while AC6 said he would have liked to be able to add the feeling of pride, which was currently missing. Another finding regarding the feelings that children expressed can be observed in the design of AC2 (see Figure PII.4). In particular, he associated both positive and negative feelings with a positive experience (playing a video game), namely happiness, anger and sadness.

Another interesting finding regarded the nature of things that children would like to log in such a technology. In more detail, when asked whether they would like to input the things that happened and they liked, those they did not like, or both, eight out of eleven children responded that they would only like to log the positive experiences. The explanations for that included that they *"don't want to remember the negative things" (AC3, AC4)*, because that would make them *"sad" (NC1)* or *"upset and angry" (NC4)*, or because they *"simply don't want to" (AC2)*. The exceptions were NC2, who would *"like to be able to also log the negative experiences to look at them afterwards and maybe improve them in the future"*, AC5, who would *"like to* *log both the positive and negative experiences, but be able to see only the positive afterwards"*, and AC6, who said that he'd *"like to log if [he] had a fight with [his] friends, to also be able to input the next day that they made up and played together"*. Finally, it should be noted that we found no notable differences to report between the co-design with children with ADHD and neurotypical children who participated in the co-design. This applied both to the process of the co-design, as well as the findings we derived from the co-design sessions.

The findings from the eleven co-design sessions further underlined the importance of free expression and reflection as vehicles to well-being, additionally linking them to aspects of empowerment such as satisfaction and agency, since the activity appealed to all children and they enjoyed "being able to freely express themselves".

PII.7 Step 4: Focus Group

As a next step, in order to get valuable input from the children's therapists and inform them of the progress, as well as further refine the design implications, we conducted a focus group with three psychologists specialising in children and family therapy. The session, which lasted two hours, took place at the therapy centre. Participants for the focus group were E7, E8, and E9, namely the therapists of AC1-AC6 (see participants marked in column Step 4 in Table PII.1).

PII.7.1 Process & Analysis

The focus group took place in person at the therapy centre where E7-E9 work. The participants engaged in a conversation with the researcher concerning the findings of the co-design sessions. The focus group was audio recorded with the participants' consent, transcribed verbatim, and translated from Greek to English for analysis. Two authors analysed the transcripts by performing open coding, using the MaxQDA software. After an initial round of open-coding, two authors applied thematic analysis by using affinity diagramming. We identified two emerging themes from the data: *Communication for Collaboration* and *Enabling Expression and Reflection.* These themes correspond to the perceived benefits of such a technology. The findings from Step 4 are presented below.

PII.7.2 Focus Group Findings

Here, we discuss the main findings from the focus group conducted with E7-E9. Based on our analysis, we identified two themes: *Communication for Collaboration* and *Enabling Expression and Reflection.*

Communication for Collaboration. Overall, the therapists were excited about the idea of a technology that would allow children to log their experiences, reflecting upon them and noting their feelings. In particular, *"this kind of externalisation and visualisation is important, as it can significantly decrease the noise in the communication" (E9).* It also enables both therapists and other care ecosystem members to *"assess and evaluate the child's feelings easier" (E7, E8).* The idea of such an application additionally providing similar functionality for the adult members of the care ecosystem was also discussed. Having access to such "posts" from children but also from other members of the care ecosystem, e.g. their parents or teachers, would enable therapists to *"complete the picture, to have a more holistic view" (E9)* from the various care ecosystem layers. The therapists were particularly excited about the possible benefits of such an application on their communication and collaboration with other care ecosystem members, as it would *"allow for coordination and getting insights you would not otherwise have" (E7). "This coordination could lead to common standards and goals" (E9).*

Enabling Expression and Reflection. The second identified theme regards how such an application would enable free expression and could foster reflection. When asked about their opinion on showing children positive past events and discussing their feelings about them, all three therapists agreed on the usefulness of such a feedback, associating it with free expression, satisfaction, and the possibility for reflection:

> *"Children can see and review their development and can be reminded that they are having fun in life. The app itself is a tool, "I have something where I can express myself". Even in its simplest form this is useful. Some children don't even enter the process of expressing themselves, just being able to do so is evolutionary" (E9).*

This echoes the answer of AC6 about the use of such a technology to *freely express* himself. Other benefits of expressing oneself in this way were emphasised by E8:

> *"Such an application can be used as a means of expression, as a soothing and relieving medium, for instance instead of having a stress ball, the child could channel their energy into the application and also get feedback from the app. Sometimes we forget what makes us happy if we don't pay attention to it at that moment" (E8).*

However, the therapists noted that although reflecting on negative experiences could be beneficial, this should only be considered after a discussion with a particular child's therapist, or for older children. The ability to "share posts" of these expressions made in such an application among the care ecosystem stakeholders and the child could also *"help children with empathising by seeing others' posts" (E7)*. Additionally, it *"would also be helpful for emotion regulation and for achieving feelings of togetherness" (E8).* The two concepts of empathy and emotion regulation were highlighted as particularly important possible outcomes of such technologies by the therapists. Empathy refers to *"the ability to share someone else's feelings or experiences by imagining what it would be like to be in that person's situation"* (Cambridge Dictionary). Emotion regulation refers to *"attempts to influence which emotions one has, when one has them, and how one experiences or expresses these emotions"* [216], and it is common for individuals with ADHD to struggle with controlling their emotional responses, or even struggle due to emotion *dys*regulation [35, 514]. The therapists particularly underlined that the above are not simple tasks and that children with ADHD can face challenges in that respect.

The two identified themes (*Communication for Collaboration* and *Enabling Expression and Reflection*) reflect the key concepts we had identified in Step 1 and Step 2. Step 4 additionally demonstrated how the terms "empathy" and "emotion regulation" relate to these concepts and are possible and desired outcomes.

PII.8 Discussion

Designing technologies for children with ADHD and their care ecosystem is complex given the vulnerability of the population and the interrelations that exist within the care ecosystem. In order to explore how to design for this population's overall well-being, without a primary focus on addressing ADHD-related symptoms, and thus answer our RQ, we employed a multi-step approach, consisting of four steps, actively involving both children with ADHD and key stakeholder groups of their care ecosystem. Based on our findings, we identified key concepts that future technologies should consider in order to foster their overall well-being: empowerment through facilitating i) communication and collaboration, and ii) free expression and reflection on experiences and emotions. Notably, our analysis did not show any particular differences between neurotypical children participants and children with ADHD in that context, neither in the co-design sessions process nor in our findings. Perhaps this was due to the fact that, in the case of participants with ADHD, their therapists were present for the duration of the co-design process, providing them with support and nudging them to continue even when they got a bit distracted or "off-task". This potentially mitigated challenges that could have arose, coupled with the fact that all children enjoyed the activity, even children with ADHD who according to their therapists usually had a more active behaviour and sometimes struggled with staying focused. The above further supports that involving stakeholders of the care ecosystem in participatory design activities could help mitigate challenges associated with the participation of children with ADHD [549], by offering additional support [41].

In the following sections, we reflect on our findings and envision how they can inspire the design of future systems that empower children with ADHD and their care ecosystems, aiming to promote their well-being.

PII.8.1 Recording, Sharing, and (Collaboratively) Reflecting on Data & Emotions

Our work showed that a technological artefact allowing both children and members of their care ecosystem to log posts -*recording aspect*-, share them among each other -*sharing aspect*-, and reflect upon their experiences and emotions -*(collaborative) reflection aspect*- could empower them and would be beneficial for their well-being. This reflection process can happen both on an individual level, i.e. when the child (or adult) records and reviews their logged data and emotions, as well as on a collaborative level.

We identify two distinct ways in which technologies could offer collaborative reflection support in this context. One, technologies could prompt and scaffold further communication of users with other care ecosystem members regarding a specific logged experience, allowing one user to share their own perspective and feelings about the data of another, thus collaboratively reflecting on the logged data and emotions while using the technology. An example of this would be a parent viewing the logged data of their child about a recent experience and logging their own emotions regarding the specific post as well as adding a conversation-triggering comment within the application. Two, such technologies could foster collaborative reflection that takes place outside of the technology use scenario, by sparking further discussions to take place in person, based on the new information or perspectives acquired while using the technology. For example, the therapist could observe specific emotions that a child expresses regarding an activity and prompt the child to engage in a discussion about it during their sessions, encouraging the child to reflect on the experience and associated emotion (i.e. collaborative reflection).

A technological artefact facilitating collaborative reflection could support children's agency, which is directly in line with the manifestations of empowerment for this population (Step 1 of our approach). In particular, such technologies could enable children to have their voice heard, as they are expressing themselves and their emotions. Children's agency is also supported by allowing them to choose whether and which posts they share and with which members of their care ecosystem. We found that such an artefact would be desired by both the caregivers and, importantly, the children themselves, relating to the aspect of satisfaction that we identified as another possible path to empowerment for children with ADHD.

Below, we discuss how the aspects of recording, sharing, and (collaboratively) reflecting on data and emotions relate to and are supported by previous work. In particular, our findings regarding the usefulness of these capabilities echo those of Marcu et al. [354], in that electronic collection of patient-related information could increase its availability, meaningfulness, granularity and reliability during reflection [354]. To elaborate, a technological artefact following the principles derived from our studies, would i) make data available for stakeholders in real-time across contexts, ii) provide stakeholders with useful data as well as information on emotions, while *"decreasing noise in the communication" (E9)*, iii) increase granularity of data that would be relevant to caregivers, e.g. via the posts themselves, as well as statistics the technology could provide based on the logged data, and iv) increase reliability, as information about the same event could be collected from more than one source, e.g. both child and teacher. Saario et al. [478] also noted how collaborating stakeholders in the health-care sector, do not usually have access to the systems being used for data collection, limiting their ability to develop a shared understanding. We recommend addressing this issue by including both children and their care ecosystem as target users, and giving them access to the system (both for viewing and for recording data). Furthermore, a technology that employs the concepts we identified based on our analysis would be in line with the recommendation by Marcu et al. [354] that data collection tools could be designed to facilitate reflection of children themselves, in addition to their various caregivers. This is also in line with the implications derived from Stefanidi et al.'s literature review of technologies for children with ADHD [549], who called for future systems where the target user group includes both children and various care ecosystem stakeholders.

Moreover, our findings extend previous knowledge on technology-mediated reflection, and particularly on aspects of previous models that encompass reflection. In particular, the concept of (collaborative) reflection on data and emotions that we constructed based on our findings considers both children and their caregivers in contrast to related work [335, 353]. Marcu et al.'s [353] "collaborative reflection process" and the "safety, connection and reflection" framework by Loke et al. [335] both document reflection processes in therapy and intervention-related contexts. The first regards the decisions that treatment teams have to make for children with behavioural needs and targets interventions. In more detail, Marcu et al.'s [353] model consists of a short-term inner loop and a long-term outer loop, and describes how treatment teams reflect on data and corroborate interpretations of the data with others. While this model focuses only on patient-related data, aiming to improve the efficiency and effectiveness of treatment teams, Loke et al. [335] emphasised that caregivers must also be aware of their own emotions to scaffold the reflective experience of children [335]. Their framework illustrates how therapists can scaffold reflective experiences in the case of children with trauma, with the goal of social emotional learning, based on their needs: safety, relatedness, empathy, and social resilience. Our work adds to HCI researchers' and designers' understanding of how the collaborative reflection process can look like when designing "beyond symptoms" for children with ADHD and their care ecosystem. We explore how children themselves can engage in reflection along with other members of their care ecosystem, who are actively taking part in the reflection process, including both professional and informal caregivers. Our findings contribute to the understanding of how reflecting on experiences and emotions can lead to empowerment in the context of fostering children's overall well-being, without a specific focus on therapy or social emotional learning.

At the same time, our findings indicate that providing users with the ability to share their posts, could not only support reflection [96], but also actively help with communication and crossing the barriers that impede achieving a shared understanding. To illustrate, Richards et al. [456] identified the following barriers to the development of shared understanding in care teams of children with behavioural needs: differences in approaches and motivations, inability to rely on documentation, and information loss during transfer across the care team. They also proposed a framework for mitigating these barriers, in which sharing descriptive information (contextual or holistic knowledge) is a key mechanism. Based on the concepts we derived from our studies, we could enable both children and their care ecosystem to share their experiences across different contexts, facilitating the sharing of descriptive information. Traditionally, this requires intentional effort and one-on-one and group communication, as well as moving across contexts for observation and learning [456]. By rendering information available "on-demand" through a technology that allows viewing this information and collaboratively reflecting on it, the aforementioned effort and movement can be significantly reduced. This in turn would facilitate a more seamless integration of perspectives on experiences and emotions. We thus argue that technologies that follow the principles derived from our multi-step, multi-stakeholder approach can help mitigate these barriers. Moreover, our findings showed that communication across barriers, which can lead to shared understanding and uniform goals, constitutes a path to empowerment. On the other hand, communication barriers connect to negative consequences for children, creating obstacles to empowerment, as visualised in Figure PII.3.

Therefore, we extend previous work by proposing that enabling both children with ADHD and their care ecosystem to record and reflect on their experiences and emotions, and share these among them can be a way towards crossing communication barriers, serving as a vehicle towards their empowerment and overall well-being.

PII.8.2 Empowering Children with ADHD and their Care Ecosystem via Non-Complex, Multi-Context Technologies

Our findings demonstrated the potential of technologies that "break" the barriers in communication and collaboration, and facilitate free expression and reflection on events and emotions for empowerment. One notable aspect, which is particularly evident from Step 3 and Step 4, is the possible simplicity of such a technology. In particular, for the implementation of a technological artefact following the principles and design implications that our approach identified, even simple mobile or tablet-based solutions, without specialised equipment, hardware, or technical expertise from users could work. This is further motivated by the evident excitement for such a technological artefact by both children and therapists in our study.

Therefore, designing technologies that are relatively simple, such as mobile applications, could be a way to address the current literature gap that notes a "great divide" in translation from design to adoption of technological artefacts designed for children with ADHD and their care ecosystem [102], thus supporting their empowerment. This is not to say that employing more complex approaches, e.g. AI, or sophisticated hardware, could not present fruitful ways forward. Rather, we point out the possibility of empowering this population towards enhancing their overall well-being utilising technologies that they are already familiar with and are easy to adopt in real life. This also connects to the interview findings regarding the mixed perceptions of technology. In particular, a system enabling logging, sharing, and reflecting on experiences and emotions could be a simple yet fun way to motivate children to use it without perceiving it as therapy or a "chore", which caregivers would also approve and use. At the same time, it could be perceived as a collaborative technology, with which children and their care ecosystem interact together.

Another aspect to consider is the use of technologies by children with ADHD and their care ecosystem, depending on the context. In particular, given the important role that the environment plays for children with ADHD, it could be important to consider the interplay between human and technology mediation within the care ecosystem. In more detail, some contexts could provide ample scope for different types of technological artefacts to facilitate communication and reflection, while in other contexts it might be best for interactions between the child and the care ecosystem to take place without the use of technology. **Future work should further explore this aspect by investigating the contexts in which technology-mediated approaches should be used, and how to design different kinds of technology mediations that fit together; some to be used in the moment by the child as interactive expressive tools, others as aggregate tools to be looked at later with their caregivers, while others as explicit shared tools to be used with other children.** This echoes the findings of Kawas et al. [285] who reviewed the values that informed the work of authors in the Interaction Design & Children community that seek to empower children and foster their agency. In particular, they identified the need to reflect on the role of technologies in addressing children's needs, and to build awareness of technology serving to augment children's experiences and not replace them. Exploring the use of a reflection tool such as the one derived from our multi-step approach, which can be used in different contexts and by different stakeholder groups, could be a step in that direction.

PII.8.3 Designing Beyond Symptoms as a Potential "Best of Both Worlds" Scenario

In this work, we started with the aspiration to design "beyond symptoms", for the overall well-being of children with ADHD and their care ecosystem. This was based on previous work outlining the need for future systems that would do that, by designing for empowerment instead of specific symptoms, thus establishing children's agency [542] and self-determination, which is related to concepts such as competence and autonomy [543]. For instance, Stefanidi et al. [549] proposed designing for empowerment of children with ADHD could be achieved by e.g. designing for ludic play. Interestingly, our findings showed that, while "designing beyond symptoms", our approach could lead to positive outcomes for children with ADHD such as emotion regulation, which is a symptom-related aspect and a goal that intervention-driven technologies might have (e.g. [106]). Therefore, our findings demonstrate how "designing beyond symptoms" has the potential to not only lead to different forms of empowerment through technology, e.g. delivering empowering experiences that are driven by neurodivergent interests, but also to support children with ADHD with symptom management. This presents a new argument for future research to make the design decision of not (only) targeting specific symptoms when seeking to empower children with ADHD through technology. **Therefore, we extend previous knowledge on "designing beyond symptoms" and inform future research by both presenting a new argument towards the importance and need for such a design approach, and by demonstrating how it can be beneficial. In particular, we argue that designing beyond symptoms can potentially deliver a "best of both worlds" approach, both catering to neurodivergent interests and supporting ADHD-related challenges.**

PII.8.4 Limitations

We recognise that our work is subject to certain limitations. In particular, we originally planned to involve both more parent participants, as well as more children with ADHD in our interviews. Acquiring access to vulnerable populations, such as children with ADHD and their families is challenging, and requires particular considerations to not place an additional burden on them. Additionally, recruiting participants in parts of the world where COVID-19 related restrictions were still on-going within the past year made the process even more challenging. Pecor et al. [419] already found that caregivers of children with ADHD and/or autism were disproportionately affected by the pandemic. However, research has demonstrated not only how important it is to involve neurodivergent populations in the design of technologies, but also how one might approach the topic and the benefits it can procure [41, 462, 549]. We also wanted to include parents of children with ADHD in the co-design process, as well as their friends, but we only involved their therapists due to time constraints and to not place an additional burden on them. Nevertheless, including their therapists in the co-design sessions already seemed to provide children participants with ADHD with enough additional support [41] during the co-design activity. Future work includes conducting co-design sessions with both parents and peers of children with ADHD. Throughout our approach, we were still able to involve an overall considerable number of participants (N=31). The interviews and co-design sessions we conducted were very rich in content, allowing us to derive key concepts and design implications for technologies that aim to foster the overall well-being of children with ADHD and their care ecosystem. Finally, it is worth noting that therapy is not always a comfortable scenario, and the presence of therapists during the co-design sessions could have impacted how children engaged with the activity. Future work should investigate how children with ADHD use technologies that realise the concepts we constructed based on our findings in multiple settings and contexts. This could help in exploring the use of such systems to address the issue identified in the interviews that therapy activities and games might eventually feel like a chore. In any case, the importance of the context of use of technologies for children with ADHD is evident from the crucial role the environment plays on their behaviour [19], underlined by the fact that a list of symptoms must impair daily functioning in *two or more settings* to merit an ADHD diagnosis [19].

PII.9 Conclusion

In this paper, we conducted a multi-step, multi-stakeholder approach (N=31). We identified design implications for technologies fostering the overall well-being of children with ADHD and their care ecosystem while "designing beyond symptoms". Our work revealed how empowerment via facilitating communication and collaboration, and free expression and reflection are key aspects for technologies that aim to foster the overall well-being of children with ADHD and their care ecosystems. In particular, our findings show how technologies allowing collaborative reflection on experiences and emotions can help with overcoming communication barriers and achieving collaboration. Our findings also indicate that designing rather simple technologies can lead to empowering experiences that could mitigate use and adoption issues. Such technologies can be used by multiple stakeholders and in different contexts, and allow recording, sharing, and both individually and collaboratively reflecting on experiences and emotions. Finally, we showed that designing beyond symptoms can potentially both cater to the interests and desires of neurodivergent children, while also supporting them with symptom-related challenges. We hope that our research inspires further work in the domain of designing beyond symptoms for children with ADHD and their care ecosystems that is driven by neurodivergent interests and seeks to empower them.

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Transition II

After having established a conceptual basis through papers P I and P II, the next part focuses on designing and evaluating a range of technologies based on the insights gleaned from these first two studies. Therefore, with the following chapters which present papers P III, P IV, P V, and P VI, this dissertation continues with addressing the *Design* aspect of Figure 3.1 (RQ2), and also addresses the *Evaluate* aspect of Figure 3.1 (RQ3). This section explains which stakeholders were involved in these four papers and the reasoning behind studying these specific user constellations.

First, for the study with MagiBricks (paper P III), this system of smart toy bricks was evaluated with neurotypical children engaging in distributed shared playtime together with their grandparents. The selection of these care ecosystem stakeholders as the first user constellation to interact with this prototype was due to the focus of the study to explore how such a system could facilitate intergenerational playful interactions in distributed settings, thus supporting their connectedness and well-being. Additionally, with respect to empowerment, a goal was to study how an augmented version of an otherwise regular and familiar toy (toy bricks) that allows for mutual awareness and control would impact the traditional roles of "all-knowing" adults and "all-learning" children [142].

For the study with TeenWorlds (paper P IV), this VR application was evaluated with teenagers who interacted with the system in pairs together with their friends (also teenagers) or their parents. During the course of the study, one participant pair (a parent and their teenager) disclosed being neurodivergent, but we did not recruit participants based on this criterion. In particular, the decision to investigate TeenWorlds with those two types of groups (teenager-teenager, teenager-parent) was due to the focus of the study on exploring the impact of such an application on participants' emotional expression and shared understanding in order to support their relationships and well-being. In that respect, we deemed it important to study this with those two groups as a first step, as peers and parents are the two most crucial and influential care ecosystem members for teenagers, shaping teenagers' daily experiences. Moreover, we chose to investigate emotional expression about a prior shared conflict between the participant pairs, as teenagers often encounter emotional outbursts and conflicts, impacting their relationships with peers and parents [145, 401]. In fact, this was a key reason for not targeting ADHD children in this first study with TeenWorlds. Specifically, given the possible negative emotions that could arise as part of engaging with the system, as participants expressed their emotions around a conflict, we aimed to first conduct this study with a general sample. This approach could help us identify particular aspects that might need to be implemented to support and scaffold the experience, before studying it with an even more vulnerable population that can face challenges with emotion regulation [35, 514]. Finally, we made recruitment open to teenagers and not younger children, as, despite small variations, the majority of VR headsets state that their users should be at least 12 or 13 years old[2].

In our study with MoodGems (paper P V), we evaluated the prototype as part of its iterative design with ADHD children, parents, and therapists, as well as HCI experts. Given the fact that MoodGems, comprised of a set of physical hexagonal-shaped displays and an accompanying mobile app, seeks to support the well-being of ADHD children and their families at home, by facilitating expression, reflection, and communication, we chose to recruit both ADHD children and their parents. Additionally, as part of our proof of concept, and as a necessary step before actually implementing the system, we evaluated MoodGems with HCI experts. Moreover, even though this work focused on technologies driven by the interests of ADHD children, we chose to involve therapists in this study. The reason behind this was to ensure that the technology's features would be designed in a way that considers children's and family safety and needs. Moreover, their involvement addresses the broader needs of ADHD children and their care ecosystems (based on our insights from paper P II).

Finally, in the studies reported with REMEMO (paper P VI), we involved both ADHD and neurotypical children, as well as parents, teachers, and therapists. REMEMO's goal, as a multi-stakeholder mobile app tailored to the specific needs and interests of each user group, is to support emotional expression, reflection, and communication, thereby fostering well-being and empowerment for ADHD children and their care ecosystems. Thus, this final paper aimed to encompass all key care ecosystem members of each participating child. While we were able to recruit and engage with all the aforementioned stakeholders during the iterative design of this mobile application, the subsequent field study with REMEMO in the wild engaged all these groups except teachers (as is explained in the paper, we encountered particular challenges with recruiting teachers, as e.g. their school directors were reluctant to their participation, assuming that it could require too much effort on their side, affecting their day-to-day work). Nonetheless, the participants of the field study allowed us to acquire rich data, demonstrating the potential of the application to fulfil its purpose for well-being and empowerment.

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[2] https://www.meta.com/quest/safety-center/

PUBLICATION P III

MagiBricks: Fostering Intergenerational Connectedness in Distributed Play with Smart Toy Bricks

The contents of this chapter originally appeared in: **Evropi Stefanidi**, Julia Dominiak, Marit Bentvelzen, Paweł W. Woźniak, Johannes Schöning, Yvonne Rogers, and Jasmin Niess. 2023. MagiBricks: Fostering Intergenerational Connectedness in Distributed Play with Smart Toy Bricks. In Proceedings of the 22nd Annual ACM Interaction Design and Children Conference (IDC ’23). Association for Computing Machinery, New York, NY, USA, 239–252. https://doi.org/10.1145/3585088.3589390

Abstract

Playing together is crucial to the unique and invaluable bond between grandparents and grandchildren. However, co-located interactions and play can be limited due to time, distance, or pandemic-related restrictions. To facilitate distributed play, we developed MagiBricks, a system comprised of 3D-printed smart toy bricks and baseplates that provide feedback regarding their placement. The familiarity and appeal of toy bricks to both older adults and children make them ideal for intergenerational play. We conducted a within-subjects study with six grandparent-grandchildren pairs. We compared the interactions and perceived connectedness of the pairs while playing over a distance with either i) MagiBricks or ii) identical regular toy bricks. We found that MagiBricks affected communication dynamics, role taking, nature of play, and perception of connectedness during playtime compared to regular bricks, and were unanimously preferred. We contribute design implications for future systems leveraging (smart) tangibles and fostering intergenerational connectedness.

Contributions

This paper contributes the following. First, the MagiBricks system, comprised of 3D-printed smart toy bricks, a baseplate, and a feedback system. Second, the study of MagiBricks with six pairs of grandparents and grandchildren. Finally, design implications for future systems leveraging the affordances of smart tangibles and for those aiming to empower children and foster intergenerational connectedness during play.

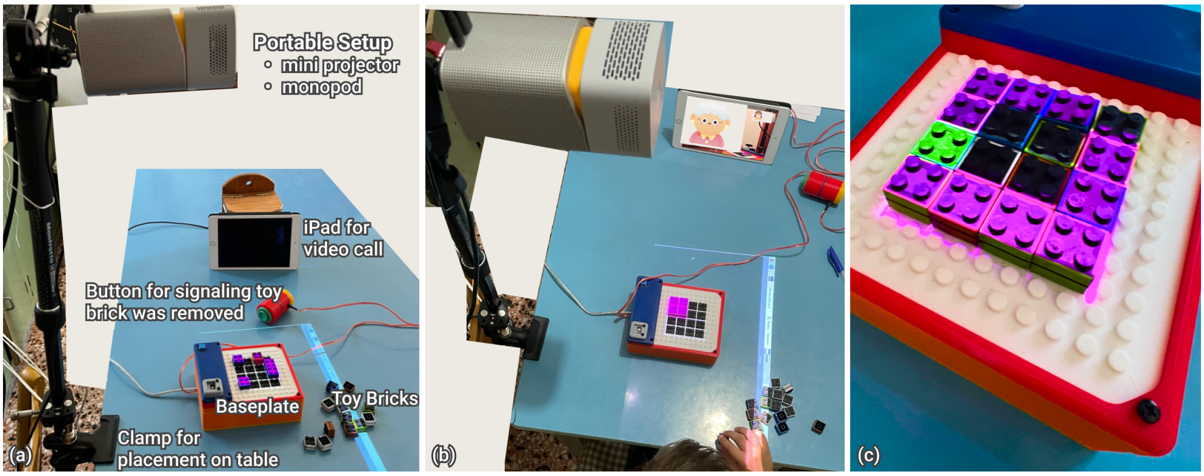

Fig. PIII.1 (a) The study setup with the MagiBricks system, including the feedback system (portable projector, monopod and clamp), the smart toy bricks and baseplate, and a tablet for a video call between participants. (b) Child playing with MagiBricks with grandmother on a video call and colour feedback visible. (c) Detail of the smart baseplate whilst creating the "square task". Green-coloured feedback indicates where the other player just placed a smart toy brick. Pink-coloured feedback indicates where the other player has already placed smart toy bricks.

PIII.1 Introduction

The bond between grandparents and grandchildren is unique; it differs from other family relationships and provides them with invaluable benefits [596]. For grandparents, these benefits include feeling joy, pride, and a sense of purpose and continuity by taking part in their grandchildren's lives [288, 305]. For grandchildren, grandparents can be invaluable life teachers, historians, nurturers, mentors and role models [306], while their shared activities can foster the child's self-esteem [305]. Research has demonstrated the importance of a close grandparent-grandchild relationship for mental health [265, 469] and how their playful interactions can particularly benefit their social communication and well-being [114, 305, 306, 358, 453]. However, various constraints can significantly limit their co-located interactions. Distance is such a constraint, made common due to trends such as globalisation, immigration, and the prevalence of nuclear families, leading to fewer co-located multi-generational families [2, 225, 486, 524, 641], and thus fewer opportunities for grandparents and grandchildren to engage in meaningful interactions [38, 225, 344]. Other constraints include time availability, lifestyle choices, and social circumstances such as divorce [275, 587]. Vetere et al. [583] characterise these constraints that lead to grandparent-grandchildren separation as physical, temporal, and social distance respectively. Moreover, the social distancing constraints imposed by the COVID-19 pandemic created additional obstacles in developing and maintaining close intergenerational relationships. Thus, social connectedness shifted to a remote, online experience, aided by technology. This shift was not entirely new; for instance, grandparents and grandchildren that live apart often rely on technologies for maintaining relationships, such as using phone calls and texting or video applications [596].

However, a known issue is that some of these systems are challenging to use by the grandparents, while they can also fail to engage and capture the interest of the children [596]. From a research perspective, the majority of work that aims to connect grandparents and grandchildren at a distance has focused on information exchange or storytelling/reading (e.g. [587, 596]). Few approaches have focused on the aspect of distributed play [127, 583], despite the fact that play between them is common and is crucial to building their relationship [583]. At the same time, smart toys are becoming increasingly common in children's homes [140], who readily interact with and adopt these technologies [337, 369], with pertinent research receiving increasing interest within the CCI community [560]. Smart toys could thus open new avenues for promoting connectedness by enabling more interactive playing activities, coupled with the benefits of tangible interfaces. Since tangible interfaces merge physical objects with digital information, simplifying user interaction, they have the potential to improve older adults' acceptance of technology [545]. Furthermore, Fuchsberger et al. [185] found that grandparents and grandchildren who are physically distant often use tangible objects in their (online) interactions. Nevertheless, and despite the fact that toy bricks are both familiar and engaging for both older adults and younger children, to the best of our knowledge no previous work has explored their potential as smart toys to foster intergenerational connectedness during distributed play. In particular, toy bricks are an ideal tangible medium for intergenerational play, as playing with them does not require e.g. reading skills, which older grandparents or younger children may not have, lowering the acceptance threshold while being an engaging and fun toy. Hence, employing smart toys such as toy bricks to deliver enhanced play experiences between grandparents and grandchildren at a distance, fostering intergenerational connectedness is an under-explored opportunity.

To address this gap, we developed MagiBricks (Figure PIII.1), a smart toy system consisting of smart toy bricks and a baseplate. The bricks are 3D-printed with conductive material allowing the detection of their position on the smart baseplate. Using a micro-controller, the MagiBricks system can provide real-time visual and audio feedback through a projector. Employing the construct of connectedness as a sense of being *actively involved* with another person [224], our research aims to actively involve grandparents and grandchildren with each other in distributed play, by promoting communication and collaboration. We aim to answer the following research questions:

- **RQ1**: How does a smart toy that allows for multi-modal feedback regarding players' actions affect the communication, collaboration, and perceived connectedness of grandparents and grandchildren while playing over a distance?
- **RQ2**: What kind of playful interactions are supported by a smart toy that allows for multi-modal feedback regarding players' actions?

To that end, we conducted a within-subjects study with six pairs of grandparents-grandchildren (N=12), where they took part in structured and unstructured distributed play while being on a video call, i) with our system -*MagiBricks condition (MB)*, and ii) with identical regular toy bricks -*Regular toy bricks condition (RB)*. Our analysis indicated that MagiBricks, and in particular the feedback they provided, positively affected the communication dynamics and perception of connectedness of participants during playtime compared to the regular toy bricks, and were unanimously preferred from the identical regular toy bricks. Furthermore, MagiBricks affected role taking behaviour and the nature of play. We contribute i) the MagiBricks system, ii) the study with six pairs of grandparents and grandchildren, as well as iii) design implications for future systems leveraging the affordances of smart tangibles and those aiming to foster intergenerational connectedness during play.

PIII.2 Related Work

In this section, we contextualise our work within previous research on tangible interfaces and smart toys. We then present related work regarding intergenerational play and connectedness.

PIII.2.1 Tangible Interfaces & Smart Toys

Tangible systems are known to support collaborative play and social communication [338, 356, 584], thus presenting a suitable solution for engaging users in collaborative playful activities. Especially regarding children, HCI and CCI researchers have designed various tangible systems, in application areas such as games and learning. For example, Africano et al. [5] presented a multi-user interactive play system, employing a tabletop touch screen and tangibles, to promote collaborative learning about geography and culture while practising basic literacy skills. Li et al. [329] developed MemorINO, a tangible game that leads children to collaborate, naturally and interdependently. Regarding their implementation, some tangible interfaces use embedded micro-controllers. For example, Navigational Blocks [77] allow navigating and retrieving historical information through tactile manipulation and haptic feedback. Electromagnets embedded in the Blocks and wireless communication allow rearranging the Blocks to form different database queries.

Many tangible interfaces come in the form of bricks and building blocks, which can procure numerous benefits for children; for example, playing with blocks and puzzles helps them develop better spatial reasoning [189]. One of the most popular application areas of blocks is allowing children to program (e.g. [81, 245, 371, 548]). For instance, Tern [246] consists of jigsaw puzzle-like blocks, whose physical forms determine their ability to connect, thus employing physical constraints as a form of physical syntax for programming. Other block-based approaches focus on learning; for instance, Smart Blocks [202] for exploring the concepts of volume and surface area of 3D objects constructed by the user; or Flow Blocks [646], employing light feedback for exploring concepts relevant to understanding causality. With respect to previous tangible, block-based approaches, we present tangible 3D-printed smart toy bricks to enhance intergenerational distributed play, bridging the application areas of play, connectedness, and collaboration.

In recent years, smart toys have attracted particular interest in the CCI and HCI communities. This is evident in research regarding tangible musical toys [567] or health monitoring toys in the form of tangible cubes enhanced with sensors [586], as well as publications such as the special issue on "Smart Toys, Smart Tangibles, Robots and other Smart Things for Children" by Sylla et al. [560]. They identified the following emerging areas: new ways of play and education; playful learning and development of social skills; design tools and considerations; designing for therapy and training; children's understanding of data and data protection. Our work touches upon the aforementioned area of "new ways of play", extending it to "new ways of distributed intergenerational play". Below, we present examples of smart toys to illustrate and clarify the focus of our work. For instance, Storymat [477] is a play carpet that can record and replay children's stories, by detecting RFID-tagged toys that are placed upon it, and replaying an image of the moving toy by projecting it onto the carpet as well as playing the recorded audio. EnterTaible [334] consists of an LCD panel that can be placed on a table surface that allows for co-located collaborative play, by augmenting traditional board games. The system allows the detection of multiple concurrent inputs from fingers and objects. Moreover, Hinkse et al. [240] compared the Augmented Knights Castle, where the movement of figurines triggers audio output, to an identical, non-augmented toy. They showed that digitally augmented play environments promote different kinds of activity, such as replying to the figurines when they were talking. A follow-up study including children with autism [165] found that the augmented version of the toy promoted less solitary and more social play.

Aside from research, numerous commercial products and repositories of maker communities concerning smart toys and 3D-printed artefacts exist. Even if thoroughly investigating them is outside the scope of this paper, we briefly present two key examples to better contextualise our work. Regarding commercial toys, Neurosmith has marketed block-based tangible toys such as MusicBlocks, which allow children to create musical scores by inserting coloured blocks into the toy's body. With respect to 3D-printing and micro-controllers, approaches such as the Smart Chess Board [136] are noteworthy. It includes 3D-printed parts and micro-controllers, as well as LED lights embedded in the chess board for user feedback regarding the placement of the opponent's pieces. In contrast to our system, described in the next section, it does not automatically detect the placement of pieces; the user rather needs to provide this as input on a dedicated surface, by tapping on letters and numbers corresponding to the possible placements on the board.

We extend previous work by exploring tangible, 3D-printed smart toy bricks and baseplates that can detect brick placement, augmented with micro-controllers and a feedback system, in intergenerational distributed play settings.

PIII.2.2 Technologies for (Intergenerational) Connectedness & Play

Designing for connectedness has received ongoing research interest [186], with researchers employing design strategies such as awareness, joint action, and memories [233]. To that end, tangible interfaces have often been employed as communication support tools, addressing remote intimacy by exploring different sensory modalities, such as a pair of drinking glasses where one of them lights up when the remote partner drinks from their glass [101], or a picture frame which lights up when touched to enhance the communication between physically distant loved ones [90]. Especially regarding family members, various interactive artefacts and tangibles have been developed aiming to connect them [236, 275, 605]. The majority of technologies facilitating the connection between (remote) family members involve information exchanges and messaging systems [253]. For instance, Butzer et al.'s [73] Grandtotem is an asynchronous communication device that aims to support the relationship between grandparents and their adult grandchildren studying abroad by sharing images, viewing them as a gallery, and sending video messages. Binda et al. [48] also focused on facilitating intergenerational information sharing in family contexts, and in particular health information. They designed PhamilyHealth, a web-based photo sharing system for family members to share health-related photos with one another and to encourage a family-wide, sustainable, healthy lifestyle.

Many recent works have also focused on intergenerational storytelling. Wallbaum et al. [596] presented StoryBox, a tangible device that supports intergenerational connectedness by sharing photos, tangible artefacts, and audio recordings of everyday life between grandparents and their grandchildren. They deployed it with two families (children aged six to ten) and found that it could help bridge the technological gap between grandparents and grandchildren. Li et al. [327] presented Story-Me, a system facilitating intergenerational story-sharing between older adults living in a nursing home and their (adult) children, through a custom-made device that the older adults use to tell stories based on memory triggers from their children. Ambe et al.'s [10] Messaging Kettle included sensing and messaging capabilities and aimed to connect dispersed families through the routine of boiling the kettle. In a longitudinal study deploying the prototype, participants (older mothers and adult daughters) expressed feelings of everyday togetherness, nurturing their relationship at a distance. Vutborg et al.'s [587] storytelling technology probe allowed audio communication and sharing of virtual objects through a shared display set for each household. They deployed it with two sets of grandparents-grandchildren living apart (ages four to eight), and found that participants were keen to stay in contact through storytelling and personal photos. Family Story Play [446] allows grandparents and grandchildren to read physical storybooks together remotely, including an audio channel and page-sensing technology to determine if they are on the same physical page. Evaluation results were positive, as children were more engaged in long-distance communication than when using Skype, and the quality of the intergenerational interactions improved.

However, interactions between grandparents and grandchildren are often opportunistic, incidental, and playful [583], rather than focusing on information exchange. Limited research has employed the aspect of play to connect grandparents and grandchildren at a distance, despite play between them being common and crucial to building their relationship [583]. Davies et al. [127] already demonstrated that intergenerational relationships at a distance can be maintained via playful activities. They deployed Magic Boxes, in which items would be placed by each household and transferred by researchers between the grandparents and grandchildren of four families residing in different households, participating in a two-week study. This led some participants to use items they placed in the boxes as part of made-up games between them, such as guessing games and puzzles. Vetere et al. [583] explored intergenerational distributed play with the Collage system, enabling grandparents and grandchildren to send photos and text messages from a mobile phone to the system, manipulate these objects on their respective touch screens, and have this manipulation be synchronously replicated to the other. Evaluation of the system (children aged two to ten) showed that both grandchildren and grandparents enjoyed the new types of playful activities the system offered. Another example of research on intergenerational technologies that go beyond information exchange and focus on shared activities is the work of Chowdhury et al. [97]. They proposed designing for intergenerational distributed co-listening of music, as current technologies do not support collaborative music listening and conversation.

Nevertheless, and despite the benefits of manipulating tangibles, the opportunity of using smart toys by augmenting tangible toys, such as toy-bricks, to facilitate intergenerational distributed play has yet to be explored. In particular, while previous work mostly focused on fostering intergenerational connectedness through systems facilitating messaging or storytelling/reading, we employ 3D-printed smart toy bricks that provide real-time visual and audio feedback about their placement, to enhance distributed play interactions and perceived feelings of connectedness of grandparents and grandchildren playing together at a distance, by fostering communication and collaboration between them.

PIII.3 MagiBricks

Our research aims to actively involve grandparents and grandchildren with each other in distributed play, seeking to enhance their play interactions by making them feel connected to each other during their play. This active involvement includes communication and collaboration, and is based on the connectedness construct put forth by Hagerty et al. [224]. To that end, based on our design rationale and relevant related work, the following design decisions (DD) were taken. The first design decision was that the system would be **comprised of tangible artefacts (DD1)**. Tangibles can be understood as resources for communication [338, 356, 584] and shared activity [167–169]. Manual interaction with physical objects is observable and can enhance clarity due to their visibility [302], thus supporting social action, and awareness and coordination in a group [510]. Moreover, they are often employed in collaborative settings, e.g. many tangible systems aim to foster collaborative learning (e.g. [559, 574]). Therefore, tangible artefacts are suitable for shared intergenerational activities, and their features are in line with our goal of promoting communication and collaboration while interacting with the system, in order to enhance users' feelings of connectedness while playing. Second, since toy bricks afford familiarity and appeal to both younger children and older adults, we designed MagiBricks to augment regular toy bricks. Given our aim to foster communication and collaboration between grandparents and grandchildren in distributed play, we decided to make **custom 3D-printed smart bricks with detectable positions to provide both visual and audio feedback (DD2)**. Yuill et al. [636] already showed that augmenting toys with audio to capture children's attention increased cooperative play. By utilising both visual feedback, in the form of colour, and audio feedback, in the form of short melodies when toy bricks are added or removed, we aimed to promote collaboration and communication between grandparents and grandchildren. In the context of our study, we used tablets for video calling to allow participants to communicate with each other. Furthermore, Yuill et al. [637] identified three mechanisms through which multi-user interfaces can support collaboration: mutual awareness, mutual control, and mutual availability. Based on this, we **employ the concept of mutual awareness (DD3)**, i.e. being aware of the other users' actions, in order to support collaboration. In more detail, MagiBricks provide both colour and sound feedback **in real-time** regarding the placement of the bricks of the other user, thus allowing mutual awareness of

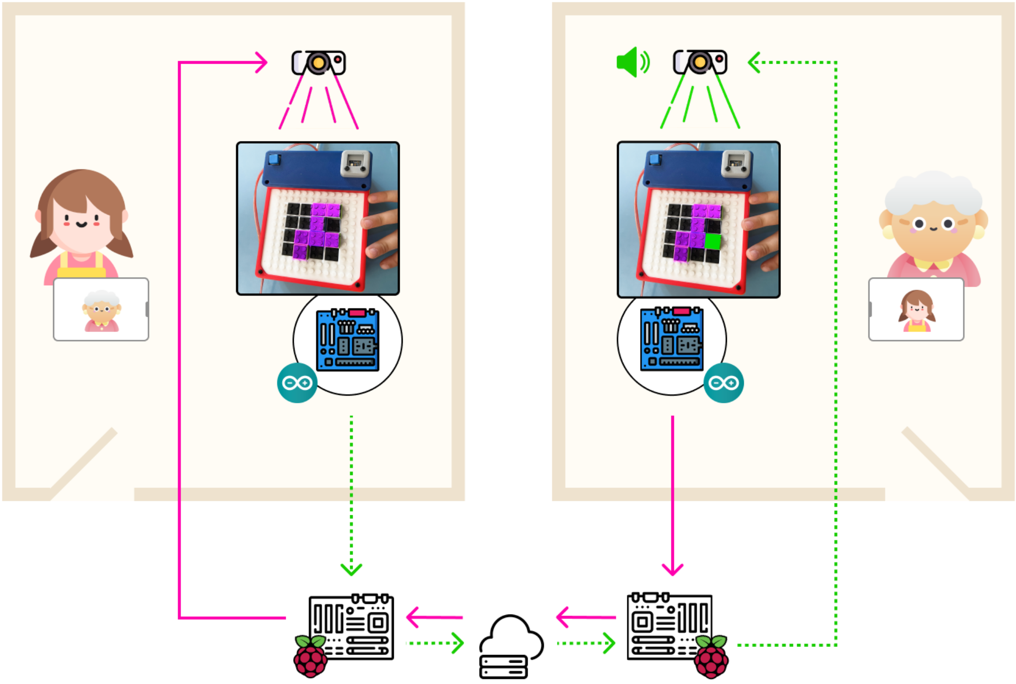

Fig. PIII.2 Visualisation of the system's architecture. The grandchild and the grandparent are in different rooms (at a distance), each having the same setup in front of them. We illustrate the data flow from the Arduino inside the smart baseplate to the corresponding python client (running on Raspberry Pi). The data continues to the server and from there to the other client, and then to the projector that displays a dynamically constructed image on top of the baseplate and a corresponding sound. In the pictured example, the grandchild placed a toy brick and so the corresponding position on the grandmother's baseplate becomes green, followed by a short sound. (This Figure has been designed using images made by Freepik from Flaticon.com)

the system's state at any moment. Designing for awareness is also in line with Hassenzahl et al.'s [233] strategies to mediate feelings of connectedness.

Based on those design decisions, the MagiBricks system was implemented. We drew inspiration from papers describing interactive paintings for entertainment on pop-up books [372, 441] or paper [129, 264, 518] for the use of conductive composite materials (paint and filaments for 3D printing). We also looked at interactive surfaces consisting of conductive PLA, such as 3D pictures and user interfaces [60, 489], mock-ups supporting urban planning [394], or extending interaction with touch screens [284]. The following subsections present the system in detail (see Figure PIII.3 for the basic components).

PIII.3.1 Smart Toy Bricks & Baseplate

The prototype was designed using Autodesk Fusion 360 and was 3D-printed using standard PLA filament and conductive material [256]. The prototype is packed in a case with the brick-detecting baseplate on top and a a chamber with the Arduino Uno Rev3 controller underneath, equipped with a shield that facilitates the connection of all cables. The main sensors responsible for detecting the elements are the Adafruit MPR121 touch module. The pins of the sensor can detect contact with the skin or an element with high resistance, as it uses

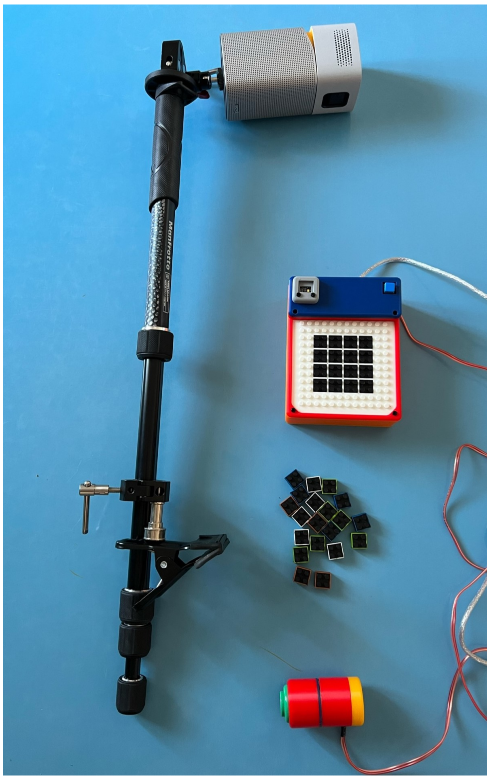

Fig. PIII.3 Basic system components: monopod with clamp and attached projector for the feedback system, smart baseplate (including button for brick removal), and smart toy bricks.

capacitive measurement. A single module has 12 such pins. Two wires are led out of the casing: the extension for the "brick removal" button that signifies the removal of a brick, as the current system version is not able to distinguish between removing and adding, and a second cable that powers the Arduino and sends information to a Raspberry Pi via UART communication. This is used for data exchange as a web socket client (feedback system). The 3D-printed toy bricks look similar to other commercially available ones, e.g. LEGOs®. A single piece of 2x2 dots (comprising a brick) consists of two types of material: a black core, printed from conductive PLA, and a coloured shell, printed from classic coloured PLA, so that each toy brick has a colourful casing around its black (conductive) core. Additionally, as the hand does not come into contact with the conductive material when removing bricks while playing with them (most users only grab the brick's outer shell when removing it), we added lines of conductive paint around them (Bare Conductive Electric Paint), thus allowing touch detection on the sides of each toy brick as well. The smart baseplate, consists of a 4x4 matrix and is filled with 2x2 dot plates. Similar to the smart toy bricks, it consists of two types of materials: conductive PLA, as a detection plate, and PLA as a base, which allows the separation of individual 2x2 plates and their even distribution. Due to their size and complexity, elements from different materials were printed separately and then glued together. In order to connect the printed elements with the electronics, a dedicated printed circuit board (PCB) was designed for easy connection of individual detection points with the pins of the touch sensor. The conductive elements were connected with the PCB using the heat set insert technique (fusing metal elements, e.g. wires or threads inside the plastic). Each tile is connected to individual pins of the touch sensor located on the PCB, which transmits information directly to the Arduino main module through I2C communication (Figure PIII.4). A PCB mechanically supports and electrically connects the electronic components using conductive tracks, pads, and other features etched from one or more sheet layers of copper, laminated onto and/or between sheet layers of a non-conductive substrate. The prototype recognises elements on one of sixteen designated points on top of the baseplate. Nevertheless, toy bricks can also be added on top of each other, in order to build vertically, since the addition of a toy brick will still be detected by the capacitance of the finger in contact with the top-most element of a vertical structure, transmitted through the conductive core of the toy brick all the way to the baseplate.

PIII.3.2 Feedback System

Regarding the feedback system (Figure PIII.2), Player 1 can experience feedback from player 2 (and vice versa), in the form of sound and colour: green when a brick is added, red when a brick is removed, and pink for showing all the current positions where player 2 has placed a brick. The colour feedback is made possible by a custom set-up we created, using a portable projector, a monopod, and a clamp to attach the monopod to a surface (e.g. a table). Thus, the projector casts the appropriate image on top of the baseplate, based on the client program running on each Raspberry Pi. An example of the colour feedback can be seen in Figure PIII.1c. We implemented an external feedback system rather than an internal light source e.g. including LED lights directly inside the prototype, for two reasons; one, having individual LED light sources inside each brick was impossible due to their small, LEGO®-like size, and two, due to the physical properties of the detection points inside the baseplate, which are crucial for brick detection. In particular, the conductive PLA material fully blocks light and cannot function as an optic fiber element, prohibiting illumination of vertical brick structures from below. Therefore, we chose to superimpose the colour feedback, which allows players to receive colour feedback even with multiple bricks stacked vertically, as this is projected on the top-most toy brick.

The architecture of the feedback system employs a web-socket-based server-client model with two clients, and the programming logic followed is event-based. The server, invisible to the players, is Python-based and communicates with two Raspberry Pis, which are in the same room as each player, running the client code. Once a change is detected (capacity change on top of the baseplate), the Arduino transfers the information about the position of a brick and whether it was added or removed from this position to the Raspberry Pi connected to it. Thus, client 1 communicates the information about the position of interest and whether a brick was added or removed by player 1 to the server, which in turns passes that information on to client 2. Once client 2 receives the information about a change, it logs the information on a structure that keeps track of all the positions where bricks have currently been placed. Then it dynamically updates the image cast by the portable projector on top of the baseplate, so that the position of interest becomes green if a brick was added there, or red if it was removed. This is accompanied by sound feedback, with a different 2-second audio clip being played based on whether a brick was added or removed. Finally, after 3 seconds, the projected image is updated again, so that nothing is projected in the position of interest if the previous colour

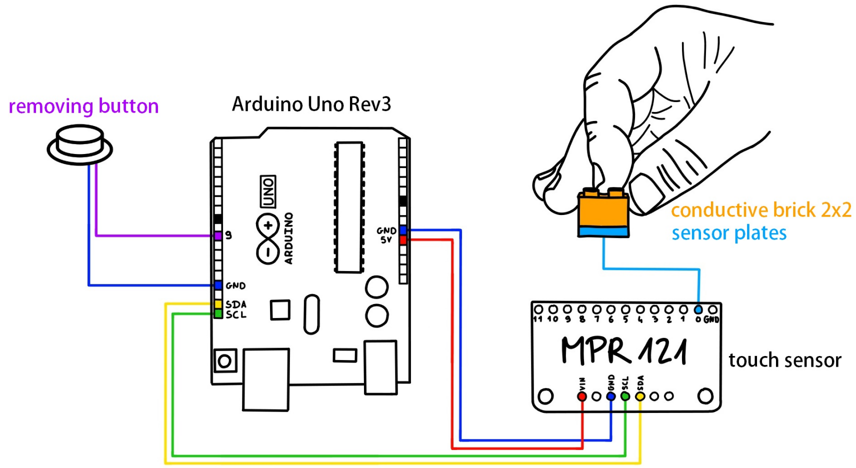

Fig. PIII.4 Smart toy brick detection circuit.

Table PIII.1 Participant Demographics.

Pair	Ages & Genders	Toy Bricks Experience	First Condition
GP1 | GC1	61 (F) | 10 (F)	yes | yes	RB
GP2 | GC2	74 (F) | 10 (F)	no | yes	RB
GP3 | GC3	71 (F) | 5 (M)	little | yes	RB
GP4 | GC4	52 (F) | 4 (F)	yes | yes	MB
GP5 | GC5	58 (F) | 4 (F)	yes | yes	MB
GP6 | GC6	77 (M) | 7 (M)	no | yes	MB

was red, or a pink colour is projected if the previous colour was green. Thus, player 2 always has an overview of any changes that player 1 makes on their baseplate, while also keeping track of all the positions where player 1 placed toy bricks.

PIII.4 User Study

We conducted a within-subjects study in the European Union with six pairs of grandparents-grandchildren (N=12), to investigate how MagiBricks affects their communication, collaboration, and perceived connectedness while playing over a distance (RQ1) and how they interact with each other while playing with MagiBricks (RQ2). Participants were engaged in two different conditions, which we counter-balanced: i) *MagiBricks condition (MB)*, where they interacted with the MagiBricks system, and ii) *Regular toy bricks condition (RB)*, interacting with regular toy bricks. To remove the influence of different toy brick quality, we used the same physical toy bricks but disabled the feedback of the MagiBricks system. Ethics approval was obtained by the Ethics Committee of Utrecht University (ERB Review Bèta S-21606) prior to the study.

PIII.4.1 Participants

We recruited N = 12 participants, six grandparents aged 52-77 ($M = 65.5, SD = 9$), five female, and their respective six grandchildren, aged 4-10 ($M = 6.6, SD = 2.5$), three female. Hereinafter, we refer to the six grandparents as GP1-GP6, and to their grandchildren as GC1-GC6. Participant demographics and the first condition they experienced are shown in Table PIII.1. All participants had no colour vision deficiency, and all grandparents lived in their own household. We focused on this age group since grandchildren can already play with toy bricks, construct structures and have basic communication skills at age 4, while on the other side of the spectrum, research shows that children aged 10 and below are more likely to play and communicate with their grandparents, as this can decline when they enter the preteen phase [161]. Participants were recruited through word-of-mouth and the personal network of the authors, using a snowball sampling strategy. The participants took part on a voluntary basis. Each pair of grandparent-grandchild received a board game that they could play together, as a token of appreciation for their participation.

PIII.4.2 Procedure

We conducted a within-subjects exploratory study, where participants engaged with the two conditions, *MB* and *RB*, in one of two different sessions, each taking place on separate days. Participant pairs were randomly but evenly assigned to one of the two conditions for the first session, in order to counterbalance. The study sessions took place at a convenient location for the participants, a house provided by a contact person of the authors. Two people from the research team were present throughout the entire study duration. Each participant was in different rooms of the house, together with a researcher, at a distance from each other and with closed doors, ensuring that they could only hear each other through the video call, thus creating a distributed play situation that was "over a distance". Each session lasted between 20 and 65 mins (M = 39 mins, SD = 13.6). Participants were able to take a break if they wished and were offered snacks and water.

At the beginning of the first session, participants were greeted and taken to the room where the grandparent's play setup was located. After the entire process was explained to them, participants were able to ask questions and it was pointed out once again that participation was voluntary, and they could stop their participation at any point during the study. Informed consent forms were signed, by both the grandparent and a parent/legal guardian of the children, in case they had not already been signed, and verbal assent from the children was obtained. Only one mother wished to stay and quietly observe the session, while the rest did not stay for the duration of the study. Following this introductory phase, demographic data were collected and the child was guided to a separate room with the leading researcher, where the second play setup was located. A brief semi-structured interview with each participant took place, in order to establish the current playing and communication habits of the grandparent-grandchild pair and prior use of toy bricks and relevant technologies for remote communication and play. The researcher also engaged in a short casual conversation with the child to help them feel comfortable, and reduce any anxiety, shyness, or uncertainty. Apart from the interview, the same process was followed in the second session, in order to re-establish rapport with the participants, remind them of the process, and give them the opportunity to ask any questions before beginning.

The system setup present in each of the two rooms is visible in Figure PIII.1a. In the *MB* condition, the researcher additionally explained to participants the meaning of each colour they could see as feedback (green, red, and pink). The researcher also explained the function of the button to signal brick removal in the *MB* condition. Each participant was assured that the researcher would be the one pressing the button when needed, so that participants do not have an additional task and can focus on their shared playtime. In each session (*MB* or *RB*), participants were asked to engage in three different playing tasks, including both structured (create specific structures) and unstructured play (interact with the toy bricks freely), as well as a "tic-tac-toe" game. Participants were instructed that they could play together as they wished, and could communicate via video call the entire time. All participant pairs received the same instructions. For the structured play part, participants were asked to create the following structures: i) a square, ii) a tower, and iii) an animal. In particular, the researcher instructed the participants that the task's goal was that they both build each structure. However, they were informed that they could create each structure the way they wanted it (e.g. the tower could be as high as they wanted). Also, they were free to communicate with each other to the degree they wished to. Following this first playing task, the grandparent and grandchild played the well-known game of tic-tac-toe, with which all participants were familiar. To clarify, in tic-tac-toe players take turns placing their symbol on an empty square to get three in a row horizontally, vertically, or diagonally. The game ends in a tie if all squares are filled without either player getting three in a row. In our study, participants used their bricks as their symbols, placing them on the 3x3 part of the grid that resided on the bottom-left corner of the baseplate closest to them. Finally, participants could engage in free play, where they could create any structures they wanted. Again, the participants were instructed that they could communicate to the degree they wished. However, this time the goal of the task was that each one creates a structure that was not predefined. The participants could either create the same structure or a different one each. If they wanted, they could also ask the researcher for ideas of what to build, in case they needed inspiration.

At the end of each session, each participant took part in a short debriefing semi-structured interview, to elicit their opinions about the toy bricks they had just played with (e.g. fun, ease-of-use) and their perceived feelings of connectedness. The interview protocol is available in the Supplementary Material. Additionally, at the end of the second session children were asked to complete the Again-Again Table [449], asking them which activities they would do again. For younger children that could not read, the researcher read the questions as well as the available answers out loud.

PIII.4.3 Data Collection & Analysis:

During the study, we collected both qualitative data by video recording the sessions and interviews, as well as quantitative data, using the Again-Again Table [447] questionnaire, indicating whether children would like to do a certain activity again [447]. The qualitative data was analysed in an iterative, collaborative manner. The interviews were transcribed verbatim, the video recordings were transcribed non-verbatim, with immediate translation from the original language to English. Based on the interaction analysis method [266, 274], the expressions, comments, actions and exhibited behaviour during the sessions, along with time stamps were logged in Excel sheets together with the transcribed dialogues. The data of the video observations and interviews were open coded, using the MaxQDA software. After an initial round of open-coding the data from three grandparent-grandchild pairs by two authors, an initial coding tree was discussed and agreed on. Then, one researcher coded the remaining material. Finally, we used affinity diagramming and derived four themes, which are presented in the next section. This process is in line with Blandford et al. [51].

PIII.5 Findings

Here, we present out findings based on the analysis of our user study. The quantitative data, comprised of the grandchildren's answers to the Again-Again Table questionnaire are available in the Supplementary Material. Based on our qualitative inquiry, four themes were conceptualised from the data: *Communication Dynamics*, *Nature of Play*, *Role Taking*, and *Perceptions of Connectedness*. Before discussing these themes in more detail, we outline general impressions from our study. In general, both conditions were perceived positively, with participants enjoying playing with both MagiBricks and the regular toy bricks. They often looked at each other and smiled upon completion of a structure (GP6 and GC6, RB), or when one successfully followed the other by looking at the feedback (GP6 and GC6, MB). All participants enjoyed the feedback, but particularly the children immediately had a smile on their faces when they *"saw the baseplate light up"* (GC2, MB), often pointing at the place where they understood their grandparent placed their toy brick: *"Oh, again! It's magic!"* (GC3, MB) or at the "pink-coloured" places where they could see their grandparent already had toy bricks: *"Grandma put it here, here, here, and there!"* (GC4, MB) This is further corroborated by the grandchildren's answers to the Again-Again Table, which demonstrates that all children enjoyed playing with MagiBricks, and already hints at their preference of playing with MagiBricks over the regular bricks, which we describe in more detail below. This is also clearly reflected in the answer of GC1, one of the oldest children, who would not want to play again with the regular toy bricks with her grandmother, but rather with MagiBricks. Below, our findings for the two conditions, *MB* and *RB*, are comparatively described and illustrated with excerpts from the sessions.

PIII.5.1 Communication Dynamics

The first theme focuses on how the communication dynamics between the grandparent-grandchild pairs differed between the two conditions. The differences spanned two dimensions: i) the communication frequency and "intensity", i.e. how much they communicated and interacted with each other, and ii) the communication content, i.e. what they communicated about and when. Regarding the first, there was a clear difference between the two conditions, as participants communicated and interacted more with each other in the *MB* condition, with frequent interactions about how to make a structure, what to build, as well as discussing the feedback. The intensity and frequency of interaction significantly decreased in the *RB* condition, where there were multiple instances with a prolonged lack of interaction between the participants. For instance, GC6 continuously ignored his grandparent in the *RB* condition when he was asking what they should make in the unstructured play part of the session, and instead talked to the researcher. In contrast, GC6 continuously engaged with his grandfather in the *MB* condition, making sure that his grandparent understood that what he wanted to build was a house, *"Okay grandpa?" (GC6, MB)*, and carefully watching where his grandfather placed his toy bricks, pointing it out when they were not placed the same as his own *"Grandpa, not there!" (GC6, MB)*.

Our analysis also showed a difference in the topics (communication content) that participant pairs talked about and when this occurred. In more detail, participants more frequently engaged in richer-in-content conversations in the *MB* condition, communicating about how to make the various structures with the toy bricks, including asking for help and giving instructions, and about the feedback from the system: *"Tell me how you do it, so I can watch you, and make it as well!" "Okay, I take the green one and I put it there, see?" "I do the same [name of child], here you go!" (GP1 and GC1, MB)*. This was additional to conversations about beginning or completing a structure, which were the main topics of conversation for participants in the *RB* condition.

PIII.5.2 Nature of Play

A key difference between the two conditions was the nature of play that the grandparents and grandchildren engaged in. While in the *RB* condition participants mostly built their own structures without collaborating, both during the structured and the unstructured play, playing with MagiBricks seemed to have the exact opposite effect. In particular, even though the activity itself remained the same in both conditions, our analysis showed that MagiBricks, by allowing participants to always be aware of where the other player placed their toy bricks, changed the play conceptualisation, from an individualistic to a collaborative activity. Participants seemed to adapt to a different kind of play in the *MB* condition, where structures had to be built together, with one participant placing their bricks first and the other following. This led to children assuming "new rules", and specifically thinking that it was "wrong" when they and their grandparents were not building the exact same structure. For instance, GC2 noticed that her grandmother was not placing her toy bricks in the same place during the structured play, and tried to help her when *"she did it wrong" (GC2, MB)*. Both grandparent and grandchildren participants wanted to ensure they were building the same thing in the *MB* condition, and that the other could follow. This materialised in various ways, for example leading them to press again on top of the toy bricks they had already placed to make sure their feedback was coming through (GP2-GC2, MB), and converse with each other about whether they could see their current movements, *"Did you see what I just removed grandma?" (GC1, MB)*, or notice from the pink-coloured feedback that some toy bricks were missing and giving out instructions to fix that: *"Grandpa, you have not put a brick on the orange one!" "So I should put one here now" "Yes, put one where I did!" (GC6 and GP6, MB)* .

On the contrary, in the *RB* condition the majority of participants built their structures separately in both the structured and unstructured playing tasks, with significantly less interaction and conversation between them. Verbal instructions sometimes became too complicated (*RB*), resulting in confusion on either the grandparents' (in the case of GP4) or the grandchild's side (in the case of GC5), or in the grandparent having to repeat the same instructions several times without success (GP5 and GC5, RB). GP5 noted the lack of feedback in their second session (*RB*) as negative, and expressed this to the researcher: *"Now there is no colour feedback? Now I won't be able to help him. I won't be able to see I mean" (GP5, RB)*. Notably, GC3, GC5, and GC6 were lifting and tilting the baseplate to show what they had created to their grandparents through the camera, demonstrating the importance of visual feedback.

In comparison to the other two playing tasks (structured and unstructured play), the importance for the feedback offered in the *MB* condition, was more prominent in the tic-tac-toe game. In order to successfully play the game (in both the *MB* and *RB* conditions), participants were required to collaborate and coordinate the placement of bricks. Therefore, in the *RB* condition, participants needed to verbally explain to each other where they had just placed their bricks for the game to continue, as this information was not relayed in another way, i.e. by the feedback. This led to some issues, as participants had difficulties with communicating this with only verbal input, leading to either restarting the game, or turning to the researcher for help.

PIII.5.3 Role Taking

The third theme we identified was role-taking. As presented in the previous theme, a key difference between the two conditions was the participants collaborating and wanting to build the same structures in the *MB* condition. This contributed to the emergence of two player roles: the leader, and the follower. These roles were assumed by both grandparents and grandchildren. In the *RB* condition, the role-taking theme was identified only for the grandparents of the two youngest children, GP4 and GP5. On the other hand, in the *MB* condition the theme was identified in all participant pairs. For most participant pairs, the role-taking was very prominent throughout their *MB* sessions, and the roles were even exchanged from one to the other throughout a specific session. Below we describe interactions that occurred i) when children were the leader, and ii) when grandparents were the leader. When grandchildren were in the lead, they were guiding their grandparents, by placing their toy bricks one by one so the grandparents could see the feedback and copy their moves. This was also frequently accompanied by verbal instructions, or the children verbally articulating their actions, such as GC1 narrating her moves while making an "ant": *"And then we do the same on top!" "From the other side?" "Yes!" (GC1 and GP1, MB)*. Additionally, grandchildren in the lead were helping their grandparents when they asked for it, and this was particularly facilitated by the system's feedback, which they used to achieve this. Grandchildren also assumed the role of the "technology expert", explaining how the MagiBricks system worked to their grandparents, for instance reminding them that toy bricks could only be placed on the black 4x4 baseplate and not the white surroundings, *"We can't place the bricks on the white part!" (GC5, MB)*. Interestingly, grandchildren assumed the role of the leader only in the *MB* condition. Regarding grandparents in the lead, while there were instances where they were verbally guiding grandchildren by giving them instructions in both conditions, in the *MB* condition grandparents would use the system's feedback as their main instruction tool. In particular, grandparents placed their toy bricks first, so their grandchild would see the feedback and be able to copy their move. It is worth noting that we observed an obvious benefit in having the feedback for following instructions, as there were various cases where difficulties arose from trying to follow verbal instructions without it, which often led to the grandchild turning to the researcher who was present in the room for help. In both conditions, grandparents played the role of the encouraging supporter, by prompting them to start with creating a structure or continue with placing the next toy brick, reassuring them - *"Take your time!" (GP3, RB)* -, and praising them - *"Good job! Now continue in the same line" (GP5, MB)*.

PIII.5.4 Perceptions of Connectedness

The fourth theme engages with the different perceptions of connectedness while playing, both between the grandparent and grandchild participants, as well as between the two conditions. Our analysis showed that the aspects that made participants feel connected to each other varied between the two conditions. On the one hand, children did not identify any specific aspect that made them feel connected with their grandparents when asked about this in interview after the *RB* condition, while the two older children, GC1 and GC2 could identify such aspects in the *MB* condition. Grandparents could identify aspects that made them feel connected in both conditions, however, the aspects differed across the two conditions. To elaborate, aspects that made grandparents feel connected to their grandchildren in the *RB* condition were the fact that they were playing together (GP3), that they were having a video call while playing which allowed them to talk (GP2), or the competition and process of playing the tic-tac-toe game (GP1, GP4). However, in the *MB* condition, their perception of connectedness changed to *"making the same thing"* (GP1, GP4, GP5, GP6), *"following each other's instructions"* (GP1, GP4), *"seeing what the other was doing through the feedback"* (GP6, GC2), and *"communication and collaboration"* (GP2, GP3, GP5, GC1). This illustrates the determining role that feedback and its effects on communication, collaboration, and conceptualisation of the play had on the perceived connectedness of participants.

PIII.6 Discussion

Our study showed that a tangible smart toy that enables a continuous state of mutual awareness through visual and audio feedback can positively affect the perceived connectedness of grandparents and grandchildren while playing over a distance *(RQ1)*. Participants found it much easier to create structures together with MagiBricks and found playing with MagiBricks more enjoyable and preferable to regular toy bricks *(RQ2)*. Additionally, our findings showed that MagiBricks shifted the nature of play between the participant pairs *(RQ2)*. Specifically, participants seemed to automatically adapt to a new conceptualisation of the same game, where "unwritten rules" dictated they should build their structures together. This led to enhanced communication between them, to collaboration, and to the emergence of interchangeable leader-follower roles within the game *(RQ1, RQ2)*. Below, we reflect on our findings and explore how and why MagiBricks, and in particular the feedback they provided, had this effect on the play interactions and connectedness of the grandparent-grandchildren pairs. We also reflect on implications for future research.

Our findings regarding the effects of MagiBricks on communication dynamics, nature of play, and perceptions of connectedness, indicate that designing for intergenerational connectedness can be facilitated by employing feedback as a mechanism for fostering mutual awareness, leading to enhanced communication and collaboration. We speculate that the real-time multi-modal feedback of MagiBricks fostered feelings of co-presence, i.e. sensing that one can perceive others and that others can actively perceive them [404], thus enhancing communication and fostering collaboration between the pairs. Casanueva et al. [83] already demonstrated the close link between collaboration and co-presence. Additionally, our findings revealed differences in the participants' perceived connectedness between the two conditions. Those differences particularly highlighted how participants felt connected to each other while playing because of the feedback and their resultant collaboration. Our findings are in line with Hinske et al. [240] and Farr et al. [165], who found that an audio-augmented castle toy increased social play and collaboration compared to an identical non-augmented version. We extend these findings by demonstrating the positive effects of multi-modal feedback on social play and collaboration, showing how this is valid not only for co-located settings but also in distributed play contexts. Smart toys can thus present new opportunities for fostering communication and collaboration in distributed play settings. Therefore, **our work demonstrates how smart toys employing real-time multi-modal feedback can lead to mutual awareness and foster users' perceived connectedness during distributed intergenerational play.**

Furthermore, the feedback of MagiBricks served as a trigger for conversation, affecting the nature of play and conceptualisation of the activity and driving grandparents and grandchildren to assume certain rules and roles within that context. Within this changed concept, participants wanted to build the same structures and used the feedback not only as a guide to do so, but as a way to enforce this new rule that their structures should be the same. This contrasted to the more individualistic game concept that was followed by the majority of participants in the *RB* condition. Kraut et al. [308] already showed that pairs who collaborate remotely to complete collaborative visual problem solving, e.g. puzzles, can benefit from a shared visual space, as it can facilitate communication by allowing monitoring each other's comprehension. Our analysis points to how a smart toy employing visual feedback to create this shared visual space can enhance communication and lead to collaboration in the case of grandparents and grandchildren playing in distributed settings. Overall, the augmentation that MagiBricks offered seems to have captured participants' attention, serving as a guide for their interactions while playing. This guide nudged participants to stay inside the constraints provided by the visual feedback, e.g. leading them to assume that placing bricks outside those constraints was "wrong" or "against the rules". Therefore, our findings show that the feedback led participants to change the way they interacted both with the toy, as well as with each other. This is in line with Hinske et al.'s [240] findings that digitally augmented play environments can encourage different forms of play than non-augmented ones. We extend research on tangible interfaces, which are known to naturally use constraints to communicate rules without having to explicitly state them [510], by showing how **smart toys, augmented with multi-modal real-time feedback, can lead to the generation of rules that would otherwise need to be explicitly communicated. Particularly, feedback could lead to changing the nature of (playful) activities, and in particular their conceptualisation from individualistic to collaborative ones.**

Regarding the changed interaction between participants with respect to role taking, interestingly, grandchildren assumed the role of the leader only in the *MB* condition. It should be noted that GC4-GC6, who had completed the *MB* condition first and assumed leader roles, did not continue with this role taking in their second, *RB* session. It therefore seems that MagiBricks placed children in a position of power, which playing with the regular toy bricks did not achieve. It empowered them to assume the expert role and give instructions, feeling confident and enabled to do so. The underlying reason could be twofold. We hypothesise that, one, it could be attributed to children usually being apt with technology, even at a younger age, and grandparents either expecting their superior digital skills, or wanting to empower and nurture them by allowing them to be the "expert". Grandparents often assume mentor roles [306], but within this digital form of distributed play they could assume the role of the less knowledgeable party, allowing grandchildren to become the teacher [1, 114, 642]. This manifested in grandparents encouraging grandchildren to take the leading role by asking them questions about how to complete specific steps. The second reason, co-existing with the first, could be that the specific features of MagiBricks led to the children feeling empowered to take the lead. Vetere et al. [583] already explored roles grandparents and grandchildren assume during different types of co-located activities, and found that grandchildren could assume the role of an unconfident follower, seeking reassurance from their grandparent giving instructions. In our case, we speculate that the continuous mutual awareness of each other's actions via the real-time feedback provided children with a sense of security and certainty in the distributed play setting, as they were ensured that not only could they have a direct overview of their grandparents' actions, but also that their grandparents could see theirs. This potentially provided children with reassurance, to not only assume the role of apprentice or imitator [583], but to also become leaders themselves. Relating this back to our original goal of designing for connectedness, Kearney [286] described "empowered connectedness" as "a sense of having a safe place within a community and a meaningful role to play". Therefore, it could be argued that systems employing MagiBricks's features could lead to empowered connectedness, by providing the certainty of real-time feedback and allowing children to take on the meaningful role of the leader/instructor. This also relates to the concept of mutual control presented by Yuill et al. [637], which constitutes a behaviour mechanism that can underlie systems fostering collaboration. Therefore, providing them with both mutual awareness and control could have contributed to children feeling empowered to take the lead. Designing for empowerment has been receiving increasing interested in the CCI community [578]. For instance, pertinent research has addressed the topic of intergenerational distributed co-design with the goal to empower children who are geographically distributed to have an active role in the design of artefacts that are ultimately meant to be used by them [597]. **We extend previous work on technologies that seek to empower children, by demonstrating how collaborative systems that allow for mutual awareness and control, e.g. via feedback, can empower even younger children to take leading roles in a collaborative setting.**

PIII.6.1 Ways Forward & Limitations

Based on our findings, we highlight possible ways forward for systems that utilise feedback and tangibility. **Firstly, future systems could leverage feedback and tangibility in the context of collaborative systems or scenarios where it is desirable that children learn collaboration or turn-taking.** An example application could be exploring the use of systems like MagiBricks for supporting children with ADHD [621], who typically struggle with social interactions, impulsivity, and turn-taking [604]. However, before applying the system in such a context, further studies should be conducted with a larger sample size to further consolidate our findings. In addition, the experience of interacting with MagiBricks is a hybrid one between a digital game and regular toy bricks. We speculate that feedback and tangibility could enable players to feel that they could manipulate something on the other end of the divide. The term "divide" here means both the physical distance between grandparents and grandchildren, as well as the well-known generational gap that deems grandchildren more technologically fluent and grandparents often reluctant to adopt and use new technologies. These aspects of feedback and tangibility could enhance an illusion of control compared to e.g. a computer game, due to the interaction with concrete physical material. Wallbaum et al. [596] already suggested that bridging the digital with the non-digital could facilitate scaffolding between the different generations.

Additionally, it is worth noting that two pairs (GP1-GC1 and GP4-GC4) experienced some feedback latency in the *MB* condition due to an unstable internet connection, which was subsequently resolved. No effect was observed, neither in their interaction before and after the latency issue, nor in comparison to other participant pairs. Specifically, participants expressed out-loud that they could not see each other's actions anymore, without this short interruption leading to decreased engagement or significant time off task. When this latency occurred, the researchers briefly explained that this was a limitation of the system and that it should work again shortly.

It also becomes particularly interesting to explore smart tangibles in the context of Mixed Reality (MR), replacing the video call that we used in our study and allowing for full-body virtual representations of the players. This would add a different layer to the digital part of the experience, by allowing grandparents and grandchildren to co-exist in the same space, albeit virtual, and interact with systems like MagiBricks, rendering the experience a mixture of visual, audio, and tangible feedback that seeks to enhance their feelings of connectedness. **Future work that seeks to bridge spatial and generational divides should take advantage of the affordances of tangibles and of different modalities of feedback, and explore how**

the resulting "illusion of control" affects connectedness in different settings, e.g. in MR environments. Deploying MagiBricks in MR settings could also address certain limitations of the current prototype, such as knowing how many bricks are placed vertically by virtually superimposing toy bricks in the MR environment. Furthermore, future research could explore the use of systems like MagiBricks over a longer period of time, investigating their utility as situated artefacts, as well as how often they are used, and how long they are usefully employed. This, however, is no simple task, as evaluating systems long-term and especially whether participants stay engaged after repeated use is not often addressed in CCI research as it can be challenging [631]. Finally, future studies could deploy similar systems during both co-located and distributed play, to investigate how the feedback and tangibility aspects affect each type of play, and how each could help grandparents and grandchildren build upon their previous interactions.

We recognise that our work is subject to certain limitations. Our sample size of six grandparent-grandchild pairs was rather small for conducting meaningful quantitative analysis. However, our sample size, being the most common sample size within HCI research [75], and a primarily qualitative approach are in line with similar work (e.g. [275, 583, 587]). Even though the age of our child participants is similar to related studies (e.g. [587, 596]), future work should explore potential age-related effects. For example, role-taking was present *only* for GP4 and GP5 in the *RB* condition, which could be related to GC4 and GC5 being the two youngest children in the study, as this might have affected GP4 and GP5 knowing they have to help out more, in comparison to older children. Nevertheless, the sessions we conducted were rich in information and allowed us to derive implications for future systems employing tangibility and feedback towards fostering connectedness.

PIII.7 Conclusion

In this paper, we presented MagiBricks, a system consisting of 3D-printed smart toy bricks that provide visual and audio feedback about their placement on a smart baseplate, for enhancing intergenerational distributed play. We conducted a within-subjects study with six pairs of grandparents and grandchildren. We compared the interactions and perceived connectedness of the participants when playing over a distance in two conditions: i) with MagiBricks (*MB*) and ii) with identical regular toy bricks (*RB*). Playing with MagiBricks enhanced the communication and collaboration between participants, leading to increased feelings of connectedness while playing over a distance. Our findings suggest that tangible artefacts that combine tangibility and feedback, leading to mutual awareness and control, can actively affect the conceptualisation of a (collaborative) activity, can lead to empowerment, and can provide suitable experiences that foster intergenerational play and connectedness over a distance. We hope that this paper will inspire further inquiry into how smart tangibles can foster connectedness between family and friends.

PIII.8 Selection and Participation of Children

The study and its protocol were approved by the Ethics Committee of Utrecht University (ERB Review Bèta S-21606). The study was explained to the children's legal guardians, who gave their informed consent for inclusion before participation, as well as to the children, who were asked for a verbal agreement to participate. They were informed that they could stop and opt out of the study at any point and for any reason, and their data would be excluded, without any negative consequences. A total of six children took part in the study (five female, and one male). The children, along with their grandparents, were invited through word-of-mouth and personal contacts of the authors, using a snowball sampling strategy. All participants' personal data were stored securely, and all personally identifiable data were removed.

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PUBLICATION P IV

TeenWorlds: Supporting Emotional Expression for Teenagers with their Parents and Peers through a Collaborative VR Experience

The contents of this chapter are under submission at the ACM Symposium on Virtual Reality Software and Technology (VRST) 2024, as: **Evropi Stefanidi**[‡], Nadine Wagener[‡], Dustin Augsten, Andy Augsten, Leon Reicherts , Paweł W. Woźniak, Johannes Schöning, Yvonne Rogers, and Jasmin Niess. "TeenWorlds: Supporting Emotional Expression for Teenagers with their Parents and Peers through a Collaborative VR Experience".

Abstract

Adolescence is a period of significant growth and exploration, characterised by increasingly complex and influential relationships with peers and parents. These relationships are crucial for teenagers' well-being, emphasising the need to support these interpersonal interactions. Emotional expression plays a key role in that respect, helping to resolve conflicts that often arise during this developmental stage. Recognising the importance of fostering environments that promote emotional sharing, this paper investigates the potential of TeenWorlds, a Virtual Reality (VR) application, to facilitate emotional expression and shared understanding among teenagers and their peers and parents. In our study, teenagers accompanied by either a peer or a parent (total n=42) engaged with TeenWorlds to visually represent their emotions related to a common conflict, discuss these emotions, and collaborate on a joint VR drawing. Our findings indicate that TeenWorlds can foster communication, reflection, and interpersonal relationships for teenagers and their peers and parents. However, significant differences were observed in interactions with peers versus parents. We contribute insights into the design of VR systems that support reflective experiences and meaningful family interactions, ultimately promoting adolescent, parent, and family well-being.

Contributions

This paper contributes the following. First, an exploratory evaluation of how TeenWorlds, a system allowing emotional expression through visually and verbally externalising and representing emotions affects reflection, communication, and interpersonal relationships of teenagers and their peers and parents. Moreover, it offers empirical findings regarding how emotional expression can be supported for both teenagers and parents through creative

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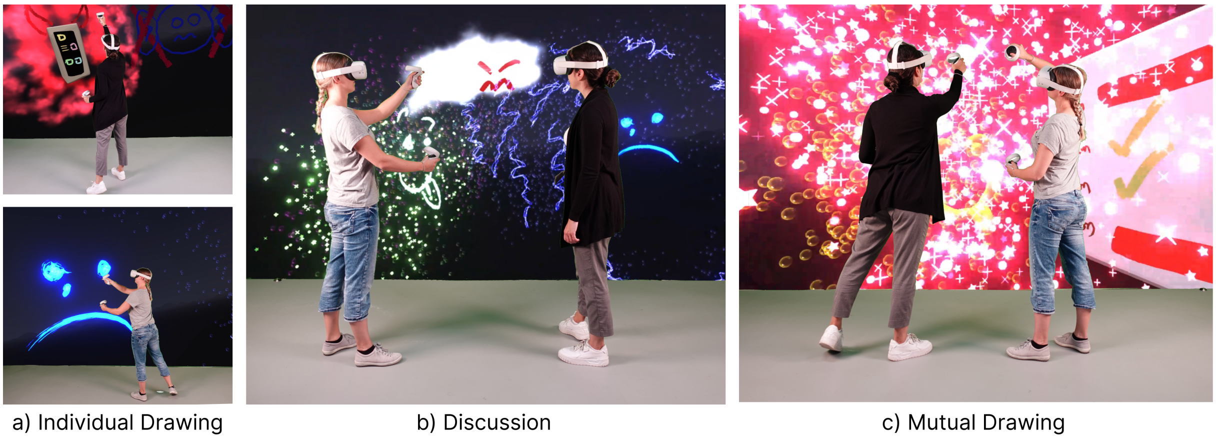
[‡] Both authors contributed equally to this research.

drawing in VR. It also provides results about the differences of interacting with TeenWorlds depending on whether teenagers engage with this system with their peers or parents. Finally, we derive design implications for future technologies that aim to effectively engage teenagers in reflection with both their parents and peers, and for building VR experiences that support meaningful and playful joint interactions supporting teenager and family well-being.



a) Individual Drawing b) Discussion c) Mutual Drawing

Fig. PIV.1 Participants engaging in a) an individual drawing regarding a shared conflict, b) a discussion phase where they visit each other's individual drawings, and c) a mutual drawing regarding their feelings after the conflict was resolved.

PIV.1 Introduction

Adolescence is a unique phase of life characterised by significant growth and exploration [484, 488, 531, 539]. While these changes can be challenging, and can lead to emotional turbulence and interpersonal conflicts [145, 401], they also present opportunities for teenagers to form their identities [157, 303, 600] and establish their autonomy [340, 540]. During this time, relationships with peers and parents become increasingly complex and influential [63, 113]. Peer interactions are crucial as they help shape teenagers' social skills, self-esteem, and behavioural patterns [63]. These relationships provide a platform for exploring social roles, managing conflicts, and developing deep emotional connections [63, 417, 521]. Simultaneously, the parent-teen relationship undergoes significant transformations as teenagers seek greater independence [150, 218, 471]. Despite these changes, the role of parents remains critical [552, 553], as they can provide not only emotional support and security [113, 218] but also guidance as adolescents navigate the challenges of growing autonomy [263, 280]. Communication and shared understanding can lead to enhanced well-being and academic success [126, 173].

Emotional expression, defined as the communication of inner emotional states towards the outside [217], is a key component of these relationships. It can foster teenagers' emotional intelligence [509] to convey their feelings and thoughts clearly, promoting deeper understanding and connection with others, and thus strengthening empathy [258, 363] and interpersonal relationships [209]. Meaningfully engaging with one's emotions can overall help in navigating emotional complexities [450, 451]. However, emotional expression is not always straightforward, and can benefit from external support, particularly for teenagers who can experience heightened sensitivity to social and emotional situations [192]. Therefore, this paper explores the opportunity of designing virtual environments that enable teenagers to express themselves emotionally with peers and parents as a way to support them in that direction.

Nowadays, teenagers increasingly utilise technological tools as a means of communication and expression. This shift is exemplified by their extensive use of textual messages, including the use of emojis [433], as well as verbal communication such as voice messages and video chats with friends [69]. Concurrently, teenagers interested in well-being and mental health often prefer digital tools over face-to-face interactions [194, 195]. Thus, there is an opportunity to design such environments that support teenager's well-being, for example through the development of technologies that provide new and extended spaces for emotional expression through behavioural, nonverbal and/or verbal means [217]. In Human-Computer Interaction (HCI) research, there is already a growing interest in designing technologies that aim to address teenagers' well-being, such as e-learning computer games to foster emotional intelligence [364], using interactive technologies for stress management [46], or supporting parent-teenage relationships and communication using meme-creating platforms [575]. Previous research has also shown that technologies that allow emotional expression could foster reflection and empathy among children of various ages, their families, and peers [550, 551]. Despite this interest, and the clear benefits of engaging teenagers in emotional expression together with their peers and parents detailed above, exploring how technologies could support *emotional expression* specifically for the user group of *teenagers,* and thereby strengthen their interpersonal relationships, remains under-explored.

One promising technology to support the emotional expression of teenagers is Virtual Reality (VR). VR applications allow highly controlled yet immersive environments [336] that can separate from real-world distractions and provide the space to express oneself in a "safe" and playful environment, in a way that is not feasible in physical reality. Moreover, prior work has demonstrated the potential of VR to successfully support both individual [593] and joint [506] emotional expression for adult users. Recently, exploratory co-design work was conducted within HCI on how teenagers could be supported by VR environments in developing strategies for regulating emotions, which can include emotional expression [299]. Additionally, research in the field of psychology has already demonstrated the suitability of VR for art therapy with this demographic, enabling participation even by teenagers who find it difficult to create content in traditional art therapy [512]. This work addresses the opportunity to employ VR in order to engage teenagers in emotional expression, both visually and verbally, together with two key stakeholders in their everyday experiences: their peers and parents.

We also explore how teenagers' experience in VR is affected based on whether they engage in this activity alongside their parent or another teenager (i.e. a peer). Literature details how teenagers spend a decreasing amount of time with their parents and an increasing amount of time with their peers [151, 320]. Moreover, previous research has shown that teenagers might communicate more openly with peers than with parents, disclosing more intimate information [413]. The different nature of relationships with peers and parents may therefore lead to contrasting experiences while using VR for emotional expression.

In this paper, we seek to address the following research questions (RQs):

RQ1: How does a VR application that allows emotional expression by visually and verbally externalising and representing emotions affect the interpersonal interactions and mutual understanding of teenagers when interacting with their peers and their parents?

RQ2: How does that differ depending on whether teenagers engage in this activity alongside a parent or a peer?

To address these questions, we conducted a study in which teenagers used *TeenWorlds*, our adaptation of the VR application OpenBrush [4], which previous research for emotional expression in VR has used in similar ways [299, 591, 593, 594]. In a multi-user setup, teenagers engaged with TeenWorlds together with their parents or their peers, to represent their emotions concerning a conflict that both participants had experienced with each other. In total, $n = 42$ participants (ten teenager-parent pairs and eleven teenager-teenager pairs) first individually represented their emotions through drawing in VR, then engaged in perspective-taking [190, 191] by visiting and discussing each other's drawings in VR, and finally created a joint drawing in VR. Based on quantitative and qualitative analysis, we found that TeenWorlds is an engaging experience that can help mediate communication, foster reflection, and increase the appreciation of the participants' relationship towards each other. However, our comparative analysis suggests that the current system setup better suits engagement with parents than with peers, suggesting the need to integrate additional support for successful emotional expression and reflection between peers. Based on our findings, we derive implications for designing VR applications that support teenagers in emotional expression and shared understanding, emphasising the need of scaffolding to reflect, and discussing how technologies like TeenWorlds could facilitate meaningful family interactions.

Therefore, this paper contributes the following: (i) empirical findings regarding how emotional expression can be supported for teenagers, their peers, and parents through creative drawing in VR, (ii) an exploratory evaluation through a user study of how our approach affects reflection, communication, and interpersonal relationships, (iii) comparative results of how this experience differed when teenagers engaged with their peers or parents, and (iv) design implications for future technologies that seek to effectively engage teenagers in reflection with both their parents and peers, as well as for building (VR) experiences that foster both teenager and family well-being.

PIV.2 Background & Related Work

This section presents relevant background on key concepts that we employ in this research: emotional expression, empathy, and well-being. We then engage with HCI literature on designing for teenagers and families. Finally, we discuss previous approaches that have employed VR for emotional expression, motivating our own use of this medium with teenagers, and their peers and parents.

PIV.2.1 Emotional Expression, Empathy, & Well-being

Emotional expression refers to communicating inner emotional states towards the outside [217]. It is a multifaceted phenomenon, encompassing everything from unconscious reactions, such as nonverbal cues (facial expressions), short utterances of awe or surprise, and verbal expressions such as naming emotions, to complex behaviour, such as visualising emotions by writing or drawing [217]. It forms the core of numerous therapeutic approaches, notably art

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[4] https://openbrush.app/. Tilt Brush, now called Open Brush, was made open source by Google in 2021 on GitHub.

therapy [222, 345], emphasising the role of visualisation and reconstruction of emotions for increasing positive affect and (self-)reflection, the process of introspection where individuals review and analyse their thoughts, emotions, and behaviours [210].

This process of expressing emotions has a number of important benefits. First of all, emotional expression can support both hedonic well-being (i.e. as an activity causing happiness) and eudaimonic well-being (i.e. to learn skills, reach one's potential, finding meaning) [132]. For example, expressing negative emotions can help with emotional regulation [217, 289]. This can result in cognitive change, which in turn can increase subjective well-being [421] (one's cognitive and affective evaluations of life satisfaction [134]). Moreover, sharing how we feel can build new relationships and strengthen existing ones [209]. However, it is important that the listener exhibits empathetic behaviour to the sharer when disclosing emotions [421]. Empathy, defined as the ability to understand and share another person's feelings, thoughts, and perspectives [28, 120, 197, 418], is integral to effective emotional expression. Similarly, the term emotional intelligence is tightly linked with empathy and emotional expression. Emotional intelligence refers to the capacity to identify, assess, and manage our emotions, as well as the emotions of others [509]. Emotionally intelligent individuals can better moderate conflicts and have an increased understanding of themselves and their relationship with others [509]. The relationship between emotional intelligence, emotional expression, and empathy is crucial, particularly for teenagers. Namely, high emotional intelligence supports social relationship development, stress reduction, and mutual understanding [188].

In the context of this work, we focus on emotional expression by externalising emotions in three different steps: visualising emotions through drawing, discussing them verbally, and combining these methods in collaborative settings. Our study delves into how VR-mediated emotional expression, both visual and verbal, affects interpersonal relationships and fosters mutual understanding between teenagers and their peers and parents. Given our focus on VR technology use, the following two sections discuss those aspects; first, by exploring technologies for teenagers and their families in a general setting, and then specifically looking into employing VR for emotional expression.

PIV.2.2 Teenagers, Parents, Families, and their Interactions with Technologies

HCI researchers have been increasingly investigating the interactions of teenagers (typically users between 13-19 years) [170] with technologies. Among other topics, they have examined teenagers' technology-supported communication [7, 214, 215] and their perspectives on social VR [348]. More recently, the topic of supporting teenagers' well-being through technology has attracted more focus. For instance, pertinent research has investigated the potential of conversational agents in addressing teenagers' emotional needs [294], or how mental health apps can foster engagement and sustained use [71].

A large body of literature has also investigated the relationship between families (including teenagers or children, and their parents) and technologies. A prominent topic around family interactions with technologies has also been that of teaching, navigating, and understanding online risks and safety for children and teenagers [310, 368, 432, 613–615]. Beyond online risks, other research has explored how technology can support interpersonal relationships in the family, for instance for supporting parents' reflection during parent-child interaction [295], or supporting intergenerational family relationships through storytelling using AR [330]. An emphasis has also been placed on the influence of the interactions between teenagers and their parents on their technology usage [615], and how parent involvement and open communication can lead to better outcomes, including improved parent-child relationships [74, 324, 333]. Thus, a recurring topic is that of technology mediation and coordination of use within families [50, 239], as technology use can be a source of conflict between teenagers and their families [443, 613, 620, 630]. Notably, Blackwell et al. [50] explored the underlying reasons for technology-related conflicts between teenagers and their families. They concluded that while parents think they openly communicate with their children about technology usage, children feel their parents only tell them what *not* to do. Additionally, echoed by the findings of Hiniker et al. [239], they highlight the desire of all family members to agree when to pay attention to one another and not to a device [50]. These studies show the importance of mutual activities and joint time together for both parents and their children. Transferring this from real-life to digital settings, numerous research works have explored how to support child-parent joint media engagement, including remote communication and play [111, 172, 547, 596, 629, 632] and co-located joint play and gaming [238, 480, 561, 633]. Most importantly for our study, Bindman et al. [49] explored joint media engagement with tablets using artistic creation. They found that family members engaged in two main ways: either collaboratively drawing together or through parental coaching, where parents offered guidance but did not use the app themselves. Further, Vacca [575] examined how joint media usage, i.e. digital media creation platforms, can improve teen-parent relationships, for instance by establishing a starting point for teenagers to reflect and more openly communicate with their caregivers.

Building on previous research that aims to support the interactions between teenagers and their parents through technology, and extending it to support peer interactions as well, this research engages them in a specific activity that has the potential to support their well-being [421]: emotional expression. Limited research so far has leveraged VR for supporting joint media engagement with these groups, particularly in an emotional expression setting. Therefore, the next section discusses literature on supporting emotional expression using VR, to further contextualise our work.

PIV.2.3 Employing VR for Emotional Expression

VR can be a powerful tool for emotional expression due to its unique features: it evokes visceral emotional responses through a sense of "being there", called presence [461], creates controllable, immersive and distraction-free spaces [336], enables the usage of dynamic elements and spatial distancing to convey significance [594], and allows users to physically explore and approach environments from various angles and perspectives [594]. These affordances are often leveraged to induce emotions [431, 585], for example in the fields of exposure therapy [377], positive change [301], mindfulness [440, 590], relaxation [434, 457], and stress management [511]. Thus, VR has been employed in clinical and therapeutic settings with adults for emotion regulation [382] and creative expression in art therapy [221, 222, 345].

Given the above, an increasing body of HCI work has been exploring the design of VR applications for expressing and reflecting on emotions. Focusing on adults, prior research has found that individual creative expression in VR can increase positive affect [593], support emotion regulation [595], and allow users to reflect and engage in perspective taking when combined with voice-based guidance [594]. Beyond VR use in individual settings, HCI researchers have also designed multiplayer VR experiences, e.g. to improve collaborative learning [323] by displaying users' facial expressions on avatars. Specifically on the topic of emotional expression, Semsioglu et al. [506] explored collaborative emotional experiences enabling adult pairs to visit each other's expressive drawings in VR with the goal of reflection and communication, but without engaging them in joint drawing.

There is a growing interest in exploring the impact of VR on teenagers' emotional intelligence. Previous work has investigated how VR can foster empathy with immigrant classmates [415], or support emotion regulation for the prevention of risk behaviours [223]. Another focus area has been using VR to support neurodivergent teenagers, for instance, facilitating emotion recognition for teenagers with autism [36, 58]. In particular, psychology researchers who employed VR for art therapy with two teenagers demonstrated how this was an effective technique to engage this demographic in externalising their emotions, even for those who find it difficult to create something in traditionally art therapy settings [512]. Drawing in virtual reality can serve as a "container" for typical adolescent emotions like anger, guilt, and confusion, allowing teenagers to express common defence mechanisms, such as disengagement and dissociation, more freely [497, 512]. Shamri [512] additionally referred to the VR environment as an "intermediate space" that can facilitate therapeutic engagement with teenagers' complex or hard-to-reach emotional issues, enhancing their communication and expression by allowing non-verbal modes of expression. Building on this, Kitson et al. [299] conducted co-design sessions to investigate how teenagers could be supported in regulating their emotions through the use of VR. They found that teenagers desire sharing an emotional space with friends and families in VR in order to connect with them. Coupled with the findings of Shamri [512] regarding the effectiveness of VR for teenagers' emotional expression, these findings highlight the opportunities for designing VR applications that allow teenagers to both individually and collaboratively express their emotions.

Therefore, building on prior work that uses VR as a medium for externalising emotions, we leverage VR affordances to foster positive affect, reflection and communication, specifically focusing on teenagers as a user group, and engaging them with peers and parents to emotionally express themselves, both individually and in a joint VR drawing.

PIV.3 Evaluation

We conducted a user study with $n = 42$ participants. Ten teenagers participated together with their parents (which we will refer to as teenager-parent pairs), while eleven teenagers participated alongside a peer (teenager-teenager pairs). The overall aim was to explore how teenagers express and discuss their emotions and empathise with their interlocutor by drawing in VR, and additionally to investigate how this might differ depending on whether they engage in this activity alongside a parent or peer. The study received prior ethics approval from the ethics board of the University of St.Gallen (HSG-EC-20230605). Most study sessions took place in a school, in a room-sized 6×11m. Each pair of participants received two wireless Oculus Quest 1 headsets, and a laptop for questionnaire completion. Two teenager-parent pairs participated in the school as well; the other teenager-parent pairs participated from their respective homes.

PIV.3.1 Participants

We recruited an overall number of $n = 42$ participants, including 32 teenagers and 10 adults. The teenager-teenager pairs were friends, except from T31-T32 who were sisters, and T17-T18 who described themselves as classmates. The participants were recruited through contacting a local school and from extended contacts of the authors. For the teenager-parent pairs, teenagers were aged 14-17 ($M = 15.8$, $SD = 1.2$) and parents 33-68 ($M = 48.5$, $SD = 10.1$), while for the teenager-teenager pairs, their ages were between 14 and 17 ($M = 15.4$, $SD = 0.9$). More information about teenager-parent participants can be found in Table PIV.1 (teenagers T1-T10, parents P1-P10), and in Table PIV.2 for teenager-teenager pairs (T11-T32). All participants gave their written consent prior to participating in the study, while for the teenagers, their parents or legal guardians additionally provided written consent for their child's participation. Participants self-assessed that they felt mentally stable and healthy at the moment of participation. Notably, P6 and T6 reported that they were neurodiverse at the time of the exit interview. Participants were remunerated for their participation in the form of a voucher for a menu item at a local restaurant (approximating 15 euros), and received free snacks and beverages during their participation. Teenagers were also provided with a certificate of participation and an exemption for classes that took place at the time of their participation.

PIV.3.2 Data Collection

For each participant pair we screen-recorded their interactions in the VR environment and took pictures of the experiment with their consent. Quantitative data was collected from five questionnaires. Further, we collected qualitative data through a combined approach of exit interviews and post-study notes.

Measures. The following questionnaires were administered to all participants:

- Basic Empathy Scale **(BES)** – measuring empathy specifically for teenagers [271]; subscales: Cognitive Empathy (CO), Affective Empathy (AF)
- Single Item Trait Empathy Scale **(SITES)** [304], measuring empathy with a single item;
- Saarbrücken personality questionnaire SPF **(IRI)** – measuring empathy [128, 416]; subscales: Empathic Concern (EC), Perspective Taking (PT), Fantasy (FS), Personal Distress (PD);
- Self-Reflection And Insight Scale **(SRIS)** – measuring levels of reflection [210]; subscales: Self-Reflection (SR), Insight (IN);

Table PIV.1 Demographics of teenager-parent pairs (N=20).

ID	Age	Gender	Nationality	VR Experience
P1	45	Female	Lebanese / German	None
T1	17	Male	Lebanese / German	1-2 times
P2	50	Male	Turkish	None
T2	14	Male	German	None
P3	55	Female	German	1-2 times
T3	16	Male	German	1-2 times
P4	54	Male	German	None
T4	15	Female	Turkish	None
P5	52	Female	German	None
T5	15	Female	German	1-2 times
P6	48	Diverse	German	1-2 times
T6	16	Diverse	German	1-2 times
P7	45	Female	German	None
T7	17	Male	German	Regular user
P8	35	Male	Turkish	1-2 times
T8	17	Female	German	None
P9	33	Female	German	1-2 times
T9	14	Female	German	1-2 times
P10	68	Male	German	1-2 times
T10	17	Female	German	None

Table PIV.2 Demographics of teenager-teenager pairs (N=22).

ID	Age	Gender	Nationality	VR Experience
T11	16	Male	German / Turkish	None
T12	16	Male	Kurdish / Turkish	None
T13	15	Male	Bosnian	None
T14	15	Male	Albanian	None
T15	15	Male	Moroccan	None
T16	15	Male	Ghanaian	More than 5 times
T17	16	Male	German	3-5 times
T18	15	Other: Gender Fluid	German	None
T19	15	Male	German / Bulgarian	1-2 times
T20	15	Male	Turkish	None
T21	17	Female	Turkish	None
T22	17	Female	German	None
T23	17	Female	Turkish	None
T24	17	Female	German	1-2 times
T25	15	Male	German	None
T26	14	Male	German	None
T27	15	Male	German	3-5 times
T28	15	Female	German / South African	None
T29	14	Male	German	None
T30	15	Male	German	1-2 times
T31	16	Female	Syrian	1-2 times
T32	15	Female	Syrian	None

- Positive and Negative Affect Scale **(PANAS)** – measuring felt emotions [601]; subscales: Positive affect (PA), Negative Affect (NA);

BES, SITES, and SRIS were translated into the local language by two independent reviewers, one of which was an HCI researcher and the other one a psychologist and HCI researcher. Both were fluent in both English and the local language. They then agreed on the most fitting translation for each questionnaire item. Given i) that our participants comprised both adults and teenagers, ii) that BES is specifically made for teenagers, and iii) to facilitate a comparative analysis to address RQ2, we employed both BES and SITES. Moreover, by assessing perspective-taking and empathetic concern with SPF-IRI as well as reflection and insight with SRIS, we could acquire insights into how the experience with TeenWorlds focusing on a conflict affected participants' mutual understanding. Finally, by using PANAS, we aimed to assess if TeenWorlds creates positive affect and reduces negative affect, which could support both interpersonal interactions and mutual understanding, thus contributing to the answer for RQ1.

Pre-study participants submitted demographic data and completed the BES, SITES, IRI and SRIS questionnaires before the AEMT, while they completed PANAS after the AEMT. Post-study, participants completed PANAS, BES, SITES, IRI and SRIS again. At the end of the study, the pairs participated in an exit interview together in order to elicit their opinions regarding their experience with TeenWorlds. Moreover, the researchers compiled post-study notes, including general remarks as well as interesting points from the pairs' participation in our study.

Interview Protocol. We conducted brief exit interviews that lasted between 4.68 and 13.63 minutes (M = 9.83, SD = 2.95) for teenagers participating with their parents and between 3.18 and 8.58 minutes (M = 5.38, SD = 1.63) for teenagers participating with a peer. Within the interview, we asked participants to elaborate on their experiences with TeenWorlds, including describing their conflict and their emotions about it while creating their drawing in VR, their thoughts and emotions when visiting each other's drawings, and what was important to them while drawing their individual and mutual drawings. The full interview protocol can be found in the supplementary material.

Post-study notes. The two researchers present in each study session also collected post-study notes. Those included general comments and remarks regarding the participants' interaction throughout the three stages (individual conflict drawing, discussion phase, mutual drawing), as well as during the interview.

PIV.3.3 Procedure

Two researchers were present during each study session. After participants were on-boarded, gave their consent, and answered the BES, SITES, IRI and SRIS questionnaires, they started a tutorial phase in which the researchers showed a video introducing the VR equipment and the VR application. As part of this phase, the participants were given approximately ten minutes to try out TeenWorlds, to familiarise themselves with the drawing functionality. They then decided on a shared conflict to use in the study and engaged in an Autobiographical Emotional

Memory Task (AEMT) [378], a validated and widely used method in HCI to induce emotions and moods by remembering that situation in detail. After that, they filled out the PANAS questionnaire.

In the main part of the study, participants were asked to engage in the following steps (see Figure PII.1).

1. ***Individual Conflict Drawing***: The participants jointly entered the virtual space, divided by a virtual wall, while they shared the physical room. The participants were given the task of expressing their emotions during the conflict by creating their own virtual environment. While creating their environments, the participants were asked to refrain from talking to each other.

2. ***Discussion***: In the discussion phase, the virtual wall was removed, allowing participants to visit each other's drawings. Participants explained their visualisation of the emotions to each other, and how they felt during the conflict.

3. ***Mutual Drawing***: Lastly, participants created a mutual drawing in shared VR, together visualising their emotions upon resolution of the conflict.

After the study, the participants filled out the post-study questionnaires, consisting of PANAS, BES, SITES, IRI and SRIS and took part in an exit interview.

PIV.3.4 Data Analysis

For our quantitative analysis, parametric tests were applied, as only validated scales were employed and since normally distributed data could be assumed based on the visual inspection of the data and the Shapiro–Wilk statistic. A one-way ANCOVA was conducted with *Post* measurements for all subscales as dependent variable, factor *Group* as factor, and with *Pre* measurements of the respective subscale as covariate [147]. With this, we aim to compare the relationships between *Pre* and *Post* measurements for the different groups, thus, studying the difference between the Groups in terms of the relationship between the *Pre* and *Post* scores. A Two-way ANOVA with *Group* and *Measurement* as factors was not adequate for the present study design, as it would lead to pairwise comparisons that are not meaningful (such as Pre *teenager-parent* vs Post *teenager-teenager*). Dugard and Todman suggest that such analyses should be avoided [147]. We chose the ANCOVA approach as it was deemed the most suitable for pre/post designs by Dugard and Todman [147]. They showed how this approach offers increased validity over a repeated-measures ANOVA solution. This approach, however, results in the Pre and Post scores being subject to two tests. Thus, a Bonferroni correction of $\alpha = .025$ was used. All p-values reported in this paper are Bonferroni-adjusted. All details of the analysis can be accessed in the supplementary material.

For our qualitative analysis, we employed a combined approach, using both the exit interviews as well as the post-study notes. First, all 21 interviews were transcribed verbatim. Then, two researchers analysed the interviews as well as the post-study notes by performing open coding in an iterative process, using the MaxQDA software. Any disagreements that arose were resolved by discussion. After an initial round of open coding, two authors applied

Table PIV.3 Mean values and standard deviations for *Pre* and *Post* measurements for all scales. ANCOVA statistics for *Post* measurements as dependent variable with factor *Group* with *Pre* measurements as covariates. Effect sizes η^2 provided for statistically significant results (see bold p-values). The first row shows the abbreviated name of the questionnaires and the second row their subscales as well as their overall or 'total' score (abbreviated as 'TOT').

	PANAS		**BES**			**SITES**	**IRI**					**SRIS**		
	PA	NA	TOT	CO	AF		TOT	EC	PT	FS	PD	TOT	SR	IN
M_{Pre}	30.238	20.643	73.048	35.833	37.214	3.690	50.548	13.952	13.738	11.810	11.048	68.786	42.714	26.071
SD_{Pre}	7.053	6.544	9.530	5.383	7.179	0.897	8.849	3.131	3.100	3.710	3.844	10.072	7.649	5.106
M_{Post}	34.833	17.595	73.071	35.595	37.476	3.714	51.214	14.381	14.071	12.000	10.762	68.381	42.190	26.190
SD_{Post}	6.629	6.045	9.681	5.653	6.645	0.970	9.257	3.283	2.975	3.832	3.999	9.200	6.729	5.718
$F_{1,40}$	0.015	15.306	1.152	0.299	1.197	1.414	1.608	2.461	4.483	0.025	0.083	5.518	1.581	4.912
p	.903	**<.001**	.290	.587	.280	.241	.212	.125	**.040**	.873	.775	**.024**	.216	**.032**
η^2		**0.277**							**0.101**			**0.121**		**0.109**

thematic analysis by using affinity diagramming in line with Blandford et al. [51] to construct themes. Subsequently, codes and themes were translated from their original language to English. Our method aligns with an interpretative research approach, which emphasises understanding the significance of data within its context [108]. Several meetings were held among the authors to build consensus and discuss coding decisions [108]. We also analysed the content of both the individual and the mutual drawings participants created in VR using the screen recordings. For example, we coded the following aspects, among others: the use of symbols, colours, and brushes, and the emotions that were depicted. The full list of codes is available as part of our supplementary material.

PIV.4 Findings

In this section, we present quantitative results from the questionnaires as well as qualitative insights from the interviews. The sessions lasted on average $M = 72.62$ minutes (min: 61.37, max: 79.92, $SD = 6.04$) for the teenage-parent pairs, and $M = 70.26$ minutes for teenage-teenage pairs (min: 61.47, max: 74.97, $SD = 4.21$).

PIV.4.1 Quantitative Results

For quantitative results, we refer to teenager-parent pairs as the *Parental* and to teenager-teenager pairs as *Peer*. For the one-way ANCOVAs found to be significant, post-hoc *Tukey HSD* were conducted comparing *Pre* and *Post* measurements (see Figure PIV.2). The ANCOVA for negative affect PANAS (NA) showed a significant effect of Group on Post with Pre as a covariate $F(1,40)$=15.306 (see Table PIV.3 and Figure PIV.2). Thus, there was a significant difference in the negative affect delta from Pre to Post between the Parental and Peer group, with Parental decreasing more than Peer (see Figure PIV.2). The ANCOVA was also found to

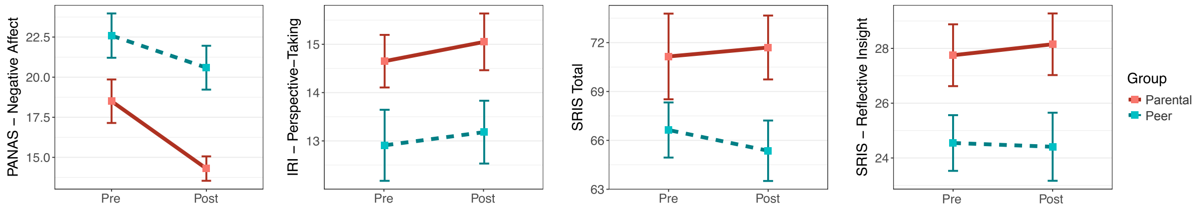

Fig. PIV.2 Line plots showing Pre and Post measurements for the sub-scales with significant ANCOVA results: PANAS Negative Affect, IRI - Perspective-Taking, SRIS Total, SRIS - Reflective Insight. Peer groups generally gave worse ratings. There seem to be some interaction effects: PANAS-NA and IRI Perspective-taking improved from *Pre* to *Post*, the SRIS scales point to different directions between *Pre* and *Post*.

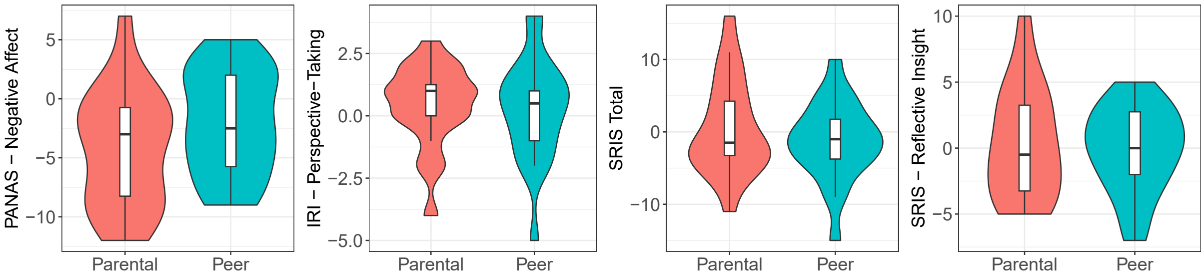

Fig. PIV.3 Violin plots showing the distributions of Pre and Post measurement deltas for the sub-scales with significant ANCOVA results: PANAS Negative Affect, IRI - Perspective-Taking, SRIS Total, SRIS - Reflective Insight. The plots' shapes look adequately distributed.

be significant for perspective-taking (IRI PT) $F(1,40)$=4.483. Thus, there was a significant difference in the perspective-taking delta from PRE to POST between the Parental and Peer group, with Parental increasing more than Peer (see Figure PIV.2). The ANCOVAs were also found to be significant for self-reflection and insight (SRIS) overall $F(1,40)$=5.518 and for the reflective insight sub-scale (SRIS-IN) $F(1,40)$=4.912. Thus, there was a significant difference in the self-reflection and insight deltas from PRE to POST between the Parental and Peer group, with Parental increasing and Peer decreasing (see Figure PIV.2). Distributions of the *Pre-Post deltas* are presented in Figure PIV.3. There were no statistically significant differences for PANAS PA, BES, SITES, IRI (TOT, EC, FS, PD), and SRIS SR (see Table PIV.3).

PIV.4.2 Qualitative Findings

Based on our qualitative inquiry, three themes were constructed: *Mediating Communication*, *Experiencing Reflection*, and *Fostering Understanding & Appreciation*. Before delving into a more in-depth discussion of these themes, we provide an overview of the general impressions gathered during the study. Overall, the majority of participants found engaging with TeenWorlds enjoyable, rating it on average $M = 8.96$ on a scale from zero to ten. They described it as a fun experience that aided them in resolving conflicts and externalising their emotional states. They particularly appreciated the collaborative drawing aspect. Nevertheless, some participants faced difficulties in identifying their emotions, determining how to represent them visually, and navigating the VR environment. Despite these challenges, participants generally

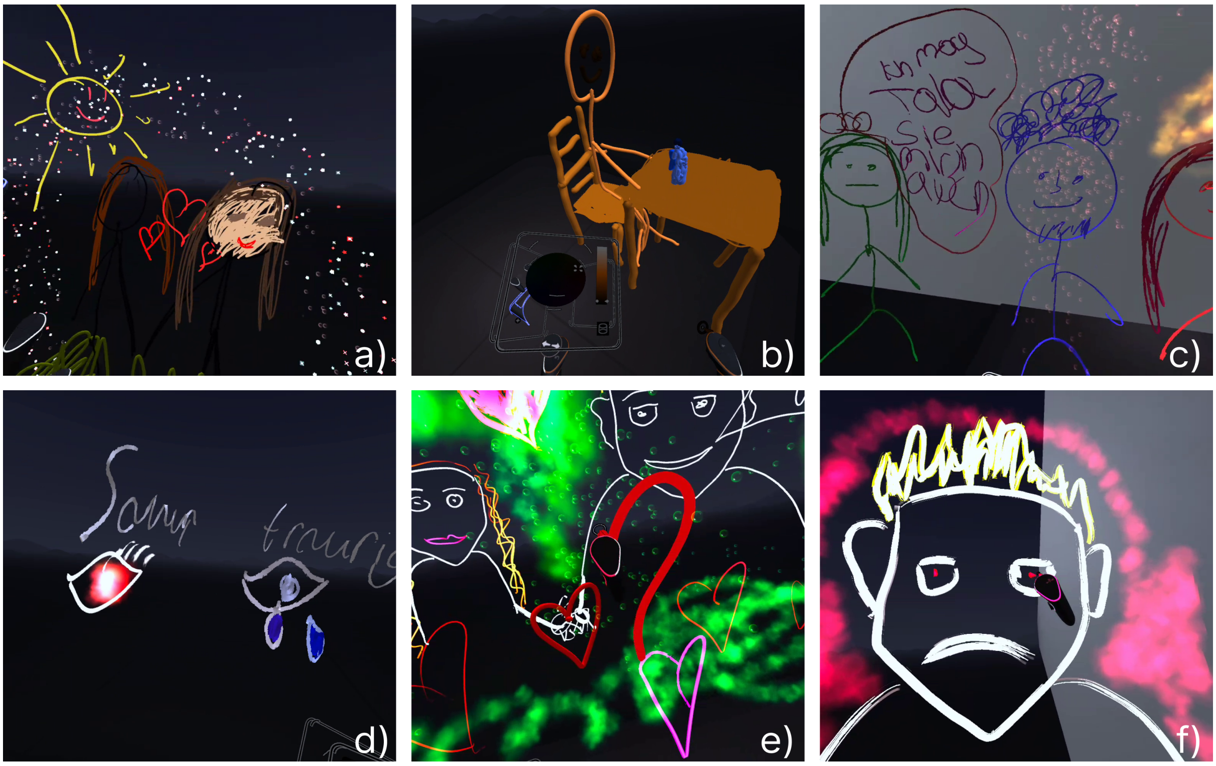

Fig. PIV.4 Examples of participants' drawings: a) T9 and P9 mutual drawing, b) T13 and T14 mutual drawing, c) T23 individual drawing, d) T13 individual drawing, e) T7 and P7 mutual drawing, f) T7 individual drawing. These screenshots showcase some interesting similarities: use of stick figures (a, b, c, d, e, f), symbols such as hearts (a, e) and tears (d, f), and holding hands (e).

perceived TeenWorlds as a helpful resource, noting that *"the drawing has been helpful, it's very therapeutic." (T25)*

From analysing the drawings that participants created (see Supplementary Material), we found that the majority of conflicts between teenagers and parents regarded screen time and technology usage or uncompleted household tasks. Regarding conflicts that teenagers experienced with their peers, the topics were more diverse. The two topics that appeared more than once were physical conflict (T13-T14, T17-T18) and arguments about purchasing the same clothing (T19-T20, T27-T28). Interestingly, we found that both constellations used stick figures and emojis to represent emotions, both in the individual and mutual drawings. Additionally, the colour red was prominent, representing anger and tears for sadness. Many mutual drawings included animated brushes such as stars and bubbles and included symbols such as hearts. In that regard, teenagers interacting with their parents often drew figures holding hands in their mutual drawing (T7-P7, T8-P8, T10-P10), and wrote words of affirmations (e.g. "I love You" (P5)). However, teenagers interacting with their peers did not draw such figures, and their mutual drawings were diverse in general, apart from the common theme of using emojis and stick figures. Figure PIV.4 shows some of the participants' drawings. Below, we describe our qualitative findings and illustrate them with excerpts from the interviews.

Mediating Communication. The first theme revolves around how TeenWorlds supported participants in acquiring new communication skills, helping with conflict management. In that regard, participants mentioned that their level of communication increased by using TeenWorlds. For instance, P1 was annoyed about T1 coming home late, but T1 highlighted that before using TeenWorlds, they did not really talk in depth about that conflict: *"I'm way happier now, that we were able to work it out that way [using TeenWorlds] without all this silence and not talking to each other, without our usual lack of communication. (T1)"*. P7 further specified how the toolset of TeenWorlds created a basis on which communication was then possible. In regard to the conflict of P7 and T7 about not doing homework directly after school but rather playing on the console, the parent shared that finally: *"We were able to talk openly about our feelings, and we could paint and really portray them together." (P7).*

Besides increasing communication between each other, TeenWorlds also enabled participants to appreciate the importance of communication for future conflict management. To elaborate, participants reported that they realised the significance of actively listening to one another, sharing their needs and thoughts, employ clearer communication, and feel encouraged to use these skills to prevent conflicts or better manage future conflicts when they arise. One participant, the teenager rather playing on the console instead of doing their homework, explains this aspect as follows: *"I can understand the other side better now and hope that we can continue to find a good solution together and talk about it better in the future and that together we don't let the feeling of anger or sadness or bewilderment or helplessness arise in anyone, but that we can simply talk about it better and find a solution together so that both of us feel better.* (T7)

Experiencing Reflection. As a second theme, we found that TeenWorlds fostered self-reflection in participants, spanning three dimensions: *How did I feel/behave?*, *Who am I?*, *How do I want to behave?*

In regard to the first dimension, participants reported that TeenWorlds encouraged reflection on their emotions and behaviours during that specific conflict. In particular, drawing their individual “world” in VR with brushes and colours made them aware of the range of emotions they actually felt. For example, one participant drew in red and blue, and through this realised that their emotions were more complex than they originally thought: *"I just had this realisation, with the aggression during the conflict. And then I just noticed that the conflict situation has also made me sad and I was not aware of it. Only when I thought about it and put it into colour did I become aware of it. (P4)"* Additionally, participants started to question their reactions and behaviour during the past conflict. As T7 put it: *"I also thought about whether my reaction was right or wrong. (T7)"*. They specified, that especially visiting the other person's drawingfacilitated perspective-taking and encouraged self-reflection. To use the words of a participant describing their behaviour of not allowing the best friend to copy from her in an exam: *"to not only hear but also see this from their perspective helped me understand how I acted in the conflict. (T22)"* Interestingly, in a few cases, the experimenters observed direct effects of reflecting on their behaviour, such as participants apologising to each other after the study.

Moreover, TeenWorlds supported some participants in acquiring more self-knowledge about who they are as a person. Participants elaborated that both the individual drawing (e.g. *"I became very aware of this [losing control when angry] through the drawing (P7)"*, as well as discussions with each other (e.g. *"I think the discussion has really helped me [to understand] that I also had a very big ego back then" (T14)*), resulted in self-reflection. Through this, they gained renewed insights into their personality, character, and general behaviour in emotionally charged situations. For example, they realised that they often lose control when angry (e.g. *"I noticed that I was very charged and also lose control when I'm angry. I then became very aware of this through the drawing (P7)"*), or that conflicts arose due to specific characteristics of oneself that could be improved (e.g. *"I've understood now that I also had a very big ego back then, and I often wanted to prove myself. And I have now also seen that I have moved in a more positive direction with my ego, so now my ego is somewhat lower (T14)"*).

As a result of reflecting on their emotions and behaviour during the conflict, and realising what kind of person they are, many recognised the benefits of regulating their emotions to prevent future conflicts from escalating out of control. As such, they contemplated how to change their behaviour in future conflicts. For instance, a participant proposed how he might change his behaviours in potential future conflicts: *"If this conflict were to arise again in any way, I would try not to get angry directly, not to let my emotions control the steering wheel directly (T14)"*.

Fostering Understanding & Appreciation. The third theme explores how TeenWorlds enhances participants' *understanding* of each other and fosters greater *appreciation* for the other person and their relationship.

First, participants mentioned that TeenWorlds facilitated a deeper understanding of each other, enabling them *"to feel [the other's] feelings"* (T24), indicating that perceived empathy was increased. They also gained profound insights into the underlying causes of conflicts. For example, one participant who had asked their friend to copy from her in an exam commented: *"I realised that I would have put her in an unfavourable situation if she had helped me. So yes, I think that [TeenWorlds] helped me (T21)"*.

Furthermore, some participants expressed a heightened sense of care and appreciation for each other, celebrating the strength of their relationships. Effectively, participants emphasised that when drawing in TeenWorlds, they focused more on the strength of their friendship than on the source of conflict. For example, two best friends fought because they both liked the same boy: *"We were thinking of ourselves when we drew it and not of the boy (T24) - Exactly! About our friendship and that nothing can come between us (T23)"*.

Notably, when teenagers experienced TeenWorlds alongside their parents, they also valued the shared activity as an experience that bonded them together, helping them to *"find something in common (P7)"*. Both parents and teenagers commented that using TeenWorlds and VR could help to mitigate existing conflicts about media usage (e.g. *"I no longer have this aggression towards his console(P7)"*) and that they will especially remember the phase of mutual drawing is fondly, as joint quality time. In that regard, T7 especially liked *"to pursue a* *goal together and then to visualise together, that we could agree with each other and that we can create something together (T7)".*

PIV.5 Discussion

This paper examined how VR could support teenagers' emotional expression and shared understanding in a multi-user context involving their parents and peers. Overall, interacting with TeenWorlds was a positive and enjoyable experience for participants. We found that TeenWorlds can mediate communication between teenagers and their parents and peers, thus having the potential to support their interpersonal interactions. TeenWorlds can not only facilitate participants' discussions about past conflicts, but help them recognise the importance of effective communication and conflict management for future interactions (*RQ1*). Moreover, our findings showed that, especially for teenagers engaging with their parents, TeenWorlds can encourage them to reflect about not only their past and future behaviours, but also about themselves and their actions, thus supporting not only mutual but also self-understanding (*RQ1*).

Our comparative analysis uncovered differences in the use of the system by teenager-parent versus teenager-teenager pairs (*RQ2*). In particular, our findings showed that there were significant differences between *parental* and *peer* pairs in terms of how perspective-taking (IRI-PT) and self-reflection and reflective insights (SRIS) changed from Pre to Post, with *parental* pairs generally showing more positive changes than *peer* pairs (*RQ2*). Finally, the extent to which pairs decreased their negative emotions from before to after the TeenWorlds experience was also more pronounced in *parental* pairs than in *teenage* pairs (*RQ2*). Taken together, this suggests that, in line with previous work [525], challenging forms of self-expression and reflection like TeenWorlds may benefit from the scaffolding, guidance, and emotional support that parents can provide [113, 218, 263, 280] – at least more so than peers were able to provide to each other in our study.

Below, we reflect on our findings and their impact on future research. First, we discuss how technologies like TeenWorlds could be enhanced by means of scaffolding of different forms, in order to deliver reflective experiences for both teenagers' interactions with their peers, as well as their parents. Then, we specifically focus on teenagers and parents, and elaborate on how experiences like TeenWorlds, combining the use of VR and individual and collaborative emotional expression can be employed as a facilitator for teenager, parent, and, more broadly, family well-being.

PIV.5.1 Encouraging Reflective Experiences through Scaffolding

While TeenWorlds primarily serves as a platform to facilitate emotional expression and communication, participants in our study reported engaging in a broader scope of reflection (see section PIV.4.2). They thought about reasons behind their conflicts, their behaviour, and their personality when being in a conflict, as well as about their relationship with each other. All these aspects show that participants encountered reflection, following Schön et al.'s [492] definition of reflection meaning understanding and thinking about potential courses of action, and one's role within these. Participants experienced both individual and collaborative reflection by engaging in TeenWorlds. In particular, Marcu et al. [353, 354] explored "collaborative reflection" in the informal processes of documentation and communication in care teams of children, referring to interpreting behaviour based on collected data. In our work, the notion of *collaborative* reflection is extended, as it incorporates children (teenagers) and their caregivers (parents). In particular, our findings show how teenagers and their parents can engage in collaborative reflection in the context of co-creating artistic visualisations that represent their experiences and emotions, and use them as basis for communication and deeper understanding of themselves, and of each other.

While not applicable to every participant, our study highlights the capacity of TeenWorlds to evoke various levels of reflection, following Fleck and Fitzpatrick's [171] framework of reflection as a spectrum of five consecutive levels (R0-R4): some participants did not report to have reflected (thus only engaging in R0: Description), but even for some of them it seemed to be an engaging and fun experience that fostered interpersonal relationships, according to the qualitative findings (see section PIV.4.2). Some participants reached R1: Reflective Description, reflecting but reinforcing their existing perspectives on their conflict management and communication strategies. In that regard, participants shared that they did not learn anything new or thought they had behaved correctly during the conflict. Others progressed to R2: Dialogic Reflection, and discovered new approaches and strategies for communication and conflict management. For instance, they realised the importance of active listening and sharing how one feels. Participants that engaged in those higher levels of reflection discovered novel constructive approaches [171] for conflict management and enhanced (self-)awareness [349]. They reported developing strategies for managing conflict situations, e.g. regulating one's emotions. They also increasingly appreciated their relationships [56], reflected in differences both in their conversations between the second and third stage of the study as well as in their individual and joint drawings. For instance, P5 wrote the words "sad" in her individual drawing, compared to "I love you" in the joint one, while T23-T24, whose conflict was about having contact with the same boy, expressed their realisation that nothing can come between their friendship. As such, we even encountered a few participants apologising to each other during or after the study, highlighting the deep level of reflection, perspective-taking, and empathetic concern that TeenWorlds helped some participants to achieve. Even though some participants declared their intentions to change their behaviour in conflict situations in the future, which could suggest reaching R3: Transformative Reflection, this cannot be verified without further studies, to evaluate whether TeenWorlds can have such an effect long term.

However, the quantitative findings show that TeenWorlds seems to be more "effective" for parental pairs than teenage pairs. To be more precise, while there was a general tendency of a decrease of negative affect, the reduction was less pronounced for *Teenage Pairs*. This suggests that it is more challenging for teenagers alongside teenage peers to regulate their emotions or keep an "emotional distance" while engaging in the activity. We also found significant differences in the change from Pre to Post between both *Parental Pairs* and *Teenage Pairs* for perspective-taking (IRI-PT), which increased for both but more for *Parental Pairs*. This suggests that teenagers among themselves did not manage to increase their perspective-taking through the TeenWorlds experience to the same extent as when together with adults. Finally, there was a significant difference in SRIS which increased for *Parental Pairs* but decreased for *Peer Pairs*. This was the case for the overall SRIS score and for the SRIS-IN subscale, suggesting that in particular the insights were more "difficult" for teenagers to achieve with a peer compared to with an adult. These findings suggest that the presence of an adult can provide encouragement for reflection, while the absence of this kind of support can lead to less successful interactions with TeenWorlds and lower levels of achieved reflection. This is in line with prior work, emphasising that reflection can be a challenging activity and needs to be encouraged [525] and that adults, especially caregivers such as a guardian, therapist, or parent, can assume the role of a "skilled partner" providing necessary guidance and encouragement for children [589]. In our case, this constitutes both a design opportunity and tension, as researchers navigate the degree to which other members of a teenager's care ecosystem should be engaged in a technologically-mediated reflection process. To elaborate, on the one hand, previous HCI research has underscored the significance of actively including the care ecosystem in design decisions of systems meant to be used by children [549, 550]; in our case, including parental guidance in systems such as TeenWorlds. On the other hand, we have to consider teenagers' need to establish their independence from adults, making them a unique user group to design for, while still benefiting from guidance to reflect, as our findings suggest. In that regard, the question of how VR can be leveraged to support reflective processes in teenagers without parental guidance remains under-researched.

Based on the above, we derive design recommendations for future systems aiming to deliver reflective experiences both for teenagers and their peers, as well as for teenagers and their parents. Regarding the first, **we recommend that future VR applications should focus on incorporating different forms of scaffolding, as this might be needed for teenagers to be able to effectively reflect together with their peers.** To that end, the system could be enhanced in order to provide this scaffolding, for instance through voice-based prompts [594] specifically designed for teenagers. Wagener et al. [594] demonstrated that voice-based guidance through voice prompts can successfully scaffold reflection for adult users who draw their emotions about a challenging situation in VR. However, as a first step, these prompts would need to be evaluated with teenagers and adjusted accordingly to cater to their unique needs. Concurrently, more research is needed to investigate other age-appropriate scaffolding elements to support users, specifically teenagers, in reaching higher levels of reflection. We envision that a physical representation of an avatar in VR could scaffold reflection in a more playful way than the pure voice prompts employed by Wagener et al. [594]. Incorporating avatars would also be in line with previous work that explored how they influence teenagers' learning of emotion regulation strategies [623]. Apart from enhancing the system, we imagine that involving other older members of teenagers' care ecosystems, as a third party to the experience, could support them to reflect. Such an example could be a school counsellor, or other qualified professionals, especially in cases where such systems would be used in therapeutic settings. For instance, previous work in art therapy engaged teenagers in VR drawing where the therapist had an observational role, accompanying them in the virtual space by viewing their creations on a 2D monitor that displays what the client is creating in their 3D world, as well as by talking to them [512]. Translating this to our work, future research could incorporate the therapist in a similar role in TeenWorlds, and explore how this supports teenagers reflecting with their peers.

With respect to future systems that aim to engage teenagers together with their parents in reflective experiences, **we recommend that future work should explore the integration of more family members in the process, and investigate the dynamics of e.g. including both parents in the interaction with TeenWorlds, or also any potential siblings.** This would have the potential to assimilate real-life situations, where interactions within a family can take place with multiple stakeholders expressing their experiences and emotions [550]. Moreover, designing such collaborative experiences is in line with recent work that has underscored the importance of designing interactions among children and as many stakeholders of their care ecosystem as possible, particularly in the domain of technologies for emotional expression and reflection [550, 551].

PIV.5.2 Facilitating Well-being through VR Experiences

Here, we discuss how engaging in experiences such as the one provided by TeenWorlds can support well-being, both individually for teenagers and parents, as well as in the context of their joint family interactions.

Supporting Well-being through Learning Skills for Emotional Expression & Conflict Management. Our findings point to the potential of experiences such as TeenWorlds to serve as a facilitator for both teenagers and their parents to learn skills for emotional expression, as part of emotional well-being [289, 291]. Both the analysis of the qualitative data, the VR drawings (see Figure PIV.4 and supplementary material) and the quantitative findings indicate that TeenWorlds helped participants express their emotions. This shows how TeenWorlds can be linked to approaches used in art therapy [345, 618], using colours and drawing to find emotional relief. Further, our findings indicate that participants enjoyed being immersed in dynamic elements and the “sealed-off” environment of VR, as it could provide necessary temporal and emotional detachment from real-life conflicts so that engaging with TeenWorlds was seen as *"very therapeutic"*. This opens up the potential of VR as a valuable asset for art therapy in collaborative settings, e.g. engaging teenagers together with their parents in therapy settings, which future work could explore. This constitutes an important aspect, given the difficulties that are linked to emotional identification, expression, and management, especially for teenagers [451, 509], and previous work that demonstrated the benefits of using VR in art therapy for teenagers in individual settings [512].

Concurrently, our findings demonstrate that TeenWorlds can be a facilitator for developing and practising skills for effective communication and conflict management, linking to psychological well-being [291]. Notably, teenagers in our study were encouraged to select *previously resolved* shared conflicts for ethical considerations, given that it was the initial study using TeenWorlds as a prototype. Nonetheless, we observed some participants apologising to each other after the study. This highlights the potential of using TeenWorlds for active conflict resolution as well, employing it as a facilitator in that respect. However, in that scenario, participants may experience strong negative emotions, posing a challenge to prevent rumination, the repetitive negative thought and emotion cycles that can result from reflective thoughts [569], which comprises a counterpoint to the beneficial activity of reflection [569]. This could hinder open communication and mutual understanding. To mitigate this in an initial evaluation, we envision integrating skilled partners such as guidance counsellors or school psychologists into the process of using TeenWorlds for active conflict management, as they can take over an observatory but guiding role, supporting teenagers in their interactions in that specific use case. Similarly, based on our findings, active conflict resolution with systems like TeenWorlds could also be used for teenagers together with their parents. In that case, an interesting point for future research is whether a third person is needed to guide this experience, be it a therapist or another family member, assuming the role of guide or even mediator. Future work could explore this, and compare the potential different needs that arise in each case, i.e. teenager using systems like TeenWorlds for active conflict resolution together with their peers or parents, as well as how VR systems need to be adjusted to facilitate each case.

Therefore, we propose that VR experiences such as TeenWorlds can be leveraged in both individual and family settings for learning skills for both emotional expression and conflict management. By using a toolset for autonomous self-expression, allowing both individual and collaborative interactions, facilitating perspective-taking, and making use of VR's immersiveness, such systems can be used to develop these skills.

Fostering Well-being through Joint Family Interactions. Additionally, we found that systems like TeenWorlds can be a facilitator for quality time between teenagers and parents, addressing their social and emotional well-being [291]. As presented in section PIV.4.2, parents elaborated on how much they enjoyed spending time together with their child while using TeenWorlds, especially underscoring the mutual drawing. This was interesting, as screen time and technology usage was a recurring conflict in our study (5 pairs), which is in line with previous IDC and HCI literature on parent-child/teenager conflict around technology usage [50, 239]. Unlike smartphones, which are frequently criticised for monopolising the attention of family members and typically carry negative connotations in family settings [573], engaging with TeenWorlds seems to be perceived more positively, perhaps due to the ability to engage in a shared activity using VR, contrary to the individual type of interactions that smartphones and other screens might promote. Moreover, as VR insulates users from outside distractions, it can provide the (head)space for a constructive joint activity that connects both parties: having the approval of the parent while satisfying teenagers' desire for interacting with technology and having ludic elements for enjoyment, similar to previous research that investigated how joint use of technology can mitigate disagreements and be enjoyed by both parents and children [550]. Thus, we see the potential of VR systems that allow both individual and collaborative emotional expression, perspective taking, and communication in VR, to counteract the tendency that family members spend less time together [319, 649], and to address their mutual desire for more experiences of "we-ness" [318] by shaping common activities that both teenagers and parents enjoy. **Therefore, we propose that VR experiences such as TeenWorlds can be leveraged as a technology to allow for joint family quality time, connecting teenagers and parents through playful and engaging experiences as a basis for**

shared family time. This would combine teenagers' interest in technology, especially ludic elements, with the desire of parents for common quality time and engaging in constructive and purposeful experiences. Thus, our work extends previous findings by showing how VR technologies, especially those allowing not only individual but also joint artistic emotional expression, could be a suitable medium in that regard.

PIV.5.3 Limitations & Future Work

In this section, we discuss the limitations of our work and explore opportunities for future HCI research when developing VR applications aiming to support teenagers in emotional expression. TeenWorlds is a VR experience combining visual and verbal emotional expression. While this was a specific design choice to leverage the benefits of emotional expression (e.g. [289]) and multi-user collaboration (e.g. [506]), we cannot deduce which effect specifically arose through viewing the other person's drawing, through discussing with them, through the mutual drawing, or a combination of the above. Additionally, we observed that a few teenagers showed limited enthusiasm, expressing the view that there was nothing more to gain since the conflict had already been resolved, which might be a reason for the rather short interviews for some pairs. We further hypothesise that this might be due to the fact that participation allowed them to stay away from class as the study was conducted during a normal school day. Despite limited enthusiasm for some pairs, the vast majority of participants enjoyed TeenWorlds. However, this further emphasises the need to carefully recruit teenagers and scaffold their technology-mediated experience when the goal is to achieve reflection. Future work could also investigate systems like TeenWorlds in longitudinal settings, studying how the same participants engage both with the system and with each other when interacting with TeenWorlds multiple times over the course of time. In particular, it would be of particular interest to explore how the reflection and communication skills they seem to acquire in one session with TeenWorlds develop over time, and whether participants report practising reflective behaviours in their everyday lives.

PIV.6 Conclusion

In this paper, we explored how VR could support teenagers' emotional expression and shared understanding in a multi-user context involving peers and parents, introducing TeenWorlds. We particularly investigated how teenagers and parents could externalise their emotions both visually and verbally using TeenWorlds, and the effects on communication and reflection, as well as how teenagers engaging in this activity with their peers or parents affected this interactions. To that end, we conducted a user study with 42 participants. Our findings show that TeenWorlds could help mediate communication between teenagers and their parents and peers, by showing them the importance of communication to avoid or mitigate conflicts, which also fostered reflection and an appreciation for their interpersonal relationships. Moreover, both our quantitative results and qualitative findings show that TeenWorlds seems to "work better" when used with parents than with peers with respect to the experienced emotions, empathy with the interlocutor, and reflection. This indicates that, in order to achieve reflection, teenagers might require specific scaffolding, which was partly provided by their parents, but in many cases was lacking when they were interacting with their peers. We discuss how future work could integrate this scaffolding, e.g. in the form of reflective prompts, and how systems like TeenWorlds could facilitate well-being, both by navigating conflicts and by connecting them with their parents through a joint activity that both parties enjoy. We hope that our work can inform future research that seeks to support teenagers' emotional expression, while in particular considering their care ecosystem.

PIV.7 Acknowledgements

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PUBLICATION P V

MoodGems: Designing for the Well-being of Children with ADHD and their Families at Home

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Abstract

Many technologies for ADHD children and their caregivers focus on symptom management rather than overall well-being, often without involving them as technology co-designers and co-users. To explore how to design systems that integrate into their home and routines, we contribute the iterative design of MoodGems, a situated, modular, and portable set of physical displays, that allows children to record and share their data with their families. We conducted an online formative evaluation ($n = 22$) with ADHD children, parents, therapists, and HCI experts. Our work demonstrates the potential of technologies affording both individual and joint tracking to allow children to navigate and reflect on their experiences and emotions, and support family communication and children’s autonomy. The evaluation also uncovered necessary refinements in the system’s design. We contribute design insights towards technologies that empower ADHD children and integrate into their homes, and discuss therapists’ role in technologies that address ADHD families’ lived experiences.

Contributions

This paper contributes the iterative design and formative evaluation of MoodGems, a set of physical hexagonal-shaped displays that allow recording and sharing of emotions and activities for ADHD children. Moreover, it delivers insights for technologies that go beyond traditional screens and have the potential to integrate into children’s homes. Furthermore, it demonstrates the potential of such technologies to empower ADHD children and support them and their care ecosystem. Finally, it contributes implications for research and design by identifying specific challenges that arise when integrating such artefacts both in the home context and beyond, e.g. in therapeutic settings.

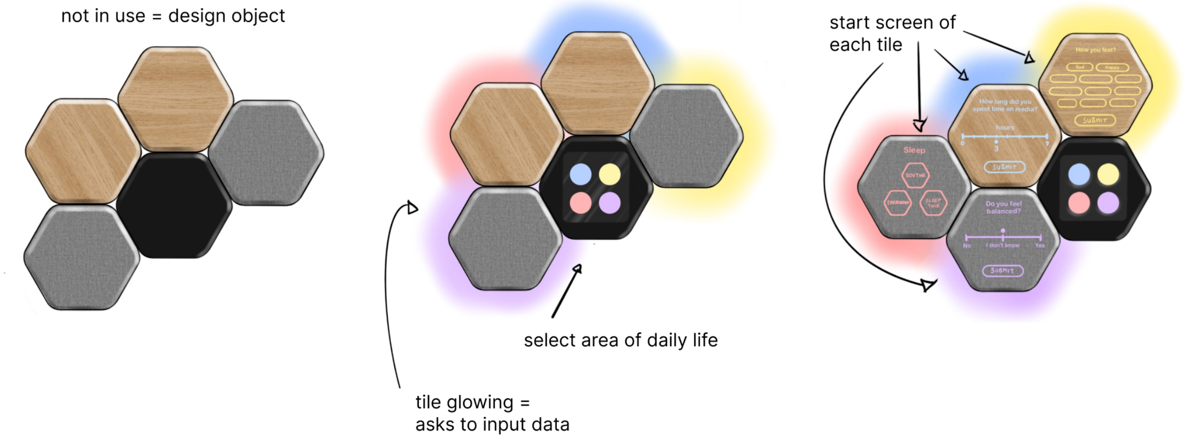

Fig. PV.1 Sketches of MoodGems when idle (left), when activated via the home tile (middle), and with all tiles activated (right).

PV.1 Introduction

Approximately 5% to 7% [436, 566] of children worldwide are affected by attention deficit hyperactivity disorder (ADHD) [621][5] , making ADHD the prevalent mental health diagnosis in children [470, 639]. It poses challenges that impact daily routines, peer interactions, bedtime resistance [163, 537, 604], and can lead to added stress and family frustrations [565]. ADHD children often face communication barriers within their care ecosystem, including family, teachers, and therapists [456, 550], which hinder caregivers' ability to support children and coordinate care effectively. This can lead to negative outcomes for both ADHD children and their caregivers, such as unclear goals and feeling misunderstood [550]. Moreover, ADHD children often struggle with emotion regulation, which involves managing when and how emotions are experienced and expressed [216].

Human-Computer Interaction (HCI) and Child-Computer Interaction (CCI) researchers have increasingly explored technologies to support ADHD children and their care ecosystem [549]. Recent studies have highlighted various limitations in existing approaches for creating and evaluating technologies for neurodivergent individuals [542, 543], particularly those with ADHD [544, 549]. These works emphasise the need for a focus beyond mere symptom management, advocating for technologies driven by neurodivergent interests and needs [543, 549], for instance by designing "beyond symptoms" to support overall well-being [550]. A significant gap in existing efforts is the insufficient involvement of ADHD children and their care ecosystems, both as co-constructors and co-users of these technologies [544, 549, 550]. This issue is prevalent in technology design for both ADHD children and adults [543, 544, 549], underscoring the necessity for co-constructed technologies, considering ADHD's high heritability [162].

At the same time, most technologies designed for ADHD children and their caregivers are in the form of mobile apps or smartwatch applications [12, 137, 158, 523, 536]. While these

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[5] In order to show respect for the different views and preferences communities and ADHD people have expressed regarding the use of person-first language, and similar to prior work (e.g. [523, 544]), we use both "ADHD children" and "children with ADHD".

are easy to access, they contribute to the ongoing debate about children's technology use and screen time [54, 316, 445, 455], a common family conflict [379]. This presents the opportunity to design alternative tools that i) go beyond typical screens and enable families to choose how they engage with technologies at home, and ii) are a part of the home environment, where most family interactions take place. Such tools could be easily integrated into daily routines, which are key for long-term well-being [16, 298], and offer direct, situated support. Here, we refer to *situated artefacts* as interactive systems that are integrated within their location [504], for example in users' homes, in line with the long tradition of designing for the home in HCI [133]. Physical situated displays could present opportunities in that respect, building on the benefits of shared dashboards that are often-utilised in family informatics [429, 479, 480, 485], which can allow families to collaboratively reflect on behaviours and make decisions to enhance the family's well-being [112, 410]. Through the incorporation of data into physical spaces, situated visualisation effectively places tracking and reflective practices within everyday living areas and activities [59, 383].

Going beyond typical screen-based interfaces, custom-made physical displays could also incorporate tangible aspects - with tangibles known to foster reflection [122] and improve family communication by encouraging interaction and collaboration [247]. Thus, this paper explores how such an artefact could be designed, as a situated system that could integrate in the home of families with ADHD children, as previous research suggests that technologies that include joint use aspects by ADHD children and their caregivers could mitigate disagreements over technology use and be favorable to both parties [550].

Therefore, we seek to address the following research questions (RQs):

> **(RQ1):** How can we design an artefact that goes beyond traditional screens, situated in the home, that supports children with ADHD and their families in their everyday lives?
>
> **(RQ2):** How could such an artefact enable children to record and reflect on their experiences and share them with their family, and how could it affect their emotional well-being and family dynamics?

To examine our research questions, we contribute the iterative design of *MoodGems*. MoodGems is a situated artefact comprised of modular and portable custom-made physical displays in the home context (see Figure PV.1), allowing children to record their experiences and choose whether to share their recorded data with their families. It consists of hexagon-shaped displays (hereby called "tiles"), each representing a different area of interest, e.g. areas of daily life, such as sleep routines. Its goal is to support expression and reflection, both individually for the children as well as together with their families in situ, i.e. within their home, and to serve as a conversation starter, decreasing existing communication barriers [455]. In this paper, we present its initial design and the online formative evaluation we conducted, involving four children with ADHD, eight parents, five therapists, and five HCI experts ($n = 22$). Considering the challenges in recruiting children with ADHD and their caregivers, especially post-pandemic [419], this initial formative evaluation was conducted online, with participants introduced to MoodGems via a video presentation, and being able to interact with a virtual prototype, a 3D desktop application [6]. This was followed by a heuristic evaluation and a functionality inspection in the case of HCI experts, and by in-depth semi-structured interviews for all other participants.

Our analysis identified both opportunities and challenges, as well as issues that can inform the refined design of MoodGems. It suggests that systems like MoodGems have the potential to support emotional expression and reflection in children by enabling documentation and exploration of experiences. Importantly, the burden of self-tracking should be considered, presenting opportunities for integration of systems like MoodGems with other technologies that allow automated tracking, e.g. smartwatches. Additionally, systems like MoodGems could enhance family communication and fostering children's autonomy, suggesting a potential for beyond-screens digital furniture that integrates into their living spaces and self-concept. However, integrating such an artefact into family homes could present challenges, particularly balancing children's independence with parental control. Overall, our findings highlight aspects that future technologies that seek to empower ADHD children should explore, such as designing with an emphasis on children's control, autonomy, and home integration. Thus, we contribute insights into designing novel situated devices beyond traditional screens to enhance the well-being of children with ADHD and their families, enabling externalisation and navigation of emotions and experiences, and supporting family communication.

PV.2 Background & Related Work

Here, we review related work on technologies for children with ADHD and their caregivers. We then engage with literature on technologies that support family reflection to contextualise our own work and design decisions.

PV.2.1 Technologies for Children with ADHD and their Caregivers

Various literature reviews have been conducted on technologies that can help ADHD children and their caregivers manage their behaviours and emotions [102, 103, 535, 549]. Indeed, many interactive technologies have been designed aiming to support children with ADHD and their caregivers by addressing ADHD-related challenges. For instance, ChillFish [532, 535] is a tangible respiration game aiming to help children with ADHD stay focused during breathing exercises by combining them with a video game. TangiPlan [606, 645, 647] consists of tangible connected objects, representing tasks to be performed. It assists ADHD children to structure their daily activities, with the overall goal to improve their executive functioning. Additionally, previous work has explored digital interventions for children with ADHD by investigating how smartwatches can support ADHD children in the context of distance learning to improve organisation and task completion [104]. As another example that is neither a tangible nor a smartwatch application, Matric et al. [360] explored how public screens available in a school catering to neurodivergent children, including children with ADHD and autism, could be used to support positive behaviour change, both individually and collectively. Their findings show that situated displays focused on collective behavioural performance can support reflection on individual performance, improve behaviour for ADHD students, as well as encourage teamwork and cooperative behaviour in classrooms.

Looking at the field more holistically, Sonne et al. [535] mapped the design space of assistive technologies for children with ADHD and proposed a framework including two dimensions: technology and ADHD challenges (e.g. social or academic-related challenges). In particular, they proposed two promising unexplored avenues: i) capturing contextual data for later retrieval, either for research or for personal reflection, and ii) addressing risky behaviours (e.g. accidents). Since then, CCI and HCI researchers have addressed the concept of personal reflection for children with ADHD, by exploring how smartwatch and smartphone applications can be designed to support children with ADHD and their parents for self- and co-regulation [523] and showing how ADHD children can interpret their own health data but might require caregivers' assistance for sense and meaning making [12]. However, designing technologies that go beyond the ADHD challenges dimension of Sonne et al.'s [535] framework remains under-researched. Especially given various calls to design with the interests of neurodiverse people in mind rather than only focusing on symptoms [542, 543], and previous work that identified a lack of technologies that support children with ADHD in this manner [549], there is a need to design artefacts that support children with ADHD beyond symptoms. To that end, Stefanidi et al. [550] explored this, by conducting studies with children with and without an ADHD diagnosis, parents and therapists. They found that technologies designed for and with ADHD children and their care ecosystem without only focusing on symptoms could cater to the interests of ADHD children while helping them navigate ADHD-related challenges such as emotion regulation. Particularly, they identified recording, reflecting on, and sharing experiences and emotions to be possible features that technologies could employ to foster their overall well-being. Inspired by this, we aim to address the aforementioned gap, by designing a situated physical artefact that allows expression and reflection for children with ADHD and their families. Below, we contextualise our work within research on family informatics and particularly technologies that aim to foster reflection within families.

PV.2.2 Technologies for Family (Health) Tracking & Reflection

Given the benefits of reflection (the process of introspection where individuals review and analyse their thoughts, emotions, and behaviours [210]) for well-being [341], a growing number of research works have been exploring how to design for technology-mediated reflection [42, 44, 257]. A large body of work in this area centres around personal and health data tracking and reflection on this data. For instance, Karolus et al. [283] explored how a situated, ubiquitous artefact, in the form of a smart mirror, could be used to display health data to foster reflection. They found that compromises between privacy and ubiquitousness of data needs to be made in multi-user settings when integrating such situated artefacts into everyday life. Wang et al. [598] investigated tangible displays to enhance engagement with self-tracked stress data for adults, and particularly how to use everyday spaces as an interface for interacting with health data. They propose that placing displays in contextually relevant spaces for situated interaction, and carefully choosing the display's material, could allow for better integration into everyday spaces and for improved user engagement.

In the context of families, Kim et al. [295] explored how Dyadic Mirror, a wearable smart mirror showing parents their own face as seen by their child during face-to-face interaction, could support parents' reflection during parent-child interaction. Of particular relevance to our work is literature that actively involved not only parents/caregivers, but also children in the tracking process, aiming to support shared reflection of family members, for instance by allowing shared visualisation of data [429, 479, 480, 485]. For instance, Dreamcatcher [429] combined data from wrist-worn sleep sensors and self-reported mood of families using a shared tablet display. They found that this approach allowed families to view and reflect on each other's sleep data, showing how collaboration within the family is supported by the children's active engagement in the process. While these shared experiences can be useful for collaboratively reflecting on behaviours and making decisions to enhance the family's well-being [112, 410], these systems usually need family members to use them simultaneously and might not provide much support when family members are apart [523]. Additionally, while automatically self-tracked health data has become increasingly available and can provide self-awareness, users can still find it challenging to meaningfully engage with these automatically tracked data [598]. This is of particular concern for children who might struggle more with interpreting them, e.g. when abstract constructs are involved [12]. Aimed at supporting healthy behaviours in families of ADHD children specifically, other pertinent works include MOBERO [536], a smartphone-based system that aims to support families in establishing healthy morning and bedtime routines. Moreover, ParentGuardian [428] monitors the stress levels of parents with ADHD children, providing reminders for behavioural strategies, which encompass both in-the-moment approaches for distressing situations and reflective methods suitable for any time. More recently, CoolTaco [523], a task and reward-based smartwatch and phone system, was found to be effective at supporting co-regulation within families with ADHD children. However, it also raised challenges with regards to children's independence (e.g. children needed their parents to approve their tasks to get their reward). As a next step, Silva et al. [522] conducted co-design sessions with families including ADHD children, in order to explore how to complement smartwatch-acquired health data with in-home displays to foster family well-being. Their findings highlight the opportunities for situated displays in the home context to support families with both self and co-regulation, and further underscore the importance of facilitating both joint and individual use.

Overall, previous works specifically address ADHD-related symptoms, rather than being driven by children's interests and needs [543, 544] and supporting the overall well-being of children and their families [550]. With respect to related work on personal and family informatics, and (situated) artefacts for self-tracking, we design a situated artefact that aims to support both individual *and* joint use by ADHD children *and* their families [522, 523]. In particular, in contrast to existing technologies for ADHD families, we explore self-tracking *and* sharing of both health-related data, as well as emotions. Our work builds on the design insights drawn from previous work aiming to support the well-being of children with ADHD by allowing them to record and reflect on their experiences [549]. A further aim of our research is to support children's autonomy by allowing them to choose which of their data they share with their family, as supporting both independence [523] and collaboration [550] was found to be a key aspect by previous works [522].

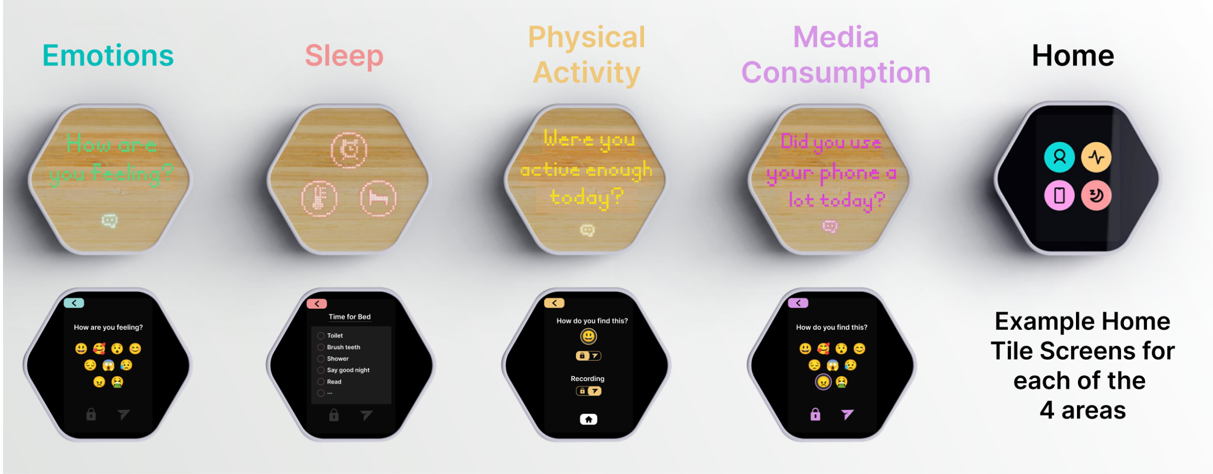

Fig. PV.2 First row: the wooden tiles MoodGems offers – emotions, sleep, physical activity, media consumption, and the home tile when no area has been selected. Second row: home tile in four example states when activated.

PV.3 MoodGems

To examine our research question RQ1, we engaged in an iterative process to design *MoodGems* (see Figure PV.2). Here, we provide an overview of the process that informed the design of MoodGems. Based on Stefanidi et al.'s [550] co-design and interviews with ADHD children and their care ecosystem, Cibrian et al's. [106] co-design of smartwatches with ADHD children, Silva et al.'s [523] findings from the deployment of a smartwatch and phone system for self and co-regulation in families of ADHD children and their subsequent co-design sessions to explore the potential role of in-home displays in that context [522], we compiled a list of initial design requirements. These works identified i) emotional expression as a key aspect for both children and caregivers as it could foster empathy and support emotion-regulation [550] ; ii) three categories of activities useful for planning and tracking (via smartwatches): social, health, and school [106]; and iii) the need to allow for both individual and joint tracking and reflection, in order to support children's independence while at the same time fostering joint interaction within the family [522, 523]. Additionally, Kuzminykh and Lank [313] showed that parents are interested in receiving the following information about their children: health (e.g. sleep, physical activity), general well-being (e.g. by asking "How are you feeling today?") and social-emotional information, particularly children's moods. Figure PV.1 presents the initial sketches of MoodGems. Below, we elaborate on our design decisions (DD) for MoodGems in detail, showing how we support the aforementioned requirements.

DD1. The artefact should allow children to easily and intuitively input their data and reflect on them. Children can utilise different ways to input their data, including recording voice notes and selecting the emojis that best represent their emotions [550]. Additionally, MoodGems asks children questions in order to prompt them to answer and reflect on their data, e.g. "How did you find this" or "Do you feel tired or full of energy?". In line with Bentvelzen et al. [44], MoodGems employs the following resources for reflection: i) temporal perspective, by allowing children and their families to track and revisit their data, and ii) conversation, by fostering both conversation with others (e.g. through the accompanying mobile app that allows feedback) and with the technology itself (as MoodGems prompts children to record and reflect on their experiences by asking them reflective questions).

DD2. The artefact should allow children to record and reflect on their experiences, with regard to both emotions and key daily activities. Enabling children to record and express their emotions could be beneficial to their overall well-being [289, 550]. MoodGems addresses the following aspects of daily life, focusing on the home context (thus not including e.g. school activities): 1) *Sleep*, due to its impact on mood, mental health and overall well-being [124, 183, 268] (and since ADHD children can struggle with bedtime routines [163, 536]), 2) *Physical Activity*, which is crucial in childhood and can affect health [14, 292], and benefits speed of processing and inhibitory control for both children with and without ADHD [89, 425], and 3) *Media Consumption*, as this is often a topic of disagreement in (ADHD) families [54, 316, 445, 455, 550]. Allowing children to record and reflect on these activities could potentially be a first step into fostering awareness about their behaviour regarding those three aspects. While this is not an exhaustive list of meaningful activities of daily life to track, we used these as a starting point for evaluation with all relevant stakeholders, to gauge their opinions about other relevant topics that they wish to be included and the degree of customisation required in that respect.

DD3. The artefact should allow children to select what they want to share with their family. By allowing them to share, we aim to support collaborative reflection between children and their care ecosystem [550] and make MoodGems serve as a conversation starter for real-life interactions. At the same time, by empowering them to choose if and what to share, we aim to support children's agency and autonomy [550], given their importance, e.g. for higher self-esteem and better mental health [131], for well-being [8], and to avoid feelings of powerlessness [460].

DD4. The family should be able to interact with the system and to view previously recorded data. We decided to accompany the physical artefact with a mobile application (to be used on the parents' phone or the family tablet), to allow the family to access the data that children share with them, similar to previous work that supported families in a multi-device manner [523]. It allows the family to view previously recorded data together (employing the temporal resource for fostering reflection [44]), underscoring the possibility of joint use of the system. Parents can also use the mobile application to react to the shared content via emojis or voice notes as feedback.

DD5. The artefact should be integrated into the everyday family life in a situated manner. Given the significant influence of the environment on the behaviour of children with ADHD [19], there is the need to explore diverse technologies to support them and their care ecosystem depending on the context [550]. Moreover, situated displays within the home have previously been shown to support self-reflection and mood tracking [59, 273, 530]. To that end, we designed MoodGems to seamlessly integrate into children's homes and daily routines. MoodGems can be easily mounted on walls due to being magnetic, rearranged in different configurations, and moved around for portable interaction. By dividing MoodGems into distinct, movable components (tiles), each serving a specific function, we aim to provide context-specific support. For instance, children can carry a tile with them to different home environments, such as the bathroom during bedtime tasks like brushing teeth, similar to other physical artefacts, which include tangible qualities, designed for children with ADHD like Tangiplan [647]. The idea of the honeycomb pattern was inspired by modularity design, also used by ambient light fixtures and speakers (e.g. [406]). Moreover, allocating specific aspects of a child's life (e.g. sleep) to a distinct tile promotes a comprehensive overview, akin to to-do lists. In particular, since short attention span is a common challenge for individuals with ADHD [37], it is beneficial to deconstruct activities into smaller parts [546, 572]. MoodGems can also captivate the child's attention by being illuminated upon entry into the room or at user-defined intervals. To that end, a thin wooden surface conceals an underlying LED matrix. Their wall-mounted positioning and wooden surface underscores their visual appeal that can serve as decoration, providing a type of wall ornament that can foster a calming ambience, allowing MoodGems to easily fade between the foreground and background of everyday life [405]. In that way, MoodGems constitutes an embedded but standalone artefact that is part of the home context, while being distinctly unique from other technologies that children might interact with, e.g. mobile applications [442, 536] and/or serious games [22, 70, 548].

Figure PV.2 presents each tile of MoodGems' initial prototype. Additionally to existing literature detailed above, we consulted experts in design, ADHD, HCI, and previous work in HCI to determine the different tiles that MoodGems should be comprised of. Here, we explain how each of the tiles functions. The **Home tile** is the central control hub. It displays the available areas: emotions, sleep, physical activity, and media consumption. When a child interacts with one of these areas, the home tile transforms into a corresponding extension tile, providing additional functions, e.g. allowing children to log their emotions using emojis. The home tile is not made of wood material, but rather an LED screen, to allow for this functionality. For each of the tiles described below, the child can choose whether to share or keep their answers private for each recorded aspect. The **Emotions** tile enables children to express and reflect on their emotions by asking "How are you feeling?". They can respond with one or more emojis (using the home screen) and/or by recording one or more voice notes (using the emotions tile). They receive daily changing questions like "What did you learn today?". The **Sleep** tile allows children to record and reflect on sleep-related aspects, including sleep times, environment, and routines. It allows children to log bedtime and wake-up times, rate their sleeping environment, and mark completed bedtime tasks. Completing tasks earns stars, visualised on a digital bed. Children can also record voice notes and express their emotions by answering the question "How did you find this?" using emojis. The **Physical activity** tile enables children to record and reflect on their physical activity by asking questions about their activity level and energy, e.g. "Were you active enough today?". They can rate these aspects on a scale, record voice notes, and use emojis to express feelings. The **Media consumption** tile records and reflects on media and screen usage. It asks questions about phone usage and satisfaction, e.g. "Did you use your phone a lot today?" or "Do you think that was enough?". Children can respond with scale ratings, voice notes, and emojis.

The tiles can be activated by tapping, and light up in different colours to indicate daily interaction (see Figure PV.1). Users can engage with one of the four wooden tiles at a time, including the home tile, by tapping the tile itself or selecting the corresponding button on the home tile. Switching between areas is possible by tapping a different tile, with each tile's state being saved. Each wooden tile presents a series of questions related to different life areas, with varying input methods, as described above, e.g. voice recordings, sliders. After completing all questions, which can vary daily and be family-configured, children can view a summary of their logs and decide what to keep private or share with their family. Additional examples and images are available in the supplementary material.

In accordance with DD4, i.e. allowing the family to interact and provide input to the system and view their previously recorded data, we also designed an accompanying mobile application. This application facilitates documentation and review of saved data for both children and their families. In particular, it allows to view past recordings across the four areas (emotions, sleep, physical activity, media consumption), including voice notes, emojis, and scales. It also allows parents to provide children with feedback regarding shared data. Finally, the mobile application also allows customisation of MoodGems, e.g. families can select the bedtime tasks they want to include in the sleep routine tile or configure settings regarding the glowing lights around each tile. Please refer to the supplementary material for more information and images.

PV.4 Formative Evaluation

In order to explore how a system like MoodGems could support the well-being of children with ADHD and their families, as well as to perform a first formative evaluation of its design and functionality, we conducted an online study (total $n = 22$), with four ADHD children, eight parents, five therapists, and five HCI experts. Ethics approval was obtained by the Ethics Committee of the University of St. Gallen (HSG-EC-20230406). All adult participants provided informed consent prior to their participation. Children's parents provided consent for the participation of their children, and children provided their assent that they wanted to participate before the study begun.

We recruited $n = 22$ participants using Prolific and by using the authors' extended social network. The five HCI experts were aged between 28 and 47 ($M = 36.4$, $SD = 9.3$), and came from Greece (IDs E1-E5). For the care ecosystem stakeholders, adult participants were aged 24-56 years ($M = 37$, $SD = 9$), while children were aged 9-14 ($M = 11$, $SD = 2$). Prolific participants were remunerated via the platform (in the case of children, their parents were compensated), while the participants recruited outside of Prolific received a multi-purpose voucher. Demographic information regarding the 17 care ecosystem stakeholder participants, i.e. ADHD children, their parents, and therapists, is visible in Table PV.1. In line with previous work that aimed to design for the well-being of children with ADHD [550], we included therapists in our study, to also elicit their opinion about how such an artefact could support families of ADHD children. In particular, given the sensitivity of the topic and the vulnerability of the studied population, we included ADHD professionals to assess both the potential opportunities and risks. Additionally, MoodGems is designed as a situated artefact for children and their families to use in the home context, but we also wanted to explore how such artefacts are perceived and could potentially be used or benefit the extended care ecosystem of children with ADHD, such as ADHD professionals themselves. This is also in line with previous work that suggested the potential of including guidance from experts when using situated displays for family health at home [522], promoting collaboration and engagement within the care ecosystem [52, 53, 522, 550]. Moreover, we included HCI experts to conduct an expert-based evaluation and identify usability issues before moving on to implementing the system, in line with the iterative design process we followed.

Participants received all study information before the evaluation. Prior to the study, participants were asked to watch a short video, which differed between adult and child participants, presenting MoodGems and examples of its functionality. In particular, the videos were tailored to the needs and attention span of the respective populations, so that the video for adults lasted approximately six minutes, while that of the children lasted approximately two. Both videos are available in our supplementary material. For the expert-based evaluation, the five HCI experts additionally received a form with functionality inspection questions, to answer with yes/partially/no (providing an explanation in the latter cases). They also completed a heuristic evaluation of MoodGems in line with Nielsen [397]. For the 17 care ecosystem stakeholders, they additionally engaged in in-depth semi-structured interviews with a researcher.

At the beginning of each study session, participants were welcomed and then asked again for their assent to participate, followed by demographic questions. Age, gender, and current country of residence were collected for all participants. Additionally, occupation was asked for therapists, and number, age, and gender of children, as well as any neurodevelopmental diagnosis was asked in the case of parent participants. Children participated in a separate interview session from their parents, but with their parents present during the interview. Following the collection of demographic data, participants were asked to download a 3D desktop application, through which they could interact with a virtual representation of MoodGems, i.e. within a virtual environment created with the Unity game engine. They could click on the different tiles comprising MoodGems, emulating what would happen if they were interacting with the physical prototype by tapping on it, and they could navigate through the virtual environment (which resembled a child's bedroom), and zoom in and out to have different perspectives of the tiles. Participants were asked to share their screen during this time, and were instructed that they could freely interact with the virtual MoodGems to discover what it can do. Participants' interaction with the virtual representation of MoodGems was followed by in-depth semi-structured interviews in the case of the 17 care ecosystem stakeholders, and by the completion of the aforementioned forms for the five HCI experts. During the interviews, we inquired about participants' opinion and perceptions of MoodGems and of specific features, what they liked and did not like about it, if, how, and when they might use it, how they think it might affect communication and family relationships, and about current daily tracking practices they might use, among others. After the interview, participants were thanked for their participation, and were informed regarding how they would receive their remuneration. In the case of parents who had stated they were interested for their child to participate as well, specifics of setting up an appointment for the online study with their child were also discussed at this time.

Regarding data collection, all online interviews were video and audio recorded for later transcription and analysis, with the consent of the participants. The study sessions lasted between 23 and 26 minutes ($M = 24.7$, $SD = 1.5$) for children participants, and between 32 and 55 minutes for adult participants ($M = 43.3$, $SD = 9.3$) During the participant's experience, we collected qualitative data using the think-aloud protocol [262]. We drew inspiration from Albastaki et al. [6], who utilised a virtual experience prototype (VEP) approach, to help participants understand and engage with our prototype [6, 68]. This approach provides a lightweight means to involve participants in remote interviews through interactive spatial experiences, enabling location-independent evaluation. However, participants are aware that they are interacting with a virtual, not a physical artefact [6]. In our case, we used this approach to allow participants to interact with a virtual representation of MoodGems during online interviews. This was a crucial part of our iterative design process, offering a proof of concept exploration, before the actual development of MoodGems. Additionally, we aimed to reduce the burden on ADHD children and their families, who are a vulnerable population disproportionately affected by the pandemic [419]. We designed the study to be conducted in the comfort of their homes during this initial formative evaluation, an integral step in MoodGems' design and development, and in line with prior work that engaged ADHD children and their families in an online manner [522].

All 17 interviews of the care ecosystem stakeholders were transcribed verbatim. Of these, 16 sessions were conducted in English, and one was translated from German to English (T5). The first author together with two other authors analysed the transcripts by performing open coding in an iterative process, using the MaxQDA software. Any disagreements that arose were resolved by discussion. After an initial round of open coding, these three authors conducted thematic analysis in line with Blandford et al. [51]. In a final discussion session between two of the authors, a final set of five themes was constructed. Our method aligns with an interpretative research approach, which emphasises understanding the significance of data within its context rather than quantifying inter-coder reliability [108]. We employed rigorous practices, including several meetings among the authors to build consensus and discuss coding decisions [108]. We thus ensured the credibility of our findings as well as the the depth of our thematic analysis through rigorous practices, capturing the richness of the data effectively. Finally, the answers to the forms administered to the five HCI experts were analysed and consolidated in a final document, using affinity diagramming by clustering similar issues.

PV.5 Findings

Our analysis verified the feasibility and suitability of such a system to support families of ADHD children, while uncovering various challenges and (usability) issues that need to be addressed in a refined version of the system before implementing it. In particular, based on our analysis of the 17 interviews, the following themes were constructed: *fostering reflection*, *supporting communication*, *facilitating autonomy & agency*, *navigating challenges*, and *MoodGems as a situated hybrid artefact*. Overall, participants responded positively to the virtual representation of MoodGems, finding it intuitive and expressing interest in a physical version for home use. Interestingly, this was the reason that P4 preferred that his son does not participate in the

Table PV.1 Demographics of care ecosystem stakeholder participants (n=17 out of total n=22). P1-P8: parents of children with ADHD; C1-C4: their respective children; T1-T5: therapists of children with ADHD.

ID	Description	Age	Gender	Country of Residence
P1	Parent of female 14, female 7 (all three with ADHD)	33	Female	UK
P2	Parent of female 9 (ADHD), male 5	41	Female	UK
P3	Parent of male 13, male 11 (ADHD), female 9	37	Female	UK
P4	Parent of male 12 (ADHD)	43	Male	UK
P5	Parent of male 11 (ADHD), female 8	45	Male	Germany
P6	Parent of male 8, male 4 (ADHD), male 1	31	Female	UK
P7	Parent of male 7 (ADHD), female 5	56	Female	US
P8	Parent of male 10 (ADHD), female 6	32	Male	Germany
C1	Child of P1 with ADHD	14	Female	UK
C2	Child of P2 with ADHD	9	Female	UK
C3	Child of P3 with ADHD	11	Male	UK
C4	Child of P5 with ADHD	11	Male	UK
T1	Children and youth psychotherapist	30	Female	Germany
T2	Paediatric physical therapist	24	Female	Spain
T3	Mental Health Support worker	31	Male	UK
T4	Speech and Language Therapist	50	Female	UK
T5	Children and Youth Psychotherapist	29	Female	Germany

study, as he liked to imagine he might be able to actually acquire MoodGems in the future and he *"thought it's something that [he] wanted to maybe bring up with [his son] a little bit inconspicuously"*. Children, parents, and therapists all saw potential benefits in the system. Children valued autonomy and using emojis for emotional expression. Parents saw it as a tool to enhance communication with their children and reduce parenting stress. Therapists focused on its utility in teaching self-expression and improving communication. All participants particularly enjoyed that MoodGems would be a physical artefact they could have on their bedroom wall and not a traditional screen-based interface.

Nevertheless, we also identified various challenges that would need to be navigated if such a technology would be integrated in situ with families. Regarding the experience of participants with the virtual representation of MoodGems, participants commented positively on the additional interaction that this allowed them, as it *"gives a real aspect to it"* and allowed them to *"imagine it being in a child's bedroom (T2)"*. Before detailing the four themes with study session excerpts, we elaborate on key insights from the five HCI experts' evaluation, suggesting refinements in MoodGems' design and functionality. In particular, 32 usability problems were uncovered, to which the experts provided severity ratings (ranging from 0 indicating that this is not a usability problem, to 4, indicating that it is a "usability catastrophe" [397]). Please refer to the supplementary material for the full list of the identified issues, the severity ratings, and statistics about the deviations from the heuristic guidelines.

Here, we present the most important aspects that need to be revisited for the refined version of MoodGems. First of all, the need for *combination of manual and self-tracking* surfaced. In particular, allowing children to select the degree to which their data tracking can be automated, e.g. using data from their smartwatches, could relieve tracking burden, while at the same time allowing children that do not own a smartphone or smartwatch to use the system. Second, *the decisions regarding what data and functionalities are available on the home tile* needs to be revisited. This connects to another issue, that *children should be able to review their data on the physical artefact* as well, and not only on the mobile companion app, which could easily be implemented using the home tile for viewing aggregated data, and using the wooden tiles for other interactions. Finally, children and their families should be able to *configure the areas of daily life* that MoodGems cover, to include interesting for them aspects. Namely, apart from the emotions tile that should always be available, users could customise the areas the tiles cover to include e.g. social and school activities. This was echoed by interview participants as well, who elaborated on these aspects of tile customisation and including new areas of daily life in MoodGems.

PV.5.1 Fostering Reflection

Our analysis showed that a system like MoodGems could support children in *documenting their everyday experiences and emotions*. Children stated they wanted to log both positive and negative experiences and emotions, their routines, or *"when something important happened (C2)"*. Moreover, MoodGems could support children's emotional identification and expression, by providing them with both visual and verbal input options. For instance, *"sometimes it's hard to explain something with words but then if you have an option to use it with images then it's* *really useful, because if I was feeling bad and I tried to explain it, but it just came out wrong, I could find the right emoji and I could just use that (C3)"*. P1 and P3 additionally noted how such a system could support reflection and emotional identification for children with autism as well, especially due to the visual nature of the emojis for mood tracking, with T5 adding that *"children with autism are also very interested in that"*. Additionally, systems like MoodGems could support children in *navigating both positive and negative experiences*. Interestingly, we found that looking back at previously recorded positive experiences and reflecting on them could serve as a way to mitigate current negative ones, thus providing children with a resource for resilience. In that respect, C3 noted that *"I think that'd be good because you could go back to a nice event. Like, cause I'm going to a [school trip] (...) and I could record that. And then (...) later when I was feeling like I had an argument with my friends because of something, I could go back then and see, oh, but we had a good time, then it's just an argument instead of feeling really bad. So I think that's awesome (C3)"*. Moreover, using a system like MoodGems could facilitate sense-making for both children and families, by allowing children to self-evaluate, and parents to understand their children better. Therapists noted how this would be helpful, by encouraging communication and helping to avoid misunderstandings. P1 emphasised how this sense making might help children by *"finding those little patterns (...) and seeing what actually happens in the days when they are very happy and helping them to recreate it"*. Participants also reported that a system like MoodGems could *increase reflective behaviours and self-awareness* for children with ADHD. For example, using MoodGems might help children think before they act, as the child *"might learn that he can go and use this device to record something, but not have to immediately throw it in someone's face or, you know, throw that anger back at someone, which is something that he does struggle with (P3)"*.

PV.5.2 Supporting Communication

Our analysis showed that a system like MoodGems could enhance communication between children and their caregivers. A system like MoodGems could allow for *indirect communication*, providing a safe space for children to express their needs and feelings without face-to-face interaction. For instance, P1 highlighted its usefulness in sending an 'SOS signal' through voice notes or emojis when a child needs help. Children found the idea of using emojis for emotional expression effective, as noted by C2: *"you can show your feelings, and then you can press send"*. Feedback features in MoodGems and the mobile app were also valued. For example, C1 liked the idea of receiving comforting voice messages from a parent during tough times. Therapists emphasised the importance of parental feedback in helping children understand and process their emotions, with T1 explaining how parents could help them to say *"I think this is sadness because of what you said in your voice message"*. Positive feedback was seen as particularly vital for children with ADHD, with P2 stating that *"if you can find ways that give them the positive feedback, it will really boost their confidence"*. Parents also imagined how a system like MoodGems could offer ways to *offload dependence and responsibility*. They elaborated on how it could offer children a way to communicate independently and could act as a rule enforcer, especially in regulating routines like screen time. P2 discussed the relief of sharing the caregiving burden, while P1 mentioned MoodGems' potential to remind children about healthy behaviours without parental enforcement. Additionally, participants imagined how MoodGems could mitigate arguments and act as a conversation starter. For example, *"[MoodGems] might be (...) a way for both of us to sort of record how we feel in the moment rather than shouting at each other (P4)"*. C1 noted that sharing MoodGems entries could open up conversations, enhancing awareness and communication. Therapists were excited about the potential for knowledge transfer between therapy and home environments. They saw MoodGems as a tool to support introspection and communication, which could assist in transferring therapeutic techniques to everyday life.

PV.5.3 Facilitating Autonomy & Agency

Our analysis suggests that MoodGems could empower children by enabling them to autonomously express their emotions and experiences with the option to share them with their family, supporting both their autonomy and agency. The control over sharing was a crucial aspect for parents, therapists, and children. T1 noted that *"children wouldn't use it if that wasn't an option"*. This control is especially important for children with ADHD, who often feel *controlled by their issues, as opposed to by the choices they get to make (P3)"*, while a system like MoodGems *"would allow a child to at least be able to start gaining some control (P3)"*. Children's reaction to MoodGems' privacy options was positive. C3, while interacting with the virtual MoodGems, appreciated the choice to keep things private: stating how *"this is really cool"*. Participants also expected MoodGems to foster a sense of ownership, supporting children's agency. P2 discussed how she envisioned MoodGems could encourage self-sufficiency, and T1 noted its appeal as a personal tool: *"that's something that's only for you. I think that's really cool, that it's in your room and that you can do it yourself and that you can use it for what you want"*. Customisation of MoodGems, both in input and appearance, was a point of interest, particularly among children. They envisaged personalising it with stickers and new tiles, making it their own. After interacting with the virtual MoodGems, participants reflected on the value of technologies that support autonomy and agency rather than only addressing symptoms. P4 appreciated MoodGems for not being associated with medical or clinical settings, while C3 expressed gratitude for a tool specifically designed to help ADHD children without *"taking away"* children's options and dictating *"oh, so this is going to happen (C3)"*.

PV.5.4 Navigating Challenges

Our analysis identified potential tensions and challenges in integrating MoodGems into homes with ADHD children. A key issue was the balance between children's autonomy and parental control. While most parents initially supported the idea of children having a choice over sharing their MoodGems recordings, some later expressed concerns. These parents feared children might not share negative experiences, which they would want to be made aware of, and suggested the system should offer an *"illusion of the choice (P7)"* while allowing parents access to all data, as "they are minors (P6, P7)." T1 highlighted a related tension: *"I'm worried about some parents... trying to overcome the system to get to that information."* Therapists pointed out another challenge: balancing the benefits of accessing children's shared emotions and experiences with maintaining children's independence and managing therapists' availability. T2 remarked on needing regulation to ensure children don't expect responses after office hours and the importance of fostering independence, as therapists "are not going to be there forever (T2)". Additionally, the use of MoodGems for expressing both positive and negative emotions raises questions about parental readiness to handle such disclosures. While T5 noted the ease for children to share emotions through the system compared to face-to-face, stating, *"it's much easier with a click. I think that's really good. Exciting"*, they also stressed the importance of preparing parents on how to react to what is shared.

PV.5.5 MoodGems as a Situated Hybrid Artefact

Participants in our study appreciated that MoodGems would be a physical artifact, not a traditional screen-based interface, which they could place on their bedroom wall. C1 expressed a preference for MoodGems over phone-based apps, saying, "*I would definitely rather use this because it's a lot more hands on and it doesn't so much rely on my phone"*. The physical nature of MoodGems, distinct from smartphones or tablets cluttered with multiple applications, was seen as less distracting and more focused. C1 added, *"you get distracted by 101 things, while [MoodGems] is one set thing"*. Participants also viewed MoodGems as a way to reduce screen time. C3 mentioned it could help *"reduce [their] screen time a bit"*, and P4 noted its utility in enforcing screen time rules in a *"hybrid way"*. The modular and portable nature of MoodGems was highlighted, with C3 appreciating the option to *"take it with you in another room"*. Parents, too, found this feature beneficial, with P2 saying *"you can then move around... brush your teeth, tick it off"*. MoodGems was perceived as a piece of digital furniture that could be embedded in homes, fostering feelings of personal ownership. P6 described MoodGems as "*very personal for them... it's more, what's the word? Easier to the eye really, it's a form of decoration"*. This personal connection to MoodGems was seen as beneficial, especially as it was not associated with the constant screen engagement typical of devices like tablets.

PV.6 Discussion

This paper described our first steps in the iterative process of designing MoodGems, a physical situated artefact that aims to be integrated in the home of children with ADHD and their families and to support them in their everyday lives *(RQ1)*. Our study showed that such an artefact has the potential to support the well-being of ADHD children and their families, as it could foster emotional expression for children, allow documentation and navigation of positive and negative experiences, and reflection, both individually and together with their family *(RQ2)*. Additionally, a system like MoodGems could have a positive impact on family dynamics, serving as a conversation starter and improving communication and sense making in the family, while allowing children to feel in control *(RQ2)*. However, we identified several challenges to be navigated in integrating such a system in the homes of families with ADHD children, including around privacy and control. Our expert-based evaluation also uncovered issues that require refinements in the design of the system, before implementation and deployment. In the following sections, we reflect on our findings and explore how they could inform future research in the domain of technologies designed for supporting children with ADHD and their care ecosystem.

PV.6.1 Giving Children with ADHD their “Missing Power”

Our findings highlight the value of integrating technology like MoodGems into children’s home environments, especially for self-expression and reflection. Such technologies could empower children, particularly those with ADHD, by giving them the autonomy to self-express and reflect and by supporting their agency to choose whether to share their recordings. This aspect of control is crucial, as neurodivergent children often feel they lack control in various aspects of their lives. Autonomy refers to the ability to make decisions and act independently [203], without external influence or control [156, 157, 473], while agency refers to the capacity to act and make choices in pursuit of one’s goals, while also acknowledging the social and cultural contexts that shape those choices [26, 200, 644]. They are closely linked to well-being [8, 472, 507] and empowerment [254]. As our findings illustrated, ADHD children’s lives often become dominated by their challenges rather than the choices they can make. This lack of control extends not only to their daily activities but also to the technologies they use, with a strong focus on serious games and technological interventions. Prior research by Spiel et al. [543] criticises how even playful activities for neurodivergent children are often laden with medical or social expectations. Similarly, Stefanidi et al. [550] emphasise the empowerment of children through technologies that allow recording, sharing, and reflection. Our work aligns with this, falling under the category of "empowering experiences" [491], which contrasts with technologies focused solely on addressing symptoms. This suggests that HCI researchers have the potential to support children with ADHD through different forms of empowerment depending on their design choices, whether they focus on addressing symptoms or other aspects, such as fostering reflection and free expression, as empowering experiences.

A critical distinction in this context lies in the concepts of "power-to" versus "power-over" and how they relate not only to empowerment [467] but also to children’s agency [254]. "Power-to" represents the ability to take action [15, 241, 467, 491], while "power-over" pertains to the dynamics between multiple actors [123, 467, 491]. Our findings suggest that ADHD children often lack "power-over" in their lives, adhering to routines and activities from a neurotypical perspective, limiting their autonomy and restricting their agency. This limitation in agency connects to neurodivergent individuals’ interaction with data on a more broad level. In particular, effective data visualisation is essential for sense-making in neurodivergent populations [624, 625]. According to Wu et al. [625], neurodivergent individuals frequently are not aware of the data being collected about them and thus do not utilise it in their daily activities, with decisions often made on their behalf without their input. This scenario illustrates a clear "power-over" disparity, highlighting the necessity for these individuals to gain more control and insight from their data, thereby enhancing their ability to express, reflect, and advocate for themselves. This is in line with the functionalities of MoodGems, hinting at its potential to integrate into the homes of ADHD families to empower them and grant them "power-over" their data and everyday experiences. By enabling ADHD children and their families to actively participate in the data collection and analysis process, MoodGems could facilitate a shift towards more autonomous decision-making, granting them "power-over" in shaping their narratives.

Hence, we propose that **future HCI research should aim to not only empower ADHD children by designing technologies that provide them with "power-to", but also that grant them "power-over"**. We propose that a way to achieve that is by not focusing only on addressing symptoms, while at the same time striving to satisfy and support the needs of multiple stakeholders -both the children *and* their caregivers- and by providing children with the ability to actively make decisions. Those decisions span both including them in the design of technologies and giving them a voice in shaping it, as well as the choice of how to use the technology, by designing technologies that actually include decisions that children get to make when using it. In MoodGems, this manifests by allowing them to choose when to share their activity stemming from the use of the technology and when to keep it for themselves. This approach aims to support the autonomy and agency of children with ADHD by allowing them more control over their lives and choices.

PV.6.2 Integrating Technology into the Child's Home, Routines & Self-concept

A key aspect of MoodGems is its adaptability within the home environment, particularly in children's bedrooms. Its modular design allows for flexibility, enabling it to be moved around the house to suit a child's needs. For instance, children could engage with their emotions privately in their bedrooms or move the sleep tile to the bathroom for bedtime routines. This versatility, where MoodGems could be used in the room relevant to each routine or activity, was highlighted by participants. Additionally, the possibility of future extensions, such as incorporating tasks related to food or school, would allow MoodGems to transition between stationary and portable roles. At the same time, we envision that systems such as MoodGems could go beyond integrating in the physical space, by allowing children to integrate them in their self-concept, empowering them to personalise it to align with their unique needs and interests. Participants suggestions like adding new tiles and choosing colours or stickers underline the significance of customisation for technologies in personal spaces like a child's bedroom. This aligns with research on smart homes and devices [130], particularly for neurodivergent children and families whose needs may vary. Personal and personalised technology has shown effectiveness for individuals with autism [206, 424, 579], often co-morbid with ADHD [13], where control and ownership over personally-gathered information can shape behaviour [164]. Moreover, the study revealed the importance of aesthetics and playful elements in technology for children. MoodGems' visual appeal and its integration as a decorative element could enable children to feel pride in their space, fostering secondary interactions beyond their care ecosystem.

Our findings also suggest that MoodGems could evolve to include connections to other devices, such as smartwatches, to reduce the burden of manual tracking. This aligns with the work by Choe et al. [94], advocating for semi-automated tracking that balances manual and automated capture, and motivation level. However, while automated sensing and tracking of physical aspects such as exercise are increasingly common, the automation of cognitive tracking, including emotions and mental states, is still evolving [490]. Thus, such aspects are usually tracked manually, e.g. through subjective note-taking [495]. While these practices may be burdensome to sustain [94], families encompassing neurodivergent children, such as those with ADHD, are typically accustomed to such manual tracking as it can form a part of their health interventions [315, 361]. These families, particularly those engaging in psycho-social treatments as an alternative to medication, are trained to meticulously observe and record behaviours [99]. This practice of self-reporting and monitoring suggests that transitioning to assistive technologies for tracking could be less burdensome by comparison. A future deployment of the refined version of MoodGems could further investigate these aspects, by exploring the degrees of manual and automated tracking that participants engage in and their perceptions of burden versus benefits they procure. Another consideration is the real-life adoption of devices for automated tracking by children and families. In particular, previous work with ADHD families has shown that automated tracking can have its limitations, due to e.g. the frequency of smartwatch use by children [104]. For instance, Cibrian et al. [104] found that ADHD children usually do not wear the watch at night, e.g. because they find it uncomfortable, which in the case of MoodGems would mean inability to report on aspects of sleep, and they also often do not wear it throughout the day. This highlights the potential benefits of assuming a semi-automated approach to tracking, by allowing all data to be manually recorded in MoodGems *and* affording the possibility for automated tracking in addition, if possible and desired.

Thus, we propose that **future systems designed for ADHD children's homes and routines should consider situated artefacts that offer modularity and portability, facilitating use in various contexts**. Given the significant impact of the environment on ADHD children's behaviour, technologies that can adapt to different settings present a promising direction. Second, we propose that future work in this domain should **aim to design artefacts that increase the sense of ownership for children with ADHD, integrating into their self-concept, by providing extensive customisation in terms of form and ways of (co-)use, including flexibility regarding the tracking**, further granting them the power to make decisions.

PV.6.3 The Role of Therapists in Technologies for (ADHD) Children's Well-being

In our work, we actively involved therapists, recognising their multidimensional roles beyond being children's therapists and design partners. Their involvement addresses the broader needs of neurodivergent individuals and their care ecosystems [550]. Unlike other research that may focus on symptom-focused interventions, we explored technologies driven by neurodivergent interests and everyday experiences in line with previous calls [543, 544, 549]. A key role of therapists identified in our study is in a regulatory and support capacity, as they can play a crucial part in guiding families, especially if technologies like MoodGems are to be used for self-care or in therapeutic settings. For instance, our findings highlighted the need for therapists to advise parents on responding to children's emotional sharing via MoodGems, particularly in dealing with negative emotions and experiences. The need for support and/or monitoring by therapists is also supported by the potential pitfalls associated with reflection on negative experiences such as rumination [152, 398], describing the negative thought and emotion cycles that can result from reflective thoughts [569]. Furthermore, MoodGems' role as a conversation starter places the child in control of when to initiate discussions about their emotions and experiences. This scenario, while beneficial, presents challenges that therapists can help parents understand and navigate.

We also reflect on our work in a context beyond HCI. Despite setting out to design an artefact that supported ADHD children “beyond symptoms”, we found that it could also support children with ADHD-related challenges, e.g. emotion regulation, echoing the findings of Stefanidi et al. [550] in that respect. In particular, therapists in our study recognised the potential use of systems like MoodGems in clinical practice, beyond it being a tool for empowerment and emotional expression to be used at home. This potential underscores the need for careful policy considerations. For instance, the prescription of digital health applications which is already taking place in countries like Germany [166], suggests the evolving role of such systems in medical and therapeutic settings, calling for amendments to existing policies or the development of new ones. Therefore, our research not only contributes to HCI but also has broader implications for policy-making [45], particularly as such systems have the potential to transition to medical or therapeutic devices. We propose that **HCI research should focus on developing a comprehensive knowledge base on designing technologies for children with ADHD and their care ecosystems, extending beyond symptom management to empower ADHD children and their families**. This could precede the finalisation of these policies by appropriate regulatory bodies, likely following clinical research and trials.

PV.6.4 Limitations & Future Work

Our work is subject to certain limitations. We recognise that our limited number of participants, especially of ADHD children, may constrain the extent of our findings. Nevertheless, our sample size is in line with recommendations from seminal work on research methods in HCI with a focus on studies with people with disabilities [322]. We originally planned to involve more children with ADHD in our study, however, engaging vulnerable populations like ADHD children and their families is challenging. Similar challenges in recruiting children with ADHD have been noted in previous studies [533, 549, 606], while still acquiring rich data and deriving important design implications. Given these challenges and the heightened difficulties post-pandemic, as COVID-19 significantly impacted children with ADHD and their families [419], we opted for an online study as a preliminary "proof of concept". This approach aimed to gather initial design insights before developing and deploying the artefact. It is also notable that four out of the eight parent participants in our study chose not to have their children participate. Their reasons varied from wanting to wait for MoodGems to be a fully implemented product (P4), concerns about their child’s young age (P6), or privacy issues (P7, P8). Nevertheless, we were still able to involve 22 participants in our study, and the interviews were very rich in content, allowing us to explore participants’ perceptions about MoodGems in depth, as well as to derive implications for future research.

We also recognise that the nature of the evaluation we conducted, i.e. online, formative, and not over multiple days, may not capture the full experience and interaction of using a physical artefact in the home setting. However, our goal with this study was to gather initial feedback regarding the design and functionality of such an artefact, and this evaluation still allowed us to gather insightful data that verified our proof of concept, and uncovered important refinements that need to be implemented before development and deployment. Additionally, our findings underscore how important it was to first conduct an initial evaluation on a virtual prototype, before using MoodGems in real-world settings. In particular, the identified challenges and tensions regarding privacy that arose based on MoodGems' feature allowing children to choose whether to share their recorded experiences and emotions pose a complex and sensitive issue, that could directly impact the well-being of families. In more detail, this is an issue that is particularly difficult to navigate to both ensure children's safety on the one hand, and autonomy and agency on the other. By engaging with the virtual prototype, without having any real-life repercussions that would arise from a field deployment, we were able to gauge some parents' concerns and viewpoints regarding this feature, that might have been more difficult to voice in a real-world setting. This directly connects to the aspect of flexibility and personalisation discussed in section PV.6.2, about how users should be able to use the system in a way that maintains their well-being, e.g. the system could allow families to choose whether this sharing would be automatic or not, after a discussion between the children and their parents.

Thus, our future work includes addressing the issues that we uncovered through our formative evaluation and subsequently deploying MoodGems in the homes of families with ADHD children to conduct an in-situ evaluation. Finally, we plan to explore different ways to engage the care ecosystem not just as feedback providers for children's logged data, but as active tracking members themselves.

PV.7 Conclusion

In this paper, we introduced our prototype for MoodGems, a set of physical hexagonal displays for children with ADHD to record and share their experiences and emotions. Our online formative evaluation of a virtual representation of MoodGems with 22 participants, including ADHD children, parents, therapists, and HCI experts, demonstrated its potential in promoting reflection, communication, and autonomy. The study also highlighted the benefits of modular, portable systems over traditional screens, and the importance of customisation in enhancing control and ownership for children. Based on our findings, we advocate for technologies that engage both children with ADHD and their caregivers, empowering children to make decisions and control their interaction with technology. We discussed the critical role of therapists in supporting the use of such systems and the need for appropriate policy regulations. We also reflected on the challenges that are associated with integrating such systems in the homes of children with ADHD. Future work will focus on refining MoodGems for physical deployment in situ, with ADHD families. We hope that our work inspires future HCI research in technologies that support the well-being of children with ADHD and their families both at home and beyond.

PV.8 Selection and Participation of Children

The study and its protocol were approved by the Ethics Committee of the University of St. Gallen (HSG-EC-20230406). Children participants were recruited together with their parents using Prolific. The study was explained to the children's legal guardians, who gave their informed consent for inclusion before participation, as well as to the children, who were asked for their verbal assent to participate. They were informed that they could stop and opt out of the study at any point and for any reason, and their data would be excluded, without any negative consequences. A total of four children with ADHD took part in the study (two female, two male, aged 9-14 years old). All participants' personal data were stored securely, and all personally identifiable data were removed.

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PUBLICATION P VI

Supporting Communication and Well-being with a Multi-Stakeholder Mobile App: Lessons Learned from A Field Study with ADHD Children and their Caregivers

The contents of this chapter are under submission at the 27th ACM Conference on Computer-Supported Cooperative Work and Social Computing (CSCW) 2024 as: **Evropi Stefanidi**, Nadine Wagener, Ioannis Chatzakis, Paweł W. Woźniak, Stavroula Ntoa, George Margetis, Yvonne Rogers and Jasmin Niess. “Supporting Communication and Well-being with a Multi– Stakeholder Mobile App: Lessons Learned from A Field Study with ADHD Children and their Caregivers”.

Abstract

Children with attention deficit hyperactivity disorder (ADHD) and their caregivers face daily challenges, especially regarding communication within their care ecosystems, comprising family, friends, educators, and therapists. Communication barriers can adversely affect the well-being of both ADHD children and their care ecosystem. To foster communication among children and their care ecosystem and support their well-being, we designed REMEMO. REMEMO is a mobile app that was iteratively designed and evaluated by actively involving ADHD children and their caregivers. REMEMO supports both individual and collaborative use, offering tailored features for different user groups: children, parents, or therapists and educators. Its primary function is to enable users to record their experiences and emotions, and choose whether to share these with other members of the care ecosystem. We deployed REMEMO in a multi-week field study with five groups encompassing ADHD children (total participants $n = 18$). The groups varied in their composition, similar to how children's care ecosystems are comprised of different members. Our analysis showed that REMEMO can support emotional expression, regulation, reflection, and transparent and affectionate communication, addressing needs of both ADHD children and their caregivers. Our findings also highlight the critical role of mutual understanding regarding technology use and contextual challenges in shaping usage patterns. We discuss opportunities and challenges in designing technologies that cater to the varying needs of different stakeholders of ADHD children's care ecosystems, and engage in critical reflection regarding evaluating technologies with vulnerable populations, such as families of ADHD children.

Contributions

This paper contributes the following. First, the iterative design, development, and evaluation of REMEMO, a multi-stakeholder mobile application that allows both individual and collaborative use by ADHD children and their care ecosystems. Second, it offers insights from a multi-week field study with five groups consisting of children with ADHD and their parents, as well as their siblings and therapists in some cases. Those range from the topics of how such systems can support emotional expression, reflection, and communication, to therapeutic practices and interactions, and to the roles of mutual understanding, trust, and background and contextual challenges for technology use and uptake. Finally, it derives implications for future studies with vulnerable populations, such as ADHD children and their care ecosystems, and for the design of technologies that seek to cater to the varying needs of these diverse stakeholders.

PVI.1 Introduction

Communication and mutual understanding are vital components of healthy interpersonal relationships and well-being, particularly in the context of children's care ecosystems [62, 208, 376, 557, 627]. These ecosystems, encompassing all the people involved in children's everyday experiences such as family, friends, teachers, and potential therapists [549], play a pivotal role in shaping a children's life, as they can offer motivational and emotional scaffolding and strongly influence quality of life, social activity, and success in school environments [105, 227, 427]. Especially for neurodivergent children, such as those with attention deficit hyperactivity disorder (ADHD), transparent communication and shared understanding between all members of their care ecosystem is of particular importance [456, 550]. ADHD is recognised as the most common neurodevelopmental condition in children [125, 470, 639], and those with ADHD may exhibit variations in attention, activity level, and impulse control when compared to peers of the same age [110]. As a result, families of ADHD children often have added stress and family frustrations [565], which is often underscored by ADHD's high heritability [162], making it likely that parents of ADHD children need to regulate themselves besides supporting the regulation of their children. This can become particularly challenging since ADHD individuals often struggle with self-regulation and with emotion-regulation [35, 452, 514].

Children with ADHD frequently encounter communication barriers within their care ecosystems [456, 550], due to the fact that they are often confronted with additional challenges and stress compared to families with neurotypical children [565]. For instance, they require time and strategies for care coordination [456]. Difficulties in emotion regulation can hinder children's ability to express and share their feelings, potentially affecting their peer relationships and communication with caregivers [85, 159, 307, 309]. Additionally, discrepancies in approaches and motivations between families and therapists can result in unclear goals and a lack of shared understanding [456, 550], which can further complicate care coordination and lead to negative outcomes for both children with ADHD and their care ecosystem [550]. Therefore, it is important to design solutions that help bridge these communication gaps, as enhancing communication within the care ecosystem can lead to clearer goals for children and mutual understanding within the care ecosystem [456, 550]. This approach, as indicated by previous research, empowers the children, fosters their sense of being understood, and supports their independence [550].

Communication, information sharing, and tracking as keys for family relationships and well-being are a recurring theme in family informatics research [389, 399, 400, 430, 455, 516, 628]. Moreover, work in the fields of Computer-Supported Collaborative Work (CSCW) and Human-Computer Interaction (HCI) has increasingly researched family care coordination. Studies in this area include exploring the role of collaborative technology in enhancing family care and resilience during children's hospitalisation and augmenting social support in caregiving teams [399, 400]. Other research has investigated how letting caregivers decide when to share health and mood data about the person they are caring for with other caregivers can impact communication, with positive results on caregivers' emotional well-being [628]. Beyond clinical settings, past research sought to support children with ADHD and their families by introducing new technologies, such as goal tracking and rewards via smartwatches for self- and co-regulation [523]. Silva et al. [523] identified the need for technologies to allow for both individual and collaborative joint use by ADHD children and their families, to allow for co-regulation and for children's independence. Our work builds on prior research that seeks to support ADHD children and their caregivers beyond (only) clinical settings [523, 550]. In particular, we explore how to design technologies that support the communication and well-being of ADHD children and their care ecosystem across different contexts (e.g. home, therapy, school).

Concurrently, recent works have highlighted the need to design with neurodivergent interests in mind [543, 544, 550]. While the development of such technologies remains underexplored, past work suggests ways in which technologies could both be desirable for children and support the broader care ecosystem by addressing some common difficulties. For instance, they argue for the active involvement of neurodivergent children and their care ecosystems throughout the design, development, and evaluation phases of technologies [549]. Therefore, while their involvement can lead to particular challenges that require participatory methods to be adapted [181], researchers have successfully involved both neurotypical and neurodivergent children towards meaningful design processes [325, 550]. Additionally, these works argue for designing technologies that do not solely focus on symptoms but incorporate ludic aspects [543, 549, 550], and for developing systems that can be used by neurodivergent children together with their care ecosystem [550]. However, the practical integration of such technologies in real-life contexts remains a question. This includes their adoption and use not only by children with ADHD and their families but also by their broader network of caregivers, including therapists. Research in this area could provide unique insights on how such multi-stakeholder technologies are used, and on their impact on communication practices and the well-being of both ADHD children and their care ecosystem. Therefore, in this work, we seek to answer the following research questions (RQs):

> **(RQ1):** How can we design technologies for ADHD children and their care ecosystems, which cater to their varying needs and interests, and provide both individual and collaborative use and support?
>
> **(RQ2):** How does the integration of a multi-stakeholder digital tool within the care ecosystem of ADHD children affect their communication, everyday interactions, and overall well-being?

Based on prior conceptual work by Stefanidi et al. [550] and design implications by Silva et al. [523], we iteratively designed, evaluated, and developed REMEMO, a multi-stakeholder mobile and tablet application, actively involving ADHD children and their care ecosystem throughout the process. Its multi-stakeholder nature lies within the ability of children and the different members of their care ecosystem to use it, as REMEMO's interface adapts, providing a tailored user interface based on whether the user is a child, a parent, and a therapist or educator. REMEMO allows to create entries in the system ("posts"), which can be kept private or shared with others. Users can view their previous posts and revisit them by providing feedback on them, as well as see and react to the posts that other members of the care ecosystem share with them in the system. We deployed REMEMO in a field study, with five groups encompassing

ADHD children (total number of participants $n = 18$, from which seven were children). The groups varied in their composition, similar to how children's care ecosystems are comprised of different members in real life. The groups used REMEMO between four and six weeks (shortest 31 days, longest 44 days). In this work, we report on our findings stemming from the app's deployment.

Our findings showcase different usage patterns of REMEMO both between groups, as well as among the various participants. Our analysis shows that by enabling free expression of experiences and emotions and autonomous sharing within their care ecosystem, REMEMO can support ADHD children and their caregivers, while being perceived as fun. In particular, it allows children and parents to identify, express, and share their emotions, and can support emotion regulation and reflection, as well as transparent, affectionate, and calm communication among children, their parents, and their therapists. Additionally, we found that REMEMO can strengthen relationships between children and their parents as well as their therapists. Moreover, our study revealed ways in which the app was used in the context of therapeutic practices, further highlighting the different usage patterns of REMEMO that we identified. Our findings also show how mutual understanding and trust regarding the expected use of the app among children and their care ecosystem plays a crucial role for how they use the app, and present how contextual and personal challenges within the groups led to very different frequencies in use. We discuss how multi-stakeholder technologies can be used both individually and collaboratively, empowering users to make their own choices regarding technology use, while catering to different needs. We then engage in critical reflection about evaluating technologies with vulnerable populations, such as ADHD children and their families, especially in the context of longitudinal studies.

Therefore, this work delivers the following contributions:

- The design and implementation of a multi-stakeholder mobile and tablet app, that can be used both individually and collaboratively by both ADHD children and their care ecosystems, which is tailored to their specific needs and interests, and was iteratively designed together with them.
- Lessons learned from an over one month field deployment in real life contexts with five groups consisting of children with ADHD and their parents, as well as their siblings and therapists in some cases.
- Insights for field studies with vulnerable populations and for the design of technologies that seek to cater to the varying needs of ADHD children and their care ecosystem.

PVI.2 Background & Related Work

This section presents relevant background and previous work on technologies designed for children with ADHD and their care ecosystem. We then engage with prior literature in family informatics, particularly with a focus on technologies that aim to support family reflection and health challenges. Following that, we discuss technologies that focus on family interactions and communication in general.

PVI.2.1 Technological Support for ADHD Children and their Care Ecosystem

Various interactive technologies have been designed aiming to support children with ADHD and their care ecosystem by addressing ADHD-related challenges, including mobile and tablet applications [428, 523, 536], smartwatches and wearables [106, 137, 523], and tangible systems [532, 606, 645, 647]. The majority of related work in this field has focused on supporting either children with ADHD, or ADHD children together with their family. Regarding the first, ChillFish [532, 535] is a tangible respiration game aiming to help children with ADHD stay focused during breathing exercises by combining them with a video game. As another example, TangiPlan [606, 645, 647] is a system of tangible connected objects, representing tasks to be performed and providing assistance in daily activities by structuring ADHD children's activities, with the overall goal to improve their executive functioning.

Prominent examples of technologies supporting children with ADHD and their families include ParentGuardian [428], a mobile and tablet system that monitors the stress of parents of children with ADHD, to deliver reminders of behavioural strategies to follow. In particular, it includes both "heat of the moment" strategies, for moments of duress, as well as reflective strategies, which can be practised at any time. On a similar note, focusing on morning and bedtime routines, MOBERO [536] is a smartphone-based system that seeks to support families in establishing healthy routines, aiming to assist children with ADHD in becoming independent and lowering parents' frustration levels. While the above systems focused specifically on the home context, CoolTaco [523] is a smartwatch and smartphone system that aims to support ADHD children and their families to collaborate in creating tasks, gain points for achieving them, and allow children to redeem rewards. Due to its inherent portable nature, it enables them to self- and co-regulate across multiple contexts (e.g. at school and at home). The above systems were all evaluated with their end users, i.e. ADHD children and their families, and were found to have positive effects on the ADHD-related aspects that they sought to address, e.g. improved organisation and time management [647], fewer conflicts with parents [647], and help with providing pervasive regulation support to children [523].

However, none of the already designed and developed technologies so far allow both individual and collaborative use, of not just ADHD children and their families, but also their therapists and educators. Moreover, despite the growing discourse advocating for the design of technologies that extend beyond solely addressing ADHD-related challenges [543, 544, 549], there remains a need for further exploration in developing technological artefacts that also cater to neurodivergent interests. Additionally, the impact of embedding such technologies with ADHD children and their care ecosystems in real life contexts has yet to be studied. Our work aims to address the aforementioned gaps.

PVI.2.2 Family Informatics

Family informatics research extends personal informatics research into the domain of families, exploring technologies around how families manage and track their health with technology [430]. In particular, Pina et al. [430] emphasised the collaborative and interconnected nature of health management among family members and how families adopt different tracking strategies when dealing with a chronic health condition – which is also highly relevant for families with children with ADHD.

Thus, there is a growing body of work focused on tracking and reflecting on family health data and, more broadly, supporting family health. For instance, research has explored how collaborative technologies can enhance or support family care coordination. In particular, Nikkhah et al.[399] explored how collaborative technology could augment family care collaboration and family resilience during children's hospitalisation [399], by looking into augmenting social support in caregiving teams [400]. They highlight how, especially in times of family crisis when communication between caregivers is often remote, such as in the case of children's hospitalisation, technology designs should be customisable and adaptable to accommodate different caregiver needs. Additionally, this remote setting deems emotional support of the caregivers particularly important; therefore, they propose that technologies should help increase connection, intimacy and provide shared experiences. Furthermore, Richards et al. [455] described how family care coordination depends on the ability to develop a shared understanding of care goals and progress, identifying barriers to it: differences in approaches and motivations, inability to rely on documentation, and information loss during transfer across the care team. They proposed building relationships across boundaries and communicating actionable information as mechanisms to overcome these barriers. Yamashita et al. [628] investigated how sharing data that caregivers track about the care recipient, such as journals, with other family caregivers, affects home care and family communication. For instance, they found that allowing caregivers to choose when to share tracked data about the health and mood of the care recipient with other family caregivers positively impacted the caregivers' emotional well-being [628]. On another note, aiming to explore how interventions can protect children from developing mental health disorders, Slovak et al. [526] examined the potential of technology to support or enhance such interventions, particularly focusing on emotion regulation. Through interviews, design workshops, and a technology probe field deployment, they show how technology-based, child-led, situated interventions, could empower children and parents, through actionable support directly within their family life. These works highlight both the importance of actively involving both children and their families in the design of supportive technologies and the significance of empowerment, whether through child-led interventions or by providing users with adaptability and choice in their use of technology. Our work builds upon these efforts by engaging multiple stakeholders in REMEMO's design, with the goal of enhancing the well-being of children with ADHD and their care ecosystem.

Another key aspect of family informatics research is reflection. Reflection is the process of introspection where individuals review and analyse their thoughts, emotions, and behaviours [210]. It can benefit well-being [341] and empathy, defined as *"the ability to share someone else's feelings or experiences by imagining what it would be like to be in that person's situation"* (Cambridge Dictionary). As such, an increasing number of researchers have been exploring technology-mediated reflection and how to design for it [42, 44, 257]. Particularly regarding shared reflection of family members, dashboards have commonly been used to facilitate it, by allowing visualisation of data in families [429, 479, 480, 485]. Of particular relevance for our research are prior works that actively involved not only parents/caregivers, but also children in the tracking process, and deployed their artefacts in the field with families. For instance, Pina et al. [429] developed Dreamcatcher, a system that combined data from wrist-worn sleep sensors and self-reported mood of families using a shared tablet display. By deploying it as a study probe with ten families between 15 and 50 days, they found that this approach allowed families to view and reflect on each other's sleep data, showing how collaboration within the family is supported by the children's active engagement in the process. They noted, however, that adults did not always wish to share their sleep-related data with other family members. Another example focusing on collaborative reflection is the work by Saksono et al. [480], who deployed Spaceship Launch in a 3-week field study with 13 lower-income families. The system employed a shared interface for parents and children to monitor each other's physical activity data, using exergames to promote physical activity. Among others, their findings show how such technologies can represent mutual quality time activities, in this case exercise, for families, which could help them form stronger bonds.

These systems [429, 480] are designed to deepen the family's insights regarding health-related behaviours, using information collected from fitness trackers. Previous research has shown that shared experiences facilitated by such technologies are beneficial for learning, jointly reflecting on behaviours, and making decisions to improve the family's overall health and well-being. [112, 410] However, they usually need both family members to use them simultaneously and might not provide much support when family members are apart [523]. Aiming to address this last aspect, and focusing on ADHD families, Silva et al. [523] deployed CoolTaco, a system that allows ADHD children, using a smartwatch app, and their parents, using a mobile app, to collaborate in creating tasks, gain points for completing them, and redeeming rewards. Their main goal was to support both self- and co-regulation flexibly, for multiple goals and across different contexts. They deployed CoolTaco with ten families of ADHD children for 3 weeks to over 6 months (average 3 months). Their findings demonstrate how such a multi-device system can support children's reflection and self-regulation autonomously. Children can receive co-regulation support even when parents are not present. However, the study also highlights tensions in children's autonomy, as it could be diminished by high dependency on parents for specific parts of using the system, such as the rewards functionality. The studies showcased in this section underline not only the benefits of both children and their families being actively involved in tracking and managing their (health) data, including family-level reflection and collaboration, but also how future systems should allow adaptable degrees of independent and collaborative use, to fit diverse family needs.

Drawing from related research, our work encompasses the design, development, and deployment of a mobile app that incorporates family informatics in both home and therapy settings. Tailored for families of ADHD children and their professional caregivers, we envision that the app serves as a flexible tool for parents, children (at home and beyond), as well as therapists and educators. With the design of REMEMO, we aim to address gaps identified in previous work by facilitating both independent and collaborative usage, and by providing assistance for individual and collaborative reflection.

PVI.2.3 Technologies Supporting Family Interactions & Communication

In addition to technologies that support family health management, tracking, and reflection, another strand of research relevant to our work are technologies that aim to support family interactions and communication. Shin et al. [516] researched this topic by reviewing how technologies can better support parent-child relationships and analysing challenges and facilitators in designing CSCW systems that achieve that. They identified that one of the common challenges that technologies should address in that respect is discrepancies in expected communication between parents and children. They found that technologies facilitating the reinforcement of transparency, affection, and trust, as well as enjoyable and age-appropriate shared content among parents and children, could help in addressing this challenge. Particularly important in the context of our work are their findings that parents and children often had difficulties with what to communicate, proposing that allowing family members to create shared memories by sharing events and experiences could satisfy the family's need to learn about each other's activities. This links directly to one of REMEMO's key functionalities, i.e. allowing ADHD children and their families to create entries in the system about their experiences and emotions, with the additional individual choice of whether to keep it private or share it with others.

Research in CSCW and HCI has explored the potential of interactive systems for recording and sharing personal experiences in daily life [40, 272, 374, 423, 554, 610]. These studies have collectively revealed that the exchange of family experiences and memories plays a vital role in fostering a sense of unity within families and in prompting discussions, as systems initiate conversation topics [272, 374]. However, while these studies have yielded design principles for digital memories in familial settings, the focus has predominantly been on enabling parents to document their children's lives, often with minimal participation from children in family communication. The aspect of utilising these recorded memories as conversation starters from the perspective of children remains largely unexplored. We aim to address this gap, by allowing both children and their care ecosystem to log their experiences and choose whether to share with other members of their care ecosystem. Shin et al. [516] additionally showed that conversation triggers can be effective facilitators for parent-child relationships through technology. They suggested that future work should explore technology-mediated opportunities to reflect on family memories. Therefore, our work also connects to this aspect, aiming to investigate this under-explored topic. We explore how a system that enables logging, sharing, and reflecting on shared content with the family and the broader care ecosystem, can impact communication and relationship building.

A number of CSCW studies around families have particularly focused on supporting family communication in remote settings, with the majority of existing literature in that area focusing on supporting intergenerational communication and relationships. For instance, Butzer et al.'s [73] developed Grandtotem, an asynchronous communication device that aims to support intergenerational relationships between grandparents and their adult grandchildren studying abroad. It allows sharing images, viewing them as a gallery, and sending video messages. Binda et al. [48] designed PhamilyHealth, a web-based photo-sharing system that allows family members to share health-related photos. Its goal is to encourage sustainable and healthy lifestyles throughout the family. While both of these systems show potential in supporting intergenerational relationships and communication, it remains to be explored how those systems would impact families through field studies. Other studies have evaluated their proposed systems either through crossectional studies or by integrating their systems with families in field deployments to explore long-term effects. For example, Stefanidi et al. [547] designed MagiBricks, a smart toy brick system that provides feedback on users' actions, to foster connectedness between grandparents and grandchildren playing in distributed settings. By evaluating it with six grandparent-grandchild pairs, they found that the system could increase their communication and interactions while playing, as well as their perceptions of connectedness, compared to the pairs interacting with a regular but identical set of toy bricks. Ambe et al. [10] deployed the Messaging Kettle, an augmented kettle that included sensing and messaging capabilities, with four pairs of mothers and adult daughters for a period that lasted between two months to more than two years. Among other findings, Ambe et al. [10] show how such a technology can nurture relationships at a distance, by sharing feelings of everyday togetherness despite being physically apart. Going beyond information exchange, other works have sought to augment family activities, e.g. by investigating shared activities. For example, Chowdhury et al. [97] proposed designing for intergenerational distributed co-listening of music, as current technologies do not support collaborative music listening and conversation. While we do not focus on remote settings, our work builds on previous research that seeks to support family communication and interactions, and extends it; first, by expanding the involved stakeholders by including ADHD children's care ecosystem research, and actively including children themselves; second, by exploring how our proposed system can support family interactions and communication across contexts. Our work is interestingly different from past efforts as we provide ADHD children and their care ecosystem with a system that they can use both individually and collaboratively, and where the collaboration can happen both when being physically present, e.g. interacting with the app together, as well as physically apart, e.g. sharing posts to each other while not being physically together.

PVI.3 Iterative Design

As a first step in the process of examining our research questions, we set out to design REMEMO, by following an iterative approach that actively involved ADHD children and their care ecosystem. Figure PVI.1 shows the process we followed for designing REMEMO. The following subsections describe this process in detail, from the design requirements elicitation, to the finalised design of the application, which was subsequently implemented.

PVI.3.1 Design Requirements & Initial Prototypes of REMEMO

Based on Stefanidi et al.'s [550] co-design and interviews research with ADHD children and their care ecosystem, we compiled a list of initial design requirements. This prior work uncovered opportunities for simple and accessible technologies, such as mobile applications, that allow expression and reflection to empower children with ADHD and their care ecosystem and to remove communication barriers toward improving their overall well-being. Stefanidi

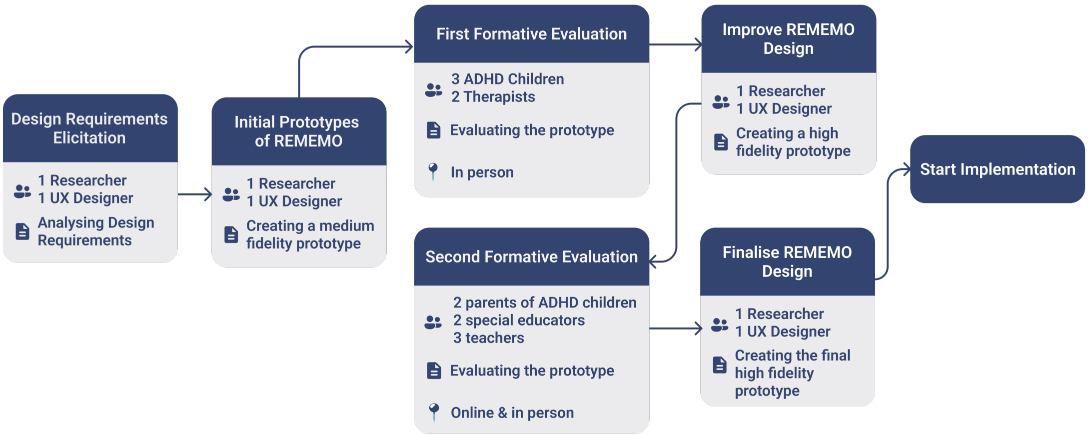


Fig. PVI.1 Visualisation of the iterative design processes we followed for REMEMO.

et al. [550] particularly identified emotional expression as a key aspect that is both driven by children's interests and is considered crucial by their caregivers, as it could foster empathy and even support emotion-regulation [550], which is an aspect that children with ADHD often struggle with [35, 386, 514].

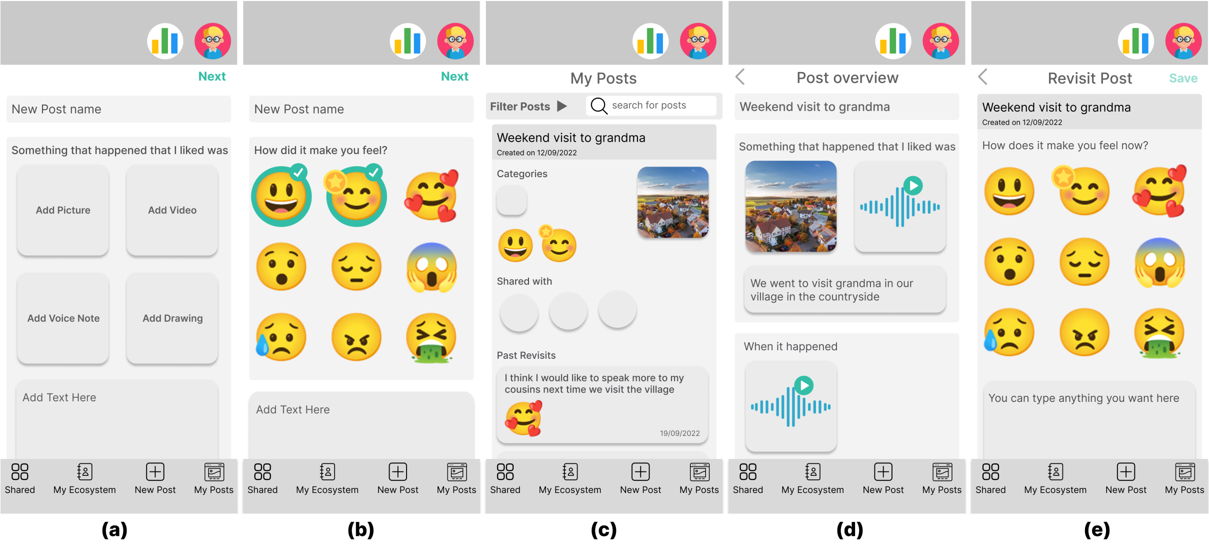
Firstly, an overarching requirement, was that the app should be tailored to the needs and interests of the different ecosystem stakeholders. This implies that, depending on the stakeholder, the app might present different user interface (UI) elements or functionalities, while still enabling them to connect with each other through the app and use it collaboratively. Therefore, based on the above, we initially started the design process for the children's and therapist's UIs. The complete list of elicited design requirements can be found in the supplementary material. Three examples that illustrate the identified requirements are listed below:

- **[child UI]:** The app should allow users to log positive experiences in the form of storytelling posts.
- **[therapist UI]:** The app should allow users to record posts about their interactions with a child.
- **[both UIs]:** Users should be able to choose whether to keep the posts for themselves or share them with other members of the ecosystem.

Based on the above, the first design for the children's and therapists' UI was designed together by the lead researcher and a UX designer. Figure PVI.2 presents some examples of this first iteration for the children's UI, and Figure PVI.3 for the therapists' UI.

PVI.3.2 First Formative Evaluation & Design Improvements

In order to evaluate the first version of REMEMO for children and therapists, we first conducted a formative evaluation with three children with ADHD (one 10-year-old-girl with ADHD, one 10-year-old-girl with ADHD and high-functioning autism, and one 9-year-old boy with ADHD and high-functioning autism), and two of their therapists. All studies of this paper received prior



Weekend visit to grandma
Created on 12/09/2022

I think I would like to speak more to my cousins next time we visit the village
19/09/2022

Weekend visit to grandma
Something that happened that I liked was
We went to visit grandma in our village in the countryside

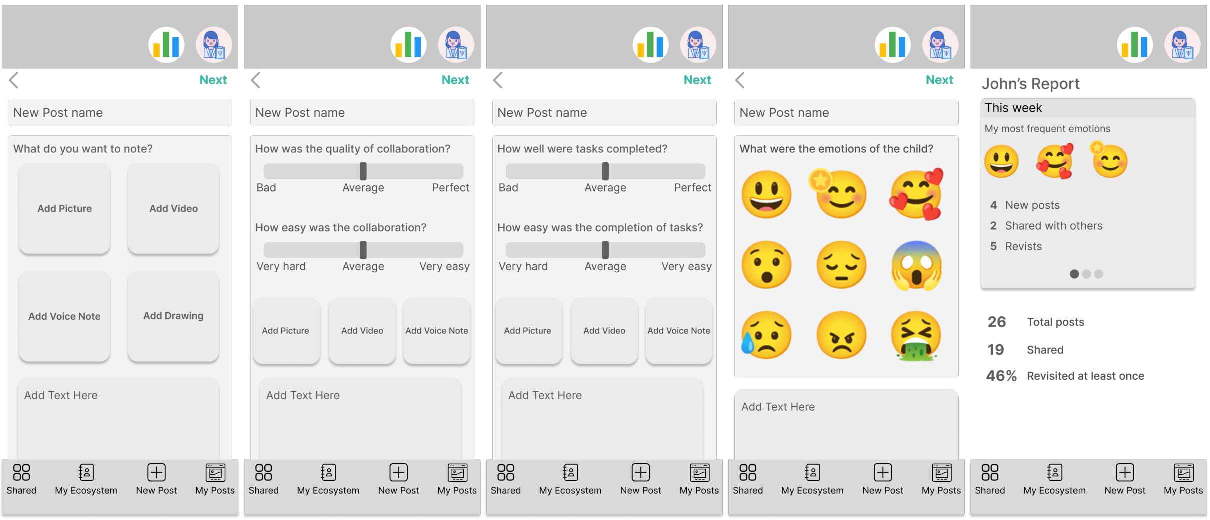
Weekend visit to grandma
Created on 12/09/2022

Fig. PVI.2 Example screens from the first iteration for the children's UI (medium fidelity mock ups). a) Post creation first question "Something that happened that I liked was", being able to add pictures, videos, voice notes, drawing, and/or text. b) Post creation question about emotions: "How did it make you feel?" with one or more emojis and/or text, c) Viewing "My Posts", d) Viewing details on the own post of a user, e) Revisiting a post, by answering "How does it make you feel now" with one or more emojis and/or text.

ethics approval by the Ethics Committee of the University of St. Gallen (HSG-EC-20230406). Participants were recruited by contacting ADHD professionals and treatment centres and through snowball sampling. All adult participants provided informed consent about their own and their children's participation prior to beginning the study. Additionally, children provided their assent for participation. Children received a small board game as a thank you at the end of their participation. The evaluations for the two groups (children and therapists) were conducted separately, at the therapist centre where the two participating therapists worked during the children's regular visit to the centre. One of the therapists was present while the evaluation with the three children took place.

The three children participated together in the evaluation, sharing two smartphones between the three of them, each one having an interactive prototype of REMEMO loaded. This allowed them to both interact with the app individually, and collaboratively when sharing the phone with one of the other children. The two therapists participated separately, using one smartphone at a time. In both cases, the study began by the lead researcher explaining the study and its purpose, and asking if there are any questions. For the main part of the study, participants were given a scenario, which was read aloud step by step by the lead researcher, and were asked to interact with the prototype to complete the steps. Following that, participants were able to interact with the app freely if they wished. At the end, short interviews were conducted, inquiring about participants' experiences and feedback regarding the app, its design, and functionality. The scenarios and the interview protocol (one for the children, one for the therapists) can be found in the supplementary material.

The participants' interactions with the smartphones were screen and audio recorded, and the interviews were audio recorded, for later transcription and analysis. The lead researcher



New Post name

What do you want to note?

New Post name

How was the quality of collaboration?

How easy was the collaboration?

New Post name

How well were tasks completed?

How easy was the completion of tasks?

New Post name

What were the emotions of the child?

John's Report

This week

My most frequent emotions

4 New posts

2 Shared with others

5 Revists

26 Total posts

19 Shared

46% Revisited at least once

(a) (b) (c) (d) (e)

Fig. PVI.3 Example screens from the first iteration for the therapists' UI (medium fidelity mock ups). a) Post creation for therapists, being able to add pictures, videos, voice notes, drawing, and/or text. b) Filling out questions about collaboration with the child with the previous media choices as well as sliders, c) Filling out questions about task completion by the child with the previous media choices as well as sliders, d) Answering "What were the emotions of the child?" with one or more emojis and/or text, e) Profile page of the child with statistics about their use of the app.

transcribed the recordings and analysed them together with the UX researcher. The analysis led to an enhanced list of design requirements and considerations.

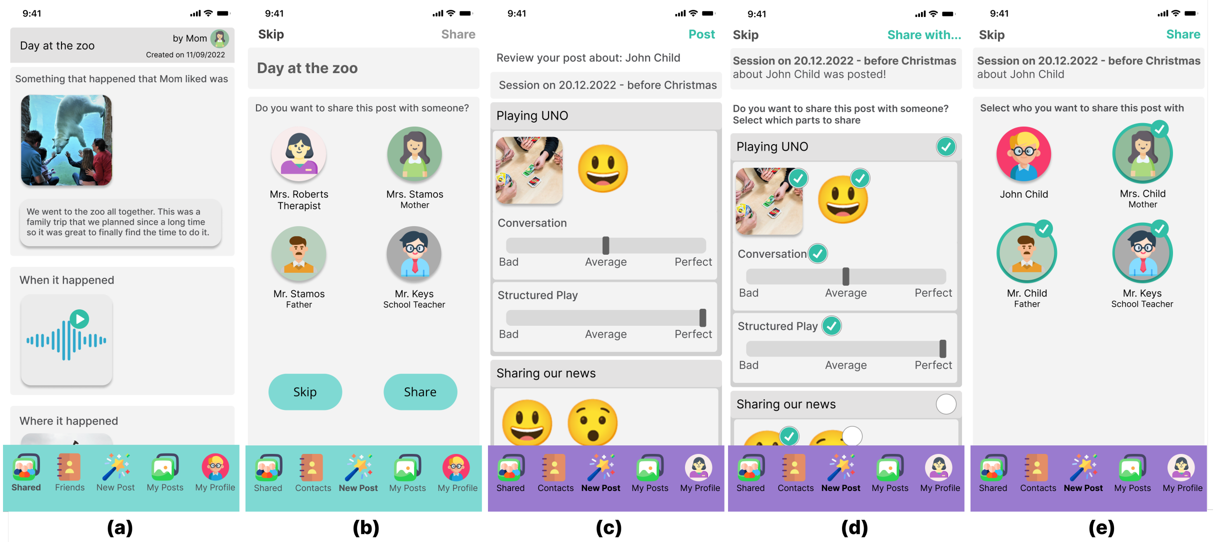
The complete list of elicited design requirements from this phase can be found in the supplementary material. Two examples that illustrate the identified requirements are listed below. The changes required to the children's UI based on this phase were minimal, while the therapists' UI required significant changes.

- **[child UI]:** The Next and Back buttons should be more prominent, and especially for younger children, they should be able to find those buttons both at the top and bottom of the screen.
- **[therapist UI]:** The therapist-user should be able to select exactly which parts of the post they want to share with others. They should even be able to remove specific aspects of their post before sharing e.g. their logging of their own emotions.

Based on the insights of the first formative evaluation, the design of REMEMO was refined. Figure PVI.4 shows some sample screens of the refined medium fidelity prototype.

PVI.3.3 Second Formative Evaluation & Final Design

Following the refinement of REMEMO's design, we conducted a second formative evaluation including parents, special educators, and teachers of ADHD children, to complement the knowledge we had acquired based on the first formative evaluation. In particular, we conducted evaluation sessions with two parents of ADHD children (online), two special educators (online), and three school teachers (in person). Participants were recruited using the authors'



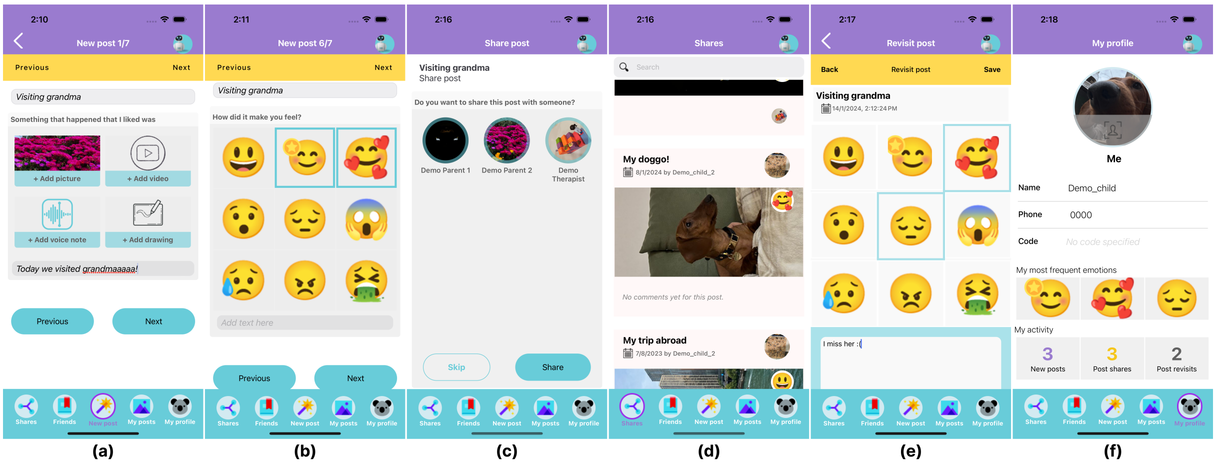
We went to the zoo all together. This was a family trip that we planned since a long time so it was great to finally find the time to do it.

Fig. PVI.4 Example screens from the second iteration for the children's UI (first 2 screens), and the therapists' UI (last 3 screens), based on the first formative evaluation. a) Details on the post that someone shared with the child, b) Choosing whether to share the post with a member of the care ecosystem, c) Reviewing post (updated contents) before posting it, d) Selecting which aspects of the post to share, e) Selecting members of the care ecosystem to share the post.

extended social network and snowball sampling. Participants gave their written informed consent to participate prior to the study. Given the first formative evaluation and prior work, we hypothesised that parents might wish for their UI to highly resemble that of the children, with some additional functionality, while (special) educators would prefer having the functionality available through the therapist's UI at their disposal. The evaluation sessions described below confirmed this assumption.

In particular, in both online and in-person sessions, participants had the chance to interact with an interactive prototype of the children's UI. For the online sessions, participants were provided with a link to access the interactive prototype, while in the in-person sessions, the experimenter gave participants access to a smartphone that had the prototype loaded. We purposefully did not show the therapists' UI, to avoid biasing participants, but rather inquired about the various functionalities that were available through the therapists' UI later, in the interviews. Regarding the process, first, the experimenter introduced the study and briefly presented the work that had been done so far, explaining the overall concept, and the functionality that the children and therapists' UI provided. Similar to the first formative evaluation, participants were provided with an interaction scenario, and were asked to interact with the prototype of the children's UI to complete the steps. Following that, participants were able to interact with the app freely if they wished. At the end, short interviews were conducted, inquiring about participants' experiences and feedback regarding the app, its design, and functionality. The scenarios and the interview protocol can be found in the supplementary material.

The participants' interactions with the smartphones were screen and audio-recorded, and the interviews were audio-recorded, for later transcription and analysis. The lead researcher transcribed the recordings and analysed them together with the UX researcher. The analysis



(a)
Visiting grandma
Something that happened that I liked was
Today we visited grandmaaaaa!

(b)
Visiting grandma
How did it make you feel?
Add text here

(c)
Visiting grandma
Share post
Do you want to share this post with someone?

(d)
My doggo!
8/1/2024 by Demo_child_2
No comments yet for this post.
My trip abroad
7/8/2023 by Demo_child_2

(e)
Visiting grandma
14/1/2024, 2:12:24 PM
I miss her :(

(f)
Name Demo_child
Phone 0000
Code No code specified
My most frequent emotions
My activity
3 New posts
3 Post shares
2 Post revisits

Fig. PVI.5 Example screens from the final design of REMEMO for children. a) Different media options for completing the system's prompt "Something that happened that I liked was" including images, videos, voice recording, drawing and text, b) Emoji and text options to answer the question "How did it make you feel?", c) Sharing options for the post, d) Posts that have been shared with the child, e) Revisiting a post by adding both text and emojis, f) The child's own profile.

of the evaluation sessions confirmed our assumption and resulted in three versions of the UI for REMEMO: one for children, one for parents (same basis as for the children, but with the additional functionality described in the next session), and one for therapists and (special) educators. The next section describes the final prototype and each of those three versions of REMEMO in detail.

PVI.4 REMEMO

Based on our iterative design process described in Section PVI.3, the final high-fidelity designs of REMEMO were created, and used for implementing the system. We implemented REMEMO to be a mobile and tablet app, making it accessible to families with different devices at their disposal. REMEMO allows children and parents to log their experiences and emotions, reflect on them, and choose whether to share them with members of their care ecosystem. We strove to allow for both individual and collaborative use of the app, so that while REMEMO can be used collaboratively, users are not dependent on others to be able to use it, fostering independence and collaboration at the same time [523]. Below, we describe each of the three UI adaptations that REMEMO offers: the UI for children, for parents, and for therapists/educators. Videos demonstrating the use of the app from each of the three adaptations are available in the supplementary material.

PVI.4.1 REMEMO for Children

REMEMO affords children five key functionalities, to which they can navigate using the navigation bar, always available on the bottom of the screen (see Figure PVI.5). The different pages are:

- "Shares", where they can see what others have shared and interact with that.
- "Friends", where they can see the friends they have in REMEMO.

- "New post", where they can make a new post.
- "My Posts", where they can see their own posts.
- "My Profile", where they can see their Profile with their account details.

Through these pages, children can do the following with REMEMO: create a post, share a post or change the people with whom a post is shared, see posts that others shared, comment on others' posts, view their own posts, revisit them (meaning to record their current thoughts and feelings about the post), see their Friends on the app, and see their own profile in the app. Below, we elaborate on each of those functionalities.

Children can create entries in the system (called posts) about their experiences and emotions by selecting "New Post" from the navigation bar. After giving a title to their post, they can answer a series of questions that aim to help them tell their story: "Something that happened that I liked was", "When did it happen", "Where did it happen", "Who was there", and "Why did you like it". They can answer each question using pictures, videos, voice notes, drawings, or text, each time being able to choose the number and type of these methods to log their answer (see Figure PVI.5a for an example). After answering the guiding questions, children can select one or more emojis to answer the question "How did it make you feel?" and optionally add some text (see Figure PVI.5b). After completing their story, they can view an overview of it, before selecting "Post" to save it. Posting their story saves it in their private "My Posts". After posting, they have the option to share it with someone from their Friends (care ecosystem members) on REMEMO (see Figure PVI.5c).

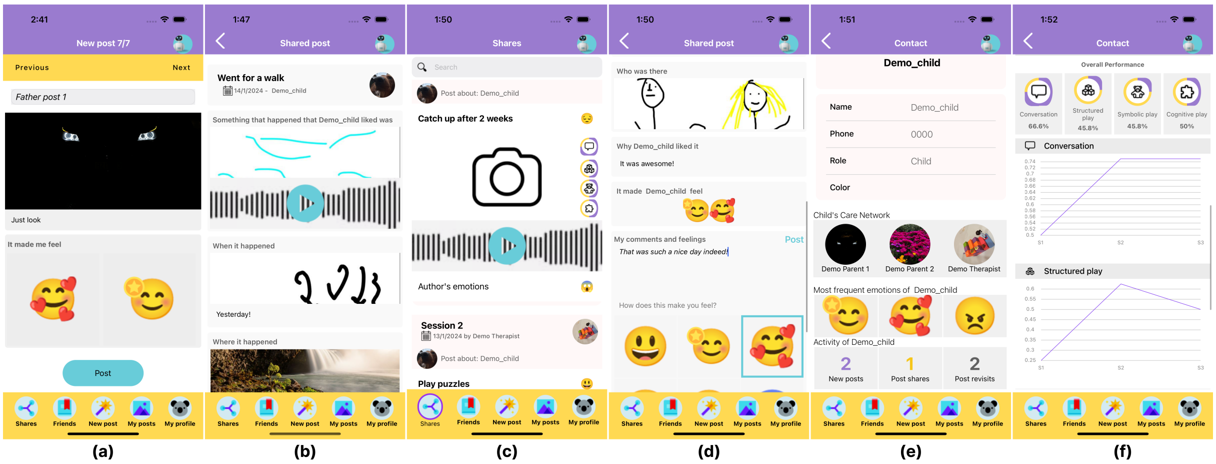
Children can additionally see and interact with posts that others share with them. This is available on the "Shares" page (see Figure PVI.5d). They can view more details about a specific shared post by tapping on it. Children can react to the shared post, by commenting on it using text and/or emojis, as well as see comments that they or others have made to the shared post.

By tapping on "My Posts", children can see all of their own posts they have created in REMEMO. By tapping on a specific post, they can see all the details about it and revisit it (or delete it, if they wish, by tapping on the bin button). From that page, children can see their previous revisits, choose to revisit the post now, or see and change options for sharing this post. When they revisit their post, they can express their current feelings by selecting one or more emojis and/or by typing something below. Then, they should tap on Save to save this (see Figure PVI.5).

If they tap on "Friends" on the navigation bar, children can see the friends they have in REMEMO, enabling them to share posts with these friends and interact with them. Finally, under "My Profile", they can view their own profile, including their account data and interesting statistics about their use of REMEMO, such as which emoji they have used the most or how many posts they have made to-date (see Figure PVI.5f).

PVI.4.2 REMEMO for Parents

REMEMO affords parents all the same functionalities that it affords children, with the following two key differences. One, when parents visit the profile of their child, they can view statistical reports about it (while children cannot see any stats of other users apart from their own). This



(a) Father post 1

Just look

(b) Went for a walk

14/1/2024 - Demo_child

Yesterday!

(c) Post about: Demo_child

Catch up after 2 weeks

Session 2

13/1/2024 by Demo Therapist

Post about: Demo_child

Play puzzles

(d) It was awesome!

That was such a nice day indeed!

(e) Demo_child

Name	Demo_child
Phone	0000
Role	Child
Color	

Demo Parent 1 | Demo Parent 2 | Demo Therapist

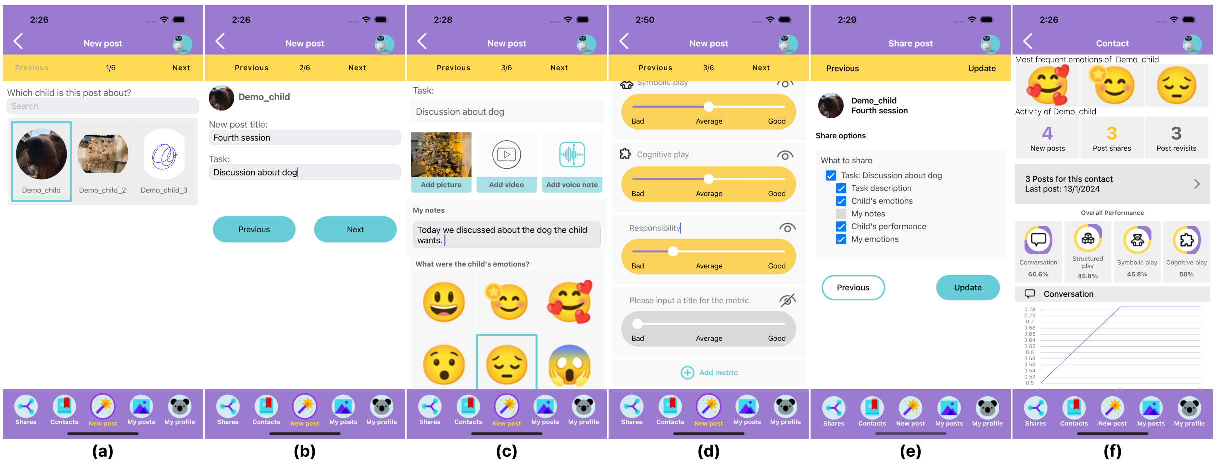
2 New posts | 1 Post shares | 2 Post revisits

(f) Conversation 66.6% | Structured play 45.8% | Symbolic play 45.8% | Cognitive play 50%

Fig. PVI.6 Example screens from the parents' UI in REMEMO. a) Overview of created post just before posting it, b) Tapping on a shared post from another parent to view its details, c) Shared posts with this parent: one from a therapist, and one from another parent, d) Commenting on a post someone shared with the user, e) Viewing the child's profile as a parent part 1, f) Viewing the child's profile as a parent part 2.

includes not only info regarding the child's use of the app, but also reports from the therapists regarding the performance of the child in specific metrics. This aspect is elaborated upon below, in section PVI.4.3. The second key difference for parents using REMEMO, is that they can receive shared posts from the therapists, which again is not the case for children. However, as outlined in section PVI.4.1, children can create and share posts with therapists. Figure PVI.6 shows some example screens from the parents' UI.

PVI.4.3 REMEMO for Therapists and Educators



(a) Demo_child | Demo_child_2 | Demo_child_3

(b) Demo_child

New post title: Fourth session

Task: Discussion about dog

(c) Task: Discussion about dog

My notes: Today we discussed about the dog the child wants.

(d) Responsibility

(e) Demo_child
Fourth session

- ☑ Task: Discussion about dog
  - ☑ Task description
  - ☑ Child's emotions
  - ☐ My notes
  - ☑ Child's performance
  - ☑ My emotions

(f) 4 New posts | 3 Post shares | 3 Post revisits

3 Posts for this contact
Last post: 13/1/2024

Conversation 66.6% | Structured play 45.8% | Symbolic play 45.8% | Cognitive play 50%

Fig. PVI.7 Example screens from the therapists' and educators' UI in REMEMO. a) Selecting a child from the user's contacts to make a post about, b) Providing a title to the post and adding the name of the first activity for this post, c) Adding different kind of media to describe the activity, and the child's emotions, d) Adding a custom metric titled "Responsibility", e) Selecting which parts of the posts should be shared, f) Viewing statistics about the use of REMEMO and the performance of the child based on previous posts.

Similar to the other two adaptions, REMEMO affords therapists and educators five key functionalities, to which they can navigate using the navigation bar, always available on the bottom of the screen (see Figure PVI.7). The different pages are:

- "Shares", where they can view what others have shared with them and interact with it.
- "Contacts", where they can see their contacts in REMEMO.
- "New post", where they can create a new post.
- "My Posts", where they can view their own posts.
- "My Profile", where they can see their Profile with their account details.

Through these pages, therapist and educators can do the following with REMEMO: create a post about their work day or sessions, related to a child (from their contacts), share a post or change the people with whom a post is shared, see posts that others shared, comment on others' posts, view their own posts, see their contacts in the app, including statistics and important information about each child, and see their own profile in the app. Below, we elaborate on each of those functionalities. To avoid repetitions, we do not go into detail regarding the functionalities that are the same with the other two UI versions (children and parents).

Therapists and educators can create posts by tapping on "New Post", and selecting a child from their list of contacts (see Figure PVI.7a) – since the posts they create are about their interactions/session with that child. They can then name their post, and add one or more activities they wish to describe to it (see Figure PVI.7b). For each activity they wish to add to the post, they can choose to describe it by uploading pictures, videos, voice note, or text, choosing how many of these options they use (see Figure PVI.7c). They can note the emotions of the child during the activity, by adding one or more emojis and/or text. They can also choose to record some metrics about the child, by using the provided sliders, especially regarding the child's performance in activities such as conversation, structured play, symbolic play, and cognitive play, or by creating their own, custom metric. They can choose to not use a metric by hiding it via the toggle button (see Figure PVI.7d). As a final step for completing the activity, REMEMO allows therapists to note their own emotions during the described activity. Users can follow the same process for adding more activities to the post. Posting their post saves it in their private "My Posts". After posting, they have the option to share it with adults from the specific child's care ecosystem (but not with the child itself). Importantly, therapists and educators can select exactly which parts of the post they wish to share (see Figure PVI.7e).

Seeing and interacting with posts of others, as well as viewing their own posts and their own profile works in the same way as it does for parent users. When visiting a child's profile, therapists/educators have a comprehensive overview, including not only aggregated information regarding their use of REMEMO, but also quick access to all the posts that have been made about this specific child that the therapist has access to (either because they created them, or because other therapists have created them about the specific child and shared them with the user). Finally, they can see statistics regarding the child's performance on the aforementioned metrics: conversation, structured play, symbolic play, and cognitive play, both as percentages, as well as in the form of graphs across multiple posts/sessions (see Figure PVI.7f).

PVI.4.4 Implementation

REMEMO is a mobile application which is based on the React Native framework [6], allowing for simultaneous development of both Android and iOS applications. This enables the development of a singular instance of code which can be installed in any mobile device, which was crucial for this study where users' devices had not only different brands of operating systems (Android and iOS), but also different versions of each. A back-end server hosted in our University's servers supports the mobile application and is responsible for storing and handling the data in a secure manner. The Strapi [7] headless Content Management System (CMS) was selected and used for the system's backend, as this allowed quick data template definition and automatic API generation functionalities.

The app is available in three languages: English, German, and Greek, with the ability to easily include additional languages via a translation table that matches words and phrases between languages.

PVI.5 Field Study

We deployed REMEMO in the field with five groups of participants, including children with ADHD, parents, siblings and therapists, adding up to $n = 18$ participants in total. Participants used the app in a longitudinal field study lasting 4 to 6 weeks (min : 31 days, max : 44 days, $SD = 5.03$), integrating it into their daily lives according to their personal preferences. We first conducted introductory sessions, followed by participants using the app for multiple weeks, and concluded the study with debriefing interviews. Participation in the sessions was either online or in person based on preference and availability, and participant groups were both from Germany and Greece. The overall aim was to evaluate how REMEMO affects users (RQ_2), with a particular focus on communication, everyday interactions and well-being. All adult participants provided informed consent about their own and their children's participation prior to beginning the study. Additionally, children provided their verbal assent for participation.

PVI.5.1 Field Study Participants

We used our extended social network and snowball sampling to recruit participants. Additionally, we contacted a therapy centre in Greece, and information flyers were distributed in both cases. There was no overlap between the participants of the formative evaluation and the ones that took part in the field study. Adult participants received remuneration of an equivalent of 150€ and children received a game or voucher equivalent to 20€. In total, $n = 18$ (15 females, 3 males) participants took part in the study, including ADHD children, their parents, and siblings and/or therapists, if applicable (parents: $M = 43$ years, $min: 35$, $max: 55$, children: $M = 10$ years, $min: 8$, $max: 13$, therapists: $M = 30$ years, $min: 25$, $max: 39$). Participants formed five groups

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[6] https://reactnative.dev/

[7] https://strapi.io/

Table PVI.1 Participants' data and summary of app usage (all values counted between 1st and 2nd session).

				Number of posts						
ID	**Description**	**Age & Gender**	**Days**	**made**	**revisited**	**shared**	**deleted**	**received**	**Comments**	**Usage time**
AC1	Child with ADHD	12 | F	42	27	7	27	3	17	20	3 hours
AP1	Mother with ADHD	52 | F	42	17	7	11	1	23	23	6.5 hours
BC1	Child with ADHD	13 | F	42	7	1	7	0	4	6	37 mins
BP1	Mother	55 | F	42	2	0	1	0	4	1	33 mins
CC1	Child with ADHD and ASD	10 | M	44	1	0	1	1	1	5	38 mins
CC2	Child with ADHD and ASD	9 | F	44	1	3	0	1	2	2	1h 8 mins
CP1	Mother	32 | F	44	1	0	1	0	2	3	1h 30 mins
CT1	Psychologist for CC1 and CC2	29 | F	43	1	N/A	1	0	3	0	19 mins
CT2	Occupational therapist for CC2	25 | F	43	0	N/A	0	0	3	1	11 mins
CT3	Speech therapist for CC2	26 | F	43	2	N/A	2	0	1	1	43 mins
CT4 **E**T1	Speech therapist for CC1 and EC1	39 | F	43	6	N/A	6	0	7	1	45 mins
DC1	Child with ADHD and ASD	9 | M	36	2	0	0	0	2	0	49 mins
DP1	Mother	42 | F	36	2	2	2	0	2	1	33 mins
DT1	Occupational therapist for DC1	28 | F	38	1	N/A	1	0	4	0	46 mins
DT2	Psychoeducator for DC1	35 | F	36	4	N/A	4	0	3	0	28 mins
EC1	Child with ADHD	8 | M	32	5	0	5	0	4	5	41 mins
EC2	Neurotypical Child	11 | F	31	1	0	1	0	7	1	29 mins
EP1	Mother	35 | F	32	3	0	3	0	5	3	22 mins

based on the children's existing care ecosystem, hence, group sizes ranged from two to seven participants per group. For more details, see Table PVI.1.

The first letter of each participant's ID denotes the group they belong to. Notably, CT4/ET1 is the speech therapist of both CC1, as well as EC1, thus belonging to both groups. In order to keep the number of participants clear, we include her in Table PVI.1 only once. Groups A and B resided in Germany, while groups C, D, and E in Greece. Each participating group, centred around a child (or children) with ADHD, is unique in its consistency, number of members and (social) backgrounds, which is essential information for understanding their usage patterns of REMEMO. Thus, we explore each group with a focused lens in the following section. Regarding recruitment, it is worth noting that while we tried to recruit teachers as well, we were not able to. This connects to the overall challenging task of recruiting vulnerable groups, such as ADHD children and their care ecosystem, made even more complex when multiple stakeholder groups are sought, as was in our case. As an example, one of AC1's school teachers was approached to participate in the study together with AC1 by AP1; and while the teacher was initially positive, the school director declined the request, as they felt it would impose time requirements to an already busy schedule on their staff. Nevertheless, evaluating REMEMO in the field with teacher participants constitutes a key part of our future work.

Contextual Information about the Groups. In the following, we present short overviews of each participant group's members and their background stories, which is essential information for understanding their varying usage patterns of REMEMO. This is based on the analysis of the information that was disclosed by participants during the introductory interviews. The group descriptions were shared with the respective participants both in English and in their native language and they had the opportunity to suggest changes. Children from participant Groups C, D, and E all attend a common therapy centre where all participating therapists are based, and it is also the location of their recruitment. As an overall note about technology use, all participants used the app on their smartphones, apart from CC1 and EC1, who used it on their tablets.

Group A Group A consists of two participants: a mother with ADHD (AP1) and a 12-year-old daughter with ADHD (AC1). The family additionally includes a father, and three older brothers. AP1 is currently in therapy, while AC1 is not attending therapy sessions. AP1 and AC1 participated together with group B (based on their request) due to a close friendship between the parents and between the children, meaning that they were part of each other's ecosystem. AP1 demonstrates a propensity for self-reflection and effective and open communication. AP1 intensely experiences emotions but finds it sometimes challenging to identify and express them. She acknowledges difficulties in organising thoughts and prioritising tasks, and recognises a tendency to be controlling and to intervene inappropriately in certain situations. AP1 is currently engaged in a "self-discovery and improvement" phase, optimistic about the potential benefits of REMEMO for enhancing communication with her daughter and demonstrating her interest in her daughter's life. AC1 is sometimes reflective of her thoughts and actions, with less emphasis on acknowledging emotional experiences. While she sometimes shares her experiences with her family, she openly admits a reluctance to talk about her feelings, as she is "not that kind of person" (AC1), and apart from sometimes talking about how she feels with her mother, she in general "just doesn't want to" (AC1). In terms of technology usage, the family adheres to stringent screen time regulations. The younger children's devices are securely stored, accessible only during specific time windows and after informing the parents of their intended usage. In the case of AC1, due to an undisclosed past incident, she has limited access to her smartphone, with an exception made for the use of REMEMO.

Group B Group B consists of two participants: a single mother (BP1) and her 12-year-old daughter with ADHD (BC1). BC1 was recently diagnosed with ADHD and the family struggled with finding the right strategies and medication for her. BP1 works multiple jobs and has a very demanding schedule. She puts value in spending quality time with her daughter, but her busy schedule does not always allow that. She is reflective, and has a deep interest in understanding herself and her thoughts. BP1 has a support system in place, including a partner (living in a different household), family members and friends, and appears to be an optimistic person overall. She was very enthusiastic about doing the interview and to "have someone to talk to". She stated that she is currently looking for alternative methods to medication for ADHD and was partly hoping that REMEMO could be an alternative method to address some of the challenges they face in their everyday life. She was quite disappointed with how a doctor handled the case of her daughter, as he "was only looking at the bad stuff and saying what BC1's struggles are, and not at any of her strengths and he was just very negative". BC1 is very privacy concerned. She pointed out that it is very important to her that her classmates do not find out that she has ADHD. BC1 is reflective, and often thinks about her decisions and their impact. Regarding expression of feelings, she mostly confides in her mother and aunt, and often talks about her feelings after being prompted by her mother. Regarding technology use, BP1's screen time is high for work-related purposes, and only spends limited “leisure” time on her smartphone to communicate with friends and family. BP1 reported struggling with regulating BC1's screen time, which is high also due to the tablet they use for school-related matters. BP1 described that she regularly restricts BC1's usage of her smartphone by hiding the phone from her "when she decides it's enough", otherwise BC1 will stay on her phone for hours.

Group C Group C consists of seven participants: a family consisting of a single mother (CP1) with her three children, of which two participated in the study, a 10-year-old boy with ADHD and ASD (CC1), and a 9-year-old girl with ADHD and ASD (CC2), and the the children's therapists, including a psychologist for both children (CT1), a speech therapist for CC1 (CT4), an occupational therapist for CC2 (CT2), a speech therapist for CC2 (CT3). The family belongs to a socio-economically disadvantaged societal group facing daily challenges. Therapists highlight the family's social, emotional, and cognitive difficulties. CP1 acknowledges a lack of personal time (CP1) and discusses the emotional and practical hurdles she encounters. Both children have difficulties "both in the communication part, in the speech and in the psycho-emotional part" (CT1), and struggle with identifying, recognising and expressing their experiences and emotions . Therapists reported that both children find it easier to express positive than negative feelings. CC1 is currently facing challenges in school. In contrast to her brother, CC2 sometimes shares her experiences with the therapists. Regarding the use of technologies, while there are no explicit screen time rules in place at home, each family member only spends a maximum of half an hour per day on their phones due to their demanding schedule. Regarding the therapists of group C, all therapists reported using their smartphones multiple hours on a daily basis.

Group D Group D consists of four participants: a family consisting of a single mother (DP1) and her 9-year-old son with ADHD and ASD (DC1), and the therapists of the participating child (DT1, DT2). DP1's daughter lives with the father, separately from DP1 and DC1 (this change happened approximately 2 months before starting the study). The participating therapists include an occupational therapist (DT1) and a psychoeducator (DT2). DT2 has a background in educational rehabilitation, but has recently changed jobs and now works as a psychoeducator at the therapy centre together with the rest of the therapists in this study. When asked to describe her current occupation, she identified as a therapist. DP1 reported spending most of her time outside of work with her son DC1, and having a challenging and stressful schedule. DC1 tends to limit the expression of emotions, particularly negative ones, and at times, exhibits outbursts and aggressive behaviours, particularly towards DP1. The therapists reported that "it is difficult for him to communicate his feelings, but also to record his feelings" (DT1), and that he may have intense (emotional) reactions, or provocative behaviour . Both therapists have only recently started working with DC1 less than 2 months prior to starting the study, and reported that while they know that DC1 exhibits such behaviours outside of their sessions, and particularly with his mother, he has not exhibited such behaviours with them. There are no specific screen usage rules in the family; it rather depends on the day's schedule, including homework and activities. Regarding the therapists, DT1 reported using her smartphone very little in general, while DE1 reported that she also does not use her smartphone more than a couple of hours a day.

Group E Group E consists of four participants: three members of a family and the therapist of one of the participating children. In particular, the family consists of a mother (EP1), a father, an 8-year-old boy with ADHD (EC1), and an 11-year-old neurotypical girl (EC2). ET1 (same person as CT4 from Group C) is the speech therapist of EC1. The family and the therapist reported healthy relationships and communication patterns with each other. EP1 describes herself as reflective but does not share her thoughts and emotions with others. EC1 shares his experiences but only if "something is very interesting to him" or “he is impressed by it”, while EC2 "will talk a bit easier" according to EP1. EP1 reports that EC1 has a very strong bond and good relationship with ET1 and have been working together for 4 years already. With regards to screen time, there are no specific screen time rules enforced in the family, with participants reporting that the children are free to use their devices (smartphone for EC2, tablet for EC1) unless EP1 says they had enough time and should stop.

PVI.5.2 Data Collection

All online study sessions were video-recorded, and all in-person sessions were audio-recorded for later transcription and analysis, with the participants' consent. For each participant group, we collected usage logs of the app which tracked their interactions with the app, including each time they launched REMEMO, overall time spent on the app, number and content of posts, who they shared their posts with, how many they deleted, as well as comments to others' posts and revisits to their own. Quantitative data was collected from two validated questionnaires, one for children and one for adult participants; for more details please see section PVI.5.2. Further, we collected qualitative data through two semi-structured interviews that took place at the introductory and debriefing sessions, and post-study notes per participant.

Interview Protocol. Participants engaged in two semi-structured interviews specifically tailored to the role of child, parent or therapist. The interviews were conducted in the respective native language of the participants. In an initial introductory session, participants shared contextual information about their routines and habits, technology usage, methods to record and express experiences and emotions, and described existing communication processes within all parties of the ecosystem. Therapists were additionally asked to elaborate on their outside perspective on the family's communication strategies and approaches to emotional expression, on tools they use in therapy, and on their sessions' structure and goals. The full interview protocol can be found in the supplementary material; an overview of these findings are presented in subsubsection PVI.5.1. The introductory interviews lasted between 5 and 23 minutes ($M = 10.6$, $SD = 6.6$) for children, between 7 and 44 minutes for parents ($M = 22.2$, $SD = 19.5$), and between 11 and 16 minutes for therapists ($M = 12.7$, $SD = 2.5$).

In the debriefing interview, participants reflected on their routines and any unusual events that transpired between the introductory and debriefing interview, both for themselves and for the child(ren) in their group. Further, they reported how they used REMEMO, discussed reasons of limited usage if applicable, gave general feedback and explored effects they experienced due to using the app. The full interview protocol can be found in the supplementary material. The debriefing interviews lasted between 5 and 25 minutes for children ($M = 15.7$, $SD = 8.3$), between 15 and 64 minutes for parents ($M = 38.6$, $SD = 23.5$), and between 26 and 44 minutes for therapists ($M = 37.8$, $SD = 6.4$).

Measures. Children and adults received different questionnaires. In particular, adult participants were asked to fill out the User Experience Questionnaire [321] in the second session. We used it to measure the user experience of REMEMO. Participants rate 26 pairs of graded antonyms and attributes of the system related to its pragmatic quality (i.e. usability and utility) and hedonic qualities of the application (i.e. the joy of using as well as the stimulation the system may evoke). The 26 items are categorised into six subscales: Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation and Novelty. The UEQ is validated for Greek and German for this study. Higher values indicate higher user experience of REMEMO.

Children participants were asked to fill out specific items of the Middle Years Development Instrument (MDI) [493], a self-report questionnaire that asks children about their thoughts, feelings and experiences. The MDI uses a strengths-based approach to assess five areas of development that are strongly linked to well-being, health and academic achievement: social & emotional development, physical health & well-being, connectedness, use of after-school time, and school experiences. In our study, we asked children to fill out the questions of the following MDI measures: Optimism, Empathy, Self-esteem, Happiness, Absence of sadness, Absence of worries, Self-regulation short-term, Self-regulation long-term, Responsible decision-making, Self-awareness, and General health. By combining MDI measures relating to children's physical health and social and emotional development that are of critical importance during the middle years, the Well-Being Index can be calculated. The Well-Being Index encompasses three categories of well-being, thereby providing a holistic summary of children's mental and physical health: 'Thriving,' 'Medium to High' well-being, or 'Low' well-being. The MDI has an officially validated German version [422]. For translation to Greek, the measures of the MDI we employed in our study were translated by two independent translators fluent in both English and Greek, and back-translated by a third person bilingual in Greek and English.

Post-session Notes. The experimenters present in each study session also collected detailed post-study notes. Those included own impressions as well as comments and remarks regarding the participants' interaction with the app collected throughout both interviews and when participants reached out to the experimenters with questions during the runtime of the study.

PVI.5.3 Procedure

The longitudinal field study was as much as possible adapted to participants' availability and preferences. For all groups, experimenters gathered contextual information in an introductory session, then participants used the app for four to six (4-6) weeks, and finally, participants shared their experience with the app in a debriefing session. We elaborate on each in the following sections. Depending on participants' preferences, the sessions were conducted either online or in person. During the field study, participants could always reach out to the experimenters via texts, phone, or video calls in case of questions and for technical support.

Introductory Session. The introductory session revolved around presenting REMEMO and gathering contextual information about the participant groups (presented in subsubsection PVI.5.1). The session started with welcoming the participants and explaining the procedure. After giving consent, they filled out questionnaires, if applicable, and conducted the introductory interview with the experimenter in a one-to-one setting. If requested by the children, the experimenter helped with answering the questionnaire. Afterwards, the experimenter installed REMEMO on the participants' devices, using TestFlight for iOS and APK files for Android. The experimenter then walked all participants through every feature of REMEMO, and participants created a test post themselves as practice. Participants were provided with a tutorial, available in print for in-person sessions or sent as a PDF for remote sessions. This tutorial could be revisited at a later stage, and is accessible in the supplementary material.

Table PVI.2 UEQ ratings for REMEMO submitted by adults along the UEQ subscales. According to the UEQ benchmark, REMEMO was rank *excellent* in all subscales.

Attractiveness		**Perspicuity**		**Efficiency**		**Dependability**		**Stimulation**		**Novelty**	
M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
2.48	0.43	2.48	0.68	2.11	0.77	1.91	0.64	2.02	0.75	2.02	1.01

Debriefing Session. The debriefing session revolved around understanding the experiences of participants during the weeks of using REMEMO. Participants filled out questionnaires and conducted a debriefing interview with the experimenter. Similar to the introductory session, some children (of group C and D) requested help with filling out the questionnaires. Finally, participants were asked if they wanted to continue using the application, stressing that it is a prototype that is not released for public use.

PVI.5.4 Data Analysis

All 36 study sessions (18 participants, two sessions per participant) were transcribed verbatim. Eight of the sessions were conducted in German, and the remaining 28 in Greek. They were all translated to English. Two authors analysed six transcripts by performing open coding in an iterative process, using the MaxQDA software. After an initial round of open coding, a coding tree was discussed and agreed on. Then, the remaining material was coded by three authors. Following that, authors conducted thematic analysis in line with Blandford et al. [51]. Any disagreements that arose were resolved by discussion.

PVI.6 Findings

Here, we present our findings based on the analysis of the field study. In particular, we present quantitative results from the questionnaires administered pre and post and from the usage logs, as well as qualitative insights from the interviews.

PVI.6.1 Quantitative Results

We analysed UEQ results by calculating summary scores along UEQ subscales and comparing them with benchmarks provided with the scale.Table PVI.2 shows the results for UEQ's subscale. According to the scale documentation[8], REMEMO was ranked *excellent* along all the UEQ subscales.

Child participants aged over 10 completed the MDI questionnaires before and after using REMEMO. Due to the sparsity of the data and to maintain full transparency, we decided not to conduct null-hypothesis testing on the data set. Instead, we present the full answer set in Table PVI.3.

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[8] https://www.ueq-online.org/

Table PVI.3 Detailed MDI results for Child participants aged over 10, before and after using REMEMO. Cases where answers changed after using REMEMO are highlighted in bold. H—high, M—medium, L—low.

PID	**Time**	**Optimism**	**Empathy**	**Self-esteem**	**Happiness**	**Absence of sadness**	**Absence of worries**	**Self-regulation (short-term)**	**Self-regulation (long-term)**	**Responsible decision-making**	**Self-awareness**	**General health**	**MDI Well-being Index**
AC1	Before	H	M	H	H	H	H	H	H	H	M	H	H
AC1	After	H	M	H	H	H	H	H	H	H	M	H	H
BC1	Before	M	H	H	M	M	L	M	M	H	**H**	M	L
BC1	After	M	H	H	M	M	L	M	M	H	**M**	M	L
CC1	Before	H	M	H	H	**H**	M	**M**	**M**	M	**L**	H	L
CC1	After	H	M	H	H	**L**	M	**H**	**H**	M	**M**	H	L
EC2	Before	H	H	H	H	H	M	H	M	H	H	H	H
EC2	After	H	H	H	H	H	M	H	M	H	H	H	H

PVI.6.2 Qualitative Findings

Based on our qualitative inquiry, five themes were conceptualised from the data: *Allowing Emotional Expression & Reflection*, *Supporting Communication & Relationship Building*, *Therapeutic Practices & Interactions*, *The Role of Mutual Understanding and Trust*, and *The Role of Background & Contextual Challenges*. Before discussing these themes in more detail, we outline general impressions from the field deployment of REMEMO.

We analysed both the users' interactions with the app, such as the content of their posts, their sharing habits, revisits, and comments, as well as the interview transcripts and post-session notes. A key aspect that surfaced was that specific user groups use REMEMO with different goals in mind, resulting in different interaction patterns. Children mainly placed the focus on themselves, i.e. their own experiences and emotions. Parents switched between using it for themselves and others, e.g. as a journal or to enhance understanding of themselves or the child, while therapists primarily focused on others, i.e. the children. When participants' main focus was self-driven, they used the app for i) self-expression, resulting in the app being an emotional outlet for them, ii) getting feedback or anticipating other users' reactions to the posts they shared, or iii) self-recording, which in some cases led to self-reflection.For instance, AP1 reported using REMEMO frequently as a form of digital diary, both to *"get [things] off [her] chest"*, and to revisit previous posts and write down new realisations after some time had passed.

When participants focused more on others, they mainly wanted to share information with members of the care ecosystem and foster empathy and better understanding of others. As an example, therapists recorded specific games for training emotional expression they used in a session and shared that with other therapists. The therapist recipients reported how insightful it was to *"see how they were doing what they wanted to do, since I (CT1) wasn't involved in that session. And as an idea, with this gaming style, how she (CT3) managed to insert through [that game] something that she wanted to work on."* As an example to foster empathy, AP1 often used the app to make her child realise how her actions affect others, *"because for me (AP1) it's more about one person being able to tell the other what it does to me when it goes like this.* AC1 confirmed that the app led her to *"sometimes"* realise *"things that [she] wouldn't have thought that at all or that was somehow new." (AC1)*

Allowing Emotional Expression & Reflection. Our analysis showed that REMEMO allowed both children and parents to engage in emotional expression and reflection, and supported becoming aware of emotions and empathy, both when using it with a focus on the self and others. Additionally, it encouraged reflection for some therapists.

Identifying, Expressing, and Sharing Emotions In allowing users to log their experiences and emotions, REMEMO supported participants to identify, express, and share their emotions. For example, AC1 commented that *"I'm just that kind of person, I don't talk about feelings. And then, if I do that with myself, so to speak, then it's just easier."* As a second example, AP1 noted how she frequently used the app as a digital diary, writing *"things of my own in there, I've just used it for myself, things that I said I didn't understand, that I kept to myself, that I didn't share with anyone, but just for fun".* While she usually finds that *"boring", "the app gives me a bit more motivation".* Additionally, children enjoyed recording their experiences and emotions, with BC1 liking *"both, I thought the fun factor was cool, but also thinking about feelings."* BP1 described seeing REMEMO as a *"positive tool"* that could help her child *"to describe feelings"* and *"helps her to cope better in everyday life, that helps her on her way to becoming an adult".*

Moreover, the app facilitated the sharing of participants' emotions with others. For instance, DC1 commented that he liked being able to *"save his feelings"* in the app *"because I can show (to others), let's say, if I think something is wow for me or if...if something makes me happy or if something makes me scared or something like that."* Notably, REMEMO specifically prompted users to log only positive experiences, based on prior work that guided our design decisions [550]. Some participants bypassed that and proceeded to log additionally negative experiences as well, such as a fight, an experience making them angry or an illness. Both AP1 and AC1 requested that future versions of the app should include the ability to select whether the experience they are logging is positive or negative, or to at least provide a neutral template, while others enjoyed the focus on positivity (e.g. BC1).

It also allowed caregivers to acquire insights on children's emotions; for instance, BP1 noted:

> "That was touching, to see how she (BC1) feels about it. Because you can't always get there in everyday life, or I have to have a lot of patience to be able to access an emotion...And that's where it helps me, or I hope that we can simply continue to do this and that I have an additional channel." (BP1)

Regulating Emotions Besides learning to identify and express emotions, using REMEMO also supported users in regulating them. To that end, first, the app can serve as an *"emotional outlet" (BP1)*. BP1 elaborated on the app's potential benefit as an outlet: *"What I've seen over the years is that these special children push the parents to their limits so much that violence comes into play. For the children it's such a great ordeal, constantly being told what they can't do, what they haven't done right, they're always being told off. And yes, whether psychological or physical violence, if there is an outlet for these families [through REMEMO], then I think that's good."*

Additionally, REMEMO affords users with necessary time and distance to process feedback and criticism, potentially resulting in a calmer demeanour than without the app. To illustrate, AP1 and AC1 have a recurring fight – dating back to before they started using REMEMO – about AC1 opening her mother's packages. AP1 narrated that this typically ends in a fight with both their emotions running high, with AC1 *"exploding"* and shouting when being criticised about this habit. With REMEMO, AP1 created posts on two occasions where AC1 again opened her packages, explaining how that made her feel, to which AC1 reacted with emojis. When the topic of opening packages was brought up again afterwards, she felt able to have a calm discussion about it with AC1. She elaborates:

> "When I try to tell her something, she often isn't willing to listen. She doesn't have the peace and quiet for that. There is this [basic attitude], 'ah now stop it, I don't feel like talking about it'. And that's why I find it easier with the app. That doesn't mean that for me the app should replace personal conversations. But especially when it comes to this package story, I said that if the app hadn't happened in advance, she would have reacted completely differently. (...) She didn't get out of control, not at all. It basically helped [AC1], if you like, to stay at a lower level. She didn't immediately freak out because she heard criticism from her mother again." (AP1)

Moreover, our findings showcased that REMEMO can also up-regulate emotions, in other words, foster positive emotions. The most prominent example of this is when participants revisited posts. EP1 explains: *"it made my mood better, for example, the post regarding our trip, was something pleasant, the experience we had [there] was nice, so yes, it made me happy to see it again"*.

Reflecting on Emotions and Behaviours Additionally, REMEMO encouraged reflection in different ways and through the use of different app features. First, the app supported self-reflection by encouraging users to think about their experiences and emotions and record them in REMEMO. According to some users, even the act of giving the post a title supported reflection: *"Well, you start at the beginning by making the title first, so to speak. And I found that interesting, because you have to think about what you're going to call the whole thing at the beginning and then develop it afterwards (AP1)"*. Further, when creating a post, some participants reported feeling like writing a post is a cathartic activity, which helps to externalise and solve problems. For instance, AP1 wrote about a problem in REMEMO, then thought about a solution, revisited the post to note down the solution, and, when getting upset again about the problem at a later stage, remembered the solution she had previously logged. AP1 clarified:

"It's not necessarily that I went back in [revising post in REMEMO to check for the solution], but that I knew I had written it down. (...) And then hopefully it [the problem] will be a bit more finalised." Users also reported their perspectives being changed, with AP1 mentioning two posts that she kept only for herself, and how *"I know for sure that one of them has changed my perspective"*.

Moreover, revisiting previous posts was helpful for reflection for some users, as *"you can also recapitulate for yourself afterwards, what feelings did I have there and how do I feel about it now? (AP1)"*. BC1 commented on it the following way:

> "Sometimes it was like, huh, I couldn't understand that at all,... why did I upload that now? ... I've looked at them sometimes, then thought about it. In retrospect, I thought, ah, that was interesting that I felt like that back then." (BC1)

Apart from REMEMO supporting self-reflection, it was also used as a way for parents to encourage their children to reflect. In that case, the app served as a feedback from the parent to the child, to get the child to (re)think about things, reflect, and realise the effect of its actions. Moreover, participants reported that REMEMO encouraged joint reflection and empathy between parent and child (e.g. between AP1 and AC1), as it nudged them to see the other's perspective and to help realise when one is in the wrong. In particular, AP1 often made posts about AC1's behaviour and shared those with her, because *"it would give her another opportunity to think about it. She can look at it at any time and can also think about it again herself."*

Interestingly, our analysis showed that the app could support reflection even in cases where the users did not actively make posts. Some participants elaborated on how they thought extensively about creating a post but without actually posting something due to contextual challenges such as becoming interrupted (see subsubsection PVI.6.2 for more information). Others thought back to what they had posted before.

Supporting Communication & Relationship Building. Our analysis also highlights how REMEMO can support communication and relationship-building between children and their care ecosystem. This was most prevalent for parent-child and therapist-child interactions. This theme explores the app's collaborative aspects, focusing on features like sharing, commenting, and jointly creating posts. We specifically examine instances where therapists engaged with children in collaborative post creation, and the emotional reactions this evoked.

Strengthening Relationships The package incident involving AP1 and AC1 demonstrates that REMEMO can aid in emotion regulation and potentially initiate reflection processes. This, in turn, enables calm discussions about conflicts, such as the one involving AC1 opening packages addressed to others. However, it seems that the app can also play a role in strengthening relationships. The mother explains, that she felt finally heard and not as if she *"has spoken into the void (AP1)"* as she felt like doing before.

Further, we found that REMEMO can support relationship building by supporting affectionate and fun communication, particularly in child-child, child-therapist, and parent-child interactions. This mainly occurred by sharing (funny) pictures and notes, caring and affirmative messages, and highlighting beautiful joint memories respectively. To illustrate, AC1 and BC1 shared several funny pictures and texts with each other, which BC1 admitted was sometimes *"nonsense"*, but that *"it was funny to see what the other person had written in there. So, I have a few funny photos of [AC1]. I put them in, and they were only sent to [AC1]. So nobody else could see them. That was rather funny (BC1)"*.

As an example of affectionate communication between child-therapist pairings, EC1 shared a post to CT4/ET1 to wish her a happy birthday, as they did not see each other that day. CT4/ET1 liked the attentiveness, stating that *"I liked [this] incredibly, I was incredibly happy"*. Moreover, concerning child-therapist interactions, we found that some therapists used REMEMO during their session with the children *together* with them, as a collaborative activity meant to strengthen their relationship. For instance, DT2 reported using REMEMO as a mutual, fun activity to build their relationship, especially since they had only recently started working together, highlighting how it helped her *"to spend some nicer moments with [DC1]"*.

Finally, with respect to affectionate parent-child communication, both parents and children posted about mutual activities and nice memories together and shared them with each other. For instance, AC1 made a post about spending time with her mother taking photos together, uploading some of these photos and using several heart emojis. When sent to her mother, she reacted to it with emojis as well. Vice versa, parents posted about their appreciation and pride about something their child had done to share how happy this made them feel. As an example, AC1 had drawn a big heart in the snow covering the front lawn while on the way to school. AP1 thought that *"it was really cute, I was really happy about it"*, thus taking photos of it several times during the morning. She shared those and how this continuously made her happy when seeing it with her child through REMEMO.

Interestingly, CT3 was wondering whether therapists should be able to directly share posts with children, as she imagined that this could have positive effects on her relationship with CC2. She noted that *"I believe that the way she could have used it is to strengthen our relationship with what she sees, that we did this together with my therapist, my therapist shared it, my therapist was happy that we did it together. To see the happiness, because it exists in a visual way, and to say this is how we are similar, and that would help our relationship."* However, she was apprehensive of the safety risks embedded in that, and agreed that specific regulations should be in place for such interactions, e.g. that the posts should automatically be shared with the parents as well, as by passing the parent in this context would be *"very problematic"* (CT3, CT1).

Transparent Communication Our analysis demonstrated how the app supports transparent communication across the ecosystem's stakeholders, especially in the context of therapist-parent and therapist-therapist interaction. First, it allowed therapists to share moments from their sessions with the children with parents, which was highly appreciated by the parents. For instance, CP1 noted how *"she liked seeing the post that [CT1] shared with her"*, while DP1 noted: *"Usually, when [DC1] goes to the sessions, I have no idea what's going on. I liked it when I saw that they were playing, they were having a good time, and through the game,* *there was this interaction (...) And I liked to see how [DC1] behaves when he is with one of the [therapists]. Because I was indeed wondering about that, because it's different when I'm in front, and it's different when I'm alone with him and when he's with someone else."* Regarding therapist-therapist communication, REMEMO supported transparent and direct communication between them, allowing them to acquire insights about and gain inspiration from each other's therapeutic work. CT1 was very excited about this opportunity: *"I knew approximately what they would work on, but not in the way that they did it with this game, that they used it for this activity. (...) I was excited when I saw, for example, from [CT3], exactly how she did it [the activity in the post], I liked it a lot. (...) Because it helped me see how they were doing what they wanted to do, since I wasn't involved in that session. And as an idea, with this gaming style, how she managed to insert something that she wanted to work on. Because [I saw that CC2] likes that."*.

Therapeutic Practices & Interactions. This theme engages with therapists' visions of how REMEMO helped or could help them in their practices and interactions.

Our analysis identified the following visions of how to use REMEMO, reflecting on how REMEMO can be an assistive and therapeutic tool.

First, REMEMO supported therapists as a tool that is portable and instantly accessible in preparing for and documenting their sessions. The app serves both as a means for inspiration and as a reminder for goal setting. For example, CT4 noted: *"I go back to see what goals I had set the last time, so I can continue with the goal from where I left it off"*, and particularly CT1 got new ideas on how to include certain methods used by other therapists into their own session, thereby also fostering the communication between therapists (see section PVI.6.2). Furthermore, they utilised REMEMO as a recording and documentation tool, either replacing or augmenting the regular documentation that takes place after each session. CT4 imagined how REMEMO could replace her other documentation strategies, leveraging that it allows for different forms of documentation through the use of media, as well as instant sharing of this documentation with others.

To further facilitate the usage of REMEMO as an assistive tool for therapists, therapists suggested receiving notifications if a post is shared with them (CT1, CT2, CT4). However, they noted that they *"would like to have the option to decide whether to receive the notification or not (CT4)"*. Additionally, CT4 reflected that using REMEMO would increase her work-life balance, as work-related messages would not be sent via private messaging apps as is the case now: *"so that Viber (a private messaging app) does not ring, let's say, for work issues (CT4)"*.

Second, therapists used REMEMO as a therapeutic tool during their sessions. They used it together with the children, either to help them practice emotional expression and reflection, or to engage in a mutual activity, thereby strengthening their therapist-child relationship (see subsubsection PVI.6.2). In that regard, therapists, together with the children, created posts either on their own or on the children's apps. They envisioned, that they could also make posts individually on their respective devices, but at the same time. For example, the therapist asked the child to complete the question "What were the emotions of the child?" on their app themselves (CT3 and CC2). Notably, therapists highlighted how they only let the child get glimpses of their app in those specific moments, keeping their other uses for themselves.

Although some therapists envisioned only using the app in this collaborative manner, they also discussed challenges in that regard. For instance, in the example above, CC2 required constant supervision to not get distracted, making CT3 struggle with creating the post on REMEMO at the same time. To mitigate this, CT3 proposed a saving function for posts to be able to complete them later. As another example, DT2 reported creating some posts together with DC1 in their sessions, and how she used it as a mutual, fun activity to build their relationship, especially since they had only recently started working together, highlighting how it helped her *"to spend some nicer moments with [DC1]"*.

The Role of Mutual Understanding and Trust. We also found that the way that participants used the app heavily depended on the interpersonal dynamics between them, and in particular on the concepts of mutual understanding and trust. This theme engages with those concepts and how they affected usage patterns and behaviours, especially for child-parent and therapist-parent interactions.

In the previous themes, we already showed how different participants used the app in very different ways, both individually and collaboratively. In the context of this theme, and especially in parent-child interactions, we identified that different expectations or lack of mutual understanding of how to use the app between children and parents could lead to challenges. For example, a few days after starting the study, BP1 made a post about BC1's grade in a maths test, reflecting on how, even though the grade was bad, BC1 was not as sad as BP1 expected, and it will get better with the grades in the future, especially after BC1 will start taking medication to support her in various daily challenges. BP1 included *"I admire her for her confidence and optimism"*. BP1 shared that post not only with BC1, but also with AP1, who then proceeded to mention the post and BC1's grade to AC1 (in person). When meeting with BC1 in person, AC1 mentioned that to BC1, which led to a fight between BP1 and BC1, and BC1 feeling *"betrayed" (BP1)*. BP1 explained in her debriefing interview how *"BC1 was angry with me"* and *"there were tears, the doors banged"*. Even though BP1 insisted that BC1 should read over the post, and how *"it was well-meant (BP1)"*, BC1 *"couldn't read and understand that (BP1)"*. BP1 then explained how this now would make her *"think very carefully about what I share and what I don't"*. BC1 also mentioned how her *"mum didn't post anything mean about me either, but she did post my maths grade at one point and I didn't think that was cool" (BC1)*. She then elaborated that she, as a consequence, *"made sure that [she] didn't make anyone look stupid or deliberately make someone look bad or anything (BC1)"*. Therefore, different interpretations of what is acceptable to post and share with REMEMO led to BC1's trust being broken, as illustrated in the above example, as her own expectations clashed with those of her mother, and this led to changed app usage for both of them. This also links to BC1's privacy concerns which she elaborated in both her interviews. Especially in the second, BC1 further emphasised how she would not like to share her posts with people outside her care ecosystem, and that she now pays close attention with whom she shares her posts.

Another pertinent example showing how different usage expectations surfaced, is when children were using REMEMO to have fun, but parents still tried to enforce their own views about how the app should be used. In particular, AP1 criticised how AC1 used the app to share funny pictures and moments of her life. For example, AC1 made some posts with pictures of her classmates, noting to each one *"This is [name of classmate"]*, to which AP1 commented:

> "But there have also been other things where I've said to her, [name of child], stop just posting rubbish. Focus a bit like that. Do it when you really have something to say and you can show me the picture of your classmate like that (referring to the photo gallery on the phone). I know that you're not actually allowed to use these things at the moment, but before you turn it into a post where I don't know how to react to it, should I say that she looks nice or what should I say? At some point I said, well, now it's time to stop it." (AP1)

It remains unclear whether this had a significant influence on AC1's behaviour with the app, given that she did not comment on it in the debriefing interview. However, she did stop making posts about her classmates. The above examples underline how the complexities that exist in (ADHD) families and their communication in real life can potentially transfer to the technologies that they use.

The aforementioned example of participants being very mindful about privacy and what is shared via the app, connects to some concerns that therapists had about sharing posts in REMEMO. In particular, one therapist participant (we purposefully do not mention their identification) created some posts and was debating whether to share them with the parent, but was afraid to do so due to potential misunderstandings. In particular, she commented on existing communication barriers between the two of them, and noted how she was not confident that the parent would understand what she shared with them, thus potentially leading to misunderstandings that she wanted to avoid. This further underlines the complexities of communication and using technologies within the care ecosystems of ADHD children.

The Role of Background & Contextual Challenges. This theme engages with challenges regarding some participants' background and specific contexts, either in general or particularly during the weeks that we deployed REMEMO. We also explore technical difficulties that arose, and how those challenges affected participants' use of REMEMO. In particular, we specifically focus on those participants whose use of the app was limited, and engage with potential reasons for that, applying the aforementioned lenses.

First, some participants attributed their limited use of the app to the limited time available in their daily lives. Some parents reported getting interrupted in the post-creation process (e.g. BP1), as it sometimes took them about 15 minutes to create a post. Other times they also forgot to post (e.g. BP1 due to a severe illness). One example is the family of group C, which was experiencing significant challenges throughout the duration of the study period, with matters of both physical and emotional health at play. This is also corroborated by the results of the MDI questionnaire, where CC1 scored "low-well-being" both pre and post. Additionally, the tablet on which CC1 was using the app broke in the middle of the study, and the family did not have the chance to replace it. Interestingly, the mother insisted that she wanted to continue having the app on her phone when asked about it during the debriefing interview, expressing how she thinks that *"if we are calm, like now that the schools will be closed [for Christmas] and we don't have activities"* they might be able to have the time to use it. When asked why she wanted to keep using REMEMO, she stated: *"Because it's a way, through this application, to know what the child likes (CP1)".*

Further, some participants explained that they needed more time to familiarise themselves with the app and to integrate it into their routine. While true for both parents and therapists, the latter extensively focused on this aspect, which is understandable because therapists were asked to use the app in a more formal and clinical setting, unlike the comparably fun and relaxed setting that parents and children had, leading to overall different constraints on adoption. For example, one therapist restrained from saving an unpolished post due to being concerned about the perceived permanence of recording something in the app versus on paper (CT3). Some therapists also pointed out that the weeks of the study were particularly pressured and stressful, more so than usual. This was attributed to various reasons, including both personal and work-related factors. Those for example included getting married, being new to the job, having back-to-back sessions without breaks, or because the session with the participating child was the last session of the week with no time for using the app after the session finished. For instance, CT1 elaborated on one of these aspects:

> "I thought about it a lot, every time, that I should upload something....I wanted to, but every time, because the truth is that I went to one session, after another, after another, it was as if I was forgetting it, as if it was leaving my mind, this thing. That was the only reason. " (CT1)

Moreover, some therapists noted that the lack of interaction of other members of their participant group decreased their own motivation to use REMEMO. They specified that they were looking forward to interacting especially with the children, but those specific children did not use the app that often. This was especially the case for therapists who envisioned using the app in more collaborative settings, i.e. together with the children. For instance, CT2 noted how *"I wouldn't use it to record my documentation of my sessions. Maybe because I'm not used to it. I thought about it more as an activity together with the child, and as a therapeutic tool, together with the child."* However, this did not seem to be a constraint for therapists who primarily wished to use REMEMO for documentation and as a tool to support their therapeutic work (e.g. CT4).

Additionally, a few participants (DP1, DC1, EC1, EC2) faced technical difficulties with the app, in particular with a single feature: uploading images. This resulted in users failing to upload their post, and after a few failed tries, giving up. In some cases (e.g. EC1 and EC2) the researchers had a call with the participants to resolve the issue, and suggested that they use any of the other available media in the meantime. This led to positive reactions from EC1, but not from EC2, who kept insisting to use pictures. Thus, this was another challenge that led to decreased use of the app by some participants.

On another note, therapists of all groups noted how the app could be very helpful, but that there are specific criteria that a child has to fulfil *"functionally"* to use it in a meaningful way. That is, those criteria do not depend on the child's diagnosis, but on the child's *"clinical picture"*. DT1 elaborated further on this: *"Every child, regardless of their diagnosis (...) they have a completely different profile sometimes. What we look for in a child to understand where they are and what skills they have is their clinical picture. That is, a child on the spectrum may be able to use [REMEMO], and another child in the spectrum may not be able to use it. This has to do with the extent... what skills are needed to use this app? This is the clinical thinking we are going to do. The executive functions need to be at a specific point (...) they need to have a good cognitive level to understand the app's functionalities. It doesn't mean that all the children in the spectrum will have these skills or they won't have them, and the same for ADHD, some children may be able to do it and some may not be able to do it. This cannot be specific. It's not dependent on the diagnosis of the child, but on the skills and the characteristics of the child."* Therefore, therapists proposed that, while asking specific questions that children have to fill out to complete a post is good *"from a psychoeducational point of view (DT2)"*, some children *"may find it difficult (DT2)"*. This was corroborated by DP1 and DC1, who noted that they should have the ability to skip at least some questions. DP1 suggested that this was one of the reasons for DC1's limited use, that *"he doesn't have the patience for it (DP1)"*. Apart from the therapists, the majority of parent and child participants stated that they would like to be able to always answer the first introductory question and add the emojis, and skip some of the others, depending on the post they were creating.

PVI.7 Discussion

This paper described our iterative process of designing REMEMO, a mobile and tablet app that can be used by ADHD children and their care ecosystem both individually and collaboratively, by actively involving them in the process. While its features differ based on the user type (child, parent, or therapist and educator), the main objective of REMEMO is to allow logging experiences and emotions, in the form of "posts", and giving participants the choice whether to share those or keep them private **(RQ1)**. By deploying REMEMO in the field for 4–6 weeks with five different groups consisting of children with ADHD and their parents, and additionally siblings and/or therapists for some groups, we explored how embedding such a technology in their lives can impact their communication, everyday interactions, and well-being **(RQ2)**. In particular, our longitudinal field study showed that REMEMO can foster emotional expression, identification and sharing (on a technological and an emotional level), and can encourage reflection for both ADHD children and their parents. Our analysis also showed that REMEMO can support communication and relationship building between children and their care ecosystem, particularly with their parents and therapists, by offering a different channel allowing for affectionate, fun, and transparent communication. Our findings additionally demonstrate how REMEMO can support therapeutic practices, highlighting the different visions that therapists have about its use in therapeutic settings, as well as how it could have therapeutic uses outside of the therapy context, e.g. by supporting emotion regulation for children, or behaviour change through reflection. Also, our findings illustrate the important role of mutual understanding and trust among users regarding the use of such technologies for usage patterns and behaviours, and the crucial influence of background and contextual challenges on participants' use of REMEMO.

While our findings highlighted several positive aspects of the app when integrated into people's everyday lives, such as improved communication, we also identified a variety of challenges that need careful consideration. Our research has highlighted the complexities involved in incorporating new technologies like REMEMO into the fabric of daily life. A notable issue is the power imbalance between children and their parents, which can become more pronounced during app usage. Additionally, our findings suggest that the app might amplify existing challenges in day-to-day interactions, such as those between parents and therapists or between parents and children, possibly impeding the technology's adoption. Despite our efforts to design the app iteratively, tailoring it to the specific needs of each user group, including children with ADHD and their care ecosystem, there is a need to reflect on ways of providing even more nuanced designs. In other words, each user group had very diverse visions of how to use the app which resulted in diverse needs within each user group. This is exemplified by the varied usage envisioned by therapists.

Below, we reflect on our findings and our experiences in conducting this research, exploring how the derived insights could inform future research in the domain of technologies designed for supporting children with ADHD and their care ecosystem, which seek to support their varying needs and interests.

PVI.7.1 Designing Technologies that Cater to the Varying Needs of Different Stakeholders

Throughout this research effort, we sought to actively include both ADHD children and their care ecosystem, and we attempted to design a multi-stakeholder technology, i.e. that could be used by different ecosystem stakeholders, that would cater to their sometimes very different needs and interests. Our field study demonstrated the benefits of such a technology, iteratively designed together with ADHD children and their caregivers. In particular, our findings show how such technologies could allow for fun interactions (see section PVI.6.2), as well as support children with specific ADHD-related struggles, such as emotion regulation (see section PVI.6.2). These findings reflect the suggestion made by previous work to both focus on ludic aspects [549] and empower children with ADHD by allowing them to make choices in their use of technologies, e.g. *how* they use it [549], as well as support ADHD children's caregivers with symptom management, aligning with their expectations of technology use [550]. Whilst our results showed that it requires a reasonably established foundation (in terms of contextual factors as well as regarding a solid social system), our results also showed that when users actively integrated the app into their daily lives, multiple facets could be addressed. In such cases, REMEMO seems to allow for both of those aspects, i.e. for both fun and serious use. However, it does so in a different manner than previous work that often aimed to combine such aspects, for example by inserting ludic elements in family routines, such as shared mealtimes [9] or creating serious games [18, 532]; it rather provides opportunities for distinct ways of use, empowering ADHD children (and their care ecosystem) to autonomously choose their specific ways in which they wish to engage with the technology.

Previous work has argued that the burden that self-tracking can impose could sometimes be mitigated with semi-automatic tracking methods, where data is collected both manually from the user as well as automatically from the system [95]. Choe et al. [95] connect the need and reasoning for employing this type of tracking to the purpose of self-monitoring; for instance, accuracy achieved through automatic tracking is more important for assessment, while enhancing awareness through manual tracking might be more relevant for treatment. Linking this to our work, we observe that allowing children participants of our study to manually log their experiences and emotions, without external support or influencing factors such as wearables or corrections to their data from adults, allowed them to engage with REMEMO in a carefree way, potentially increasing their motivation. Choe et al. [95] propose that users' motivation needs to be considered when designing for different levels of tracking (manual, automatic, or semi-automatic).

In the context of our study on technologies designed for children with ADHD, we found that **manual tracking of emotions and experiences, done independently by the children on their own terms, potentially plays a crucial role in supporting their agency and empowerment**. This approach, however, presents a significant design challenge in balancing the often playful and expressive needs of children with the more structured requirements of adults, such as therapists and caregivers. Although children sometimes logged their emotions using emojis, which were not always perceived by therapists as accurately reflecting the children's actual emotional states, allowing children the autonomy to express themselves without adult correction seems to yield positive outcomes. Therefore, it is crucial for adults to consider this aspect of self-expression and autonomy when evaluating the data recorded by the child, as it respects the child's perspective and fosters an empowering environment for their communication. Alternatively, if adults interfere in this experience, there is the risk that using the app could turn into an additional chore, imposed by the adults [550]. Our aim is the opposite to that, seeking to design technologies that can deliver an empowering experience [491], driven by neurodivergent interests [543, 544]. Hence, finding effective ways to communicate these expressions and their meanings to adults represents not only a challenge for the respective parents and therapists themselves but also poses a unique interaction design challenge for future work.

On another note, we showed that such technologies, especially through the sharing feature, can allow for transparent communication within the care ecosystem, which could mitigate negative outcomes associated with communication barriers that can exist in care teams of children, such as information loss and unclear goals stemming from different approaches and motivations [456]. Shin et al. [515] already highlighted the importance of efficient communication between caregivers and care recipients to alleviate potential misunderstandings and reduce uncertainty by sharing experiences with people in their own networks. Previous work has established a link between providing caregivers the ability to share tracked caregiving data with other family caregivers and increased emotional well-being [628]. Our work extends this understanding by demonstrating that **well-being and relationships can be further supported by involving children (the care recipients) as active participants in tracking and sharing information on caregiving, experiences, and emotions**. Thus, by designing a system that allowed both common functionalities across users and distinct ones, depending on the stakeholder, while still enabling different ecosystem stakeholders to interact with each other through using the system, we provided a prototype that has the potential to support varying needs of different care ecosystem stakeholders. Especially given the different caregiving and parenting strategies and contexts, tailoring technologies to users' diverse needs in this setting seems to allow for a more nuanced adaptation. Thus, future work could investigate this further, by exploring how the design could support caregivers in integrating their own caregiving strategies into the different functionalities. This could potentially mitigate the burden that might be placed by technology usage, by allowing users to integrate their own strategies into their (caregiving) routines and decide how or when the technology is used. This is in line with previous work in ADHD family technologies that underlined how important it is to provide opportunities for both joint and independent use, in order not to restrict autonomy in the usage of the technology and to avoid frustrations [523].

Furthermore, the very different ways in which children, parent, and therapist participants engaged with REMEMO over the course of the field study showed insightful dynamics. In particular, while it can be a useful tool in the therapeutic process, for supporting communication, and also for relationship building within the ecosystems of children with ADHD, our findings revealed that there are certain preconditions that need to be met for these to be achieved. The first precondition regards the abilities of children that are asked to engage with such a system. In particular, through our field study, we discovered that the app requires a specific set of skills, independent of the age and diagnosis, as evidenced by the reports of the therapists, including cognitive skills and executive functioning (see section PVI.6.2 for more details). At the same time, the role of the environment plays a crucial role, as encouragement to use the app seemed to lead to increased usage frequency, i.e. children that received encouragement from their environment to use the app, and whose parents used the app frequently, tended to use it more frequently as well. Overall, it seems that the frequency in which parents engaged with the app mostly echoed that of children (see Table PVI.1). For example, it is evident throughout the different themes presented in our qualitative findings how AP1 regularly used the app and also encouraged her daughter to do the same, and how the lack of use of REMEMO by CP1 is also mirrored in the usage patterns of her two participating children. Additionally, this links to the therapists' motivation to engage with the app and how it was connected to the use of the app by other therapists or members of their group. In our field study, we observed not only the importance of inner motivation and individual engagement with the app but also a significant interplay between the usage patterns of various stakeholders. This connection among different stakeholders – family, therapists, and children – highlights a complex dynamic in the adoption and utilisation of such technologies. **A critical consideration that emerged is the need to prevent adults' perspectives on the app's ideal usage (frequency) from overshadowing the children's autonomy**. This balance is delicate and essential, especially in technologies like REMEMO, which seek to transcend merely addressing symptoms in neurodivergent children following calls from previous work [543, 544, 549]. Therefore, future research should delve deeper into how collaborative technologies designed to support both the care ecosystem and care recipients can foster varied goals and behaviours, while crucially maintaining the autonomy of child users. This exploration is vital to ensure that such technologies truly support the diverse needs and aspirations of all involved in the care ecosystem.

PVI.7.2 Evaluating Technologies with Vulnerable Populations such as Families of ADHD Children

While we identified a variety of positive aspects in our field study, our work also shed light on a number of challenges associated with such endeavours. In particular, as suggested by the difficulties of some participants with adopting REMEMO and integrating it into their daily lives due to contextual challenges in their environment, the question still remains whether it is possible (and desirable) to design technologies that address the needs and interests of care ecosystems encompassing ADHD children, *in a general manner*. In particular, while some participants integrated the technology into their lives and used it, even in varying degrees, there were others, such as the family in group C, who struggled to do so. This struggle was notable even though the participants stated that they believed in the app's potential benefits and expressed a desire to use it more regularly. However, this context and the challenges faced by group C in particular also presented challenges for the authors when making decisions regarding the participation of this group in the study. This situation highlighted the complexities involved in conducting research with vulnerable user groups. While we aim to give all members of the care ecosystem of children with ADHD and the care recipients a voice, the faced challenges underscore the need for sensitivity and careful consideration in research design and implementation. The mother's (CP1) insistence that they wish to participate, as well as her excitement about the app despite its very limited usage and her wish to keep having it on their devices after the second session sheds additional light on the vulnerabilities and tricky paths that need to be navigated in such cases. Thus, while the benefits of striving to include "everyone" (of ADHD children's ecosystems) in designing and evaluating technologies are important, it can link to challenges for the included participants [181], as well as responsibilities for the researchers and hard decisions to make. More specifically, the challenge here is to be as inclusive as possible in recruitment, but at the same time to weigh up the associated costs and benefits for the participants. Added to this is the high relevance of the participants' agency in their decisions, i.e. that they should be the ones to decide whether they wish to be involved, which the researchers did not want to take away from them. **Continuous dialogue with the research community is needed to identify potential ways of dealing responsibly with challenges associated with recruiting vulnerable participants such as families of ADHD children**. As we reflect on our experiences in the study, it seems essential to build a trusting relationship with participants in which users can be open about their decision to opt-out. At the same time, we hypothesise that a close relationship could increase the potential for participants to develop a greater desire to support us in our research, even if it may be a burden for them. Concerning these challenges, we have no concrete answers but pose a call to the research community to continue to discuss and reflect on these issues. The aforementioned challenges are particularly prevalent in the context of longitudinal / field studies, where the investment and demands from both participants and researchers are often higher. The insights stemming from our work in that respect is that there might not be a –technological– solution for everyone, i.e. for every care ecosystem with ADHD children; perhaps it is something to aspire for, and for future work to determine whether it can actually be achieved. This also links to the important concept of technology non-use, which HCI and CSCW communities have been increasingly investigating. In particular, previous work has highlighted the need to consider "non-users" of technologies alongside the users [483], arguing that both non-use and use of technologies constitute a range of meaningful and productive behaviours, with non-use at one end of a spectrum of use [31, 32, 505]. Wyatt [626] categorised non-users into four distinct groups based on their willingness and duration of non-use: resisters, rejecters, the excluded, and the expelled. Adding to this perspective, Satchell and Dourish [483] describe multiple kinds of non-users. These include active resistors, who reject or limit their technological engagement out of their own volition, disenchanted users, who perceive technology as inauthentic; and the disenfranchised, who are hindered in their ability to use or adopt technology. In the context of our own work, the limited or non-use of technology we encountered mainly refers to the last type of non-user based on Satchell and Dourish [483], who would like to adopt and use technology, but cannot for a variety of reasons (similar to the "excluded" non-users proposed by Wyatt [626]). Previous CSCW work has also engaged with parental use/non-use of technology, demonstrating the multiple and often conflicting motivations and needs of parents around this topic, especially around younger children and infants [193]. Most relevant to our work, they highlight the need for mutual understanding of usage patterns of the parents together with the children, and how that could result in increased self-regulation regarding their technology use.

In light of our findings, several critical ethical and practical considerations arise that necessitate further reflection. First and foremost is the ethical dilemma surrounding participant suitability. While certain participants displayed enthusiasm for continuing their use of the app beyond the second session, therapist assessments suggested that not all participants were ideally suited for continued involvement (partly in terms of the life challenges they were currently facing and partly in terms of their skill-set). This is directly linked to therapists in our study expressing how the specific choice of children to participate alongside them was a demotivator for the therapists to engage with the app. This situation presents a significant challenge for us as researchers: Should we prioritise the expressed wishes of participants to remain involved, or should we consider the therapists' expertise in deeming some participants unsuitable? This decision not only involves **respecting the agency of the participants but also ensuring that their participation does not become an additional burden in their lives. The need to balance these factors requires careful ethical consideration**. It underscores the importance of sensitive yet inclusive recruiting practices, especially when conducting research with vulnerable populations.

In our study, we observed a potentially low threshold for frustration among participants, particularly in families with ADHD children. This sensitivity to frustration may be attributed to various factors, including external stressors or simply a lack of time due to numerous other responsibilities, which in turn hinders their ability to report back to researchers. This behaviour became evident in instances where participants ceased using the app after encountering initial difficulties, despite having been instructed to contact the experimenters for assistance. The compounded pressures and time constraints often experienced by these families might contribute to a reduced tolerance for imperfection and challenges in technology use. Recognising these factors is crucial in the design of future studies and technologies in this field, particularly when targeting neurodivergent children and their families. It emphasises the **need for developing more robust, user-friendly, and forgiving systems, integrating lightweight or ideally even automatic reporting mechanisms of usage challenges and bugs**. For instance, subsequent versions of the REMEMO app should consider features that allow for interruptions in the post-creation phase, enabling participants to resume their work without losing progress. This improvement is particularly important, as demonstrated by the case of BP1 in our study, where the inability to save and continue posts at a later time was a significant barrier, leading to a limited number of posts.

Lastly, the challenges related to recruiting and time constraints in vulnerable groups have a profound impact on their user experience with technological prototypes they are asked to evaluate. Participants may feel guilty for not using the technology as intended, and there is also the issue of effectively communicating bugs and issues back to the researchers. This dual challenge of guilt and communication barriers needs to be addressed in future designs and studies, to ensure that participants feel comfortable and supported throughout the process. As we move forward with our research with REMEMO and similar technologies, we hope to use these insights in shaping more inclusive, empathetic, and effective research methodologies and technological designs.

PVI.7.3 Limitations & Future Work

We recognise that our work is subject to certain limitations. In particular, we originally planned to involve more groups in our field study. However, recruitment proved to be an especially challenging endeavour for this work. First, it is a challenge to acquire access to vulnerable populations, such as children with ADHD and their families. Previous studies with children with ADHD have also emphasised the challenges associated with their recruitment, and have involved a limited sample [533, 549, 606], while still acquiring rich data and deriving meaningful insights. In our case, this was made especially difficult due to both the longitudinal aspect of the study, and the fact that we sought groups of stakeholders extending beyond the family. In particular, we attempted to recruit both therapists as well as educators; however, we were successful with recruiting only the first, while the latter constitutes imminent future work. However, we were still able to involve an overall considerable number of participants ($n = 18$ in the field study alone), and to collect rich data from both the interviews as well as the questionnaires and usage logs. This allowed us to extensively explore the impact of REMEMO on the groups' communications, interactions, and well-being. Future work comprises of both continuing to run the field study with the participant groups reported in this paper, who all expressed their wish to continue participation, as well as expanding our participant list and recruiting additional groups, including educators. Furthermore, we are currently working on addressing usability issues that we uncovered as well as updating REMEMO based on some of the findings of this study, e.g. allowing participants to save their progress when creating posts, or to skip some of the questions during post-creation.

PVI.8 Conclusion

In this paper, we presented REMEMO, a multi-stakeholder mobile and tablet app for children with ADHD and their care ecosystem (family, therapists, educators). REMEMO allows logging experiences and emotions, revisiting them, and choosing whether to share them with members of the care ecosystem. The app includes both individual and collaborative features, allowing for both personal and joint use. Its multi-stakeholder nature lies within the ability of different care ecosystem members to use it, with different adaptations of the app available depending on whether the user is a child, parent, or therapist and educator. First, we described our iterative design process, which actively included ADHD children and their caregivers. Then, we report on a longitudinal (4–6 week) field study, where REMEMO was deployed with five different groups, including ADHD children and their parents, and additionally siblings and therapists in some cases. Our findings demonstrate various usage patterns of REMEMO among those stakeholders, which impacted them both individually as well as affected their interpersonal interactions. In particular, our findings show that REMEMO allows for emotional expression and reflection, and that it can support affectionate and transparent communication and strengthen relationships, while at the same time allowing children to make choices about their use of the app and have fun. We also discovered that some participants had unspoken expectations regarding the app's use. This highlighted the crucial role of mutual understanding and trust, as a breach in these aspects could affect the way they used the app. Additionally, we identified background and contextual difficulties that directly affected the frequency and patterns of use of the app and the overall experience. Based on our findings, we discuss opportunities and challenges regarding designing technologies that cater to the varying needs of different stakeholders of ADHD children's care ecosystem. We also engage in a critical discussion about (the ethical challenges of) evaluating technologies with vulnerable populations such as families of ADHD children, especially in longitudinal studies. We hope that our work will inspire future research in designing technologies that address both the needs and interests of ADHD children and their caregivers. This research should consider the intricacies and challenges of this endeavour, and discern when non-use of technology might be more appropriate than its use.

PVI.9 Acknowledgements

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PART III

DISCUSSION

Preface to the Discussion

The third and final part of this thesis presents a general discussion. First, it discusses the findings of the studies conducted in the context of this PhD, detailing how they addressed the RQs. It then delves into specific contributions and insights stemming from this work, critically examining the employed approach of “designing beyond symptoms” and involving multiple care ecosystem stakeholders. Following that, the “Children and Care Ecosystem Well-being & Empowerment Supported through Technology” (CWEST) model is proposed, which is constructed based on the findings across the studies included in this thesis. Subsequently, unanswered questions arising from this work are discussed, both in the form of limitations and future work and of a reflection on the opportunities and challenges of engaging with vulnerable populations in user studies, such as neurodivergent children and their care ecosystem. The thesis concludes with a comprehensive summary that captures the core insights of this research.

CHAPTER 4

Discussion of the Research Questions

The research described in this thesis addressed the following primary research question (RQ): ***How can technologies be designed to empower and support the well-being of both ADHD and neurotypical children and their care ecosystem?*** To that end, the primary RQ of this thesis was deconstructed into three distinct questions, investigating the roles and needs of ADHD children and their care ecosystem (RQ1), exploring how technologies can be designed to empower them (RQ2), and studying the impact of the technologies that were designed on their well-being (RQ3). Below, I elaborate on how the findings from the studies conducted as part of this PhD addressed the RQs and the insights derived.

4.1 Revisiting the Primary RQ

As an overall answer to the **primary RQ**, based on the findings of the studies in this thesis, this work posits that technologies for empowerment and well-being *can* be designed by actively including ADHD, neurotypical children, and their care ecosystem members in their design and evaluation, and as their users. The present thesis has shown that this can be achieved by creating technologies i) that can be used both individually and collaboratively by children and multiple care ecosystem members, ii) that address their different needs and interests, e.g. through tailored interfaces, and iii) by "designing beyond symptoms" to look at the bigger picture of well-being rather than specific ADHD-related challenges. I argue that technologies that employ these three aspects can empower users, granting them both power-to and power-over, while enhancing their well-being through support of psychological, emotional, and social components [290, 291]. This can be achieved by integrating key features: facilitating emotional expression, fostering reflection, supporting active decision-making in technology interactions, and promoting communication, while at the same time enabling individual and joint technology use by various care ecosystem stakeholders.

Collectively, in answering the formulated RQs, this thesis investigated the relationship between the concepts of empowerment and well-being in the context of technologies for children and their care ecosystem. This work has shown that designing for empowerment led to *also* designing for well-being, as the technology features that were demonstrated to support empowerment for ADHD and neurotypical children and their care ecosystem, can also support their well-being (see Tables 4.1 and 4.2). It should be noted that this research was not able to establish the degree of the relationship – this is beyond the scope of this work.

The findings from our studies regarding the impact of technologies on the well-being and empowerment of children, both ADHD and neurotypical and their care ecosystem are primarily positive. However, it is crucial to acknowledge that technology, both "designed beyond symptoms" as well as solutions supporting symptom management, is not a "panacea". In fact, there are scenarios where technology may not be the most effective or appropriate tool for every challenge that (ADHD) children and their care ecosystem might face. For instance, different therapeutic approaches such as cognitive and behavioural therapy can play a crucial role in mitigating challenges associated with ADHD by helping children develop skills to overcome related struggles effectively [576]. Techniques learned in therapy, such as behavioural modification and strategies for emotion regulation [148, 385, 635], can support children in ways that technology cannot, including but not limited to the benefits of direct human interaction. Therefore, it is critical to also consider the aspect of technology *non-use*, acknowledging that not every "problem" needs a technological solution and that sometimes not engaging with any type of digital devices and rather going outside to play is the most beneficial scenario for children's well-being [88]. Recognising when technology might overcomplicate or detract from other goals or human interactions is vital, in order to ensure that it serves as a tool for enhancement rather than a replacement for fundamental therapeutic practices or interpersonal interactions.

Below, I engage with each of the RQs separately, discussing how the studies included in this thesis addressed them.

4.2 RQ1: Investigating the Roles and Needs of ADHD Children and their Care Ecosystem in Technology Design, Evaluation, and Use

In answering **RQ1**, the roles and needs of ADHD children and their care ecosystem in technology creation and use were identified. Based on our findings from paper P I, we demonstrated that prior work in technology design and evaluation does not sufficiently involve ADHD children and their care ecosystem. Moreover, existing approaches often do not target multiple care ecosystem stakeholders as users, limiting the ability for joint use by children and their care ecosystem members. This clashes with children's need for better communication and collaboration among them and their care ecosystem members and can lead to obstacles to empowerment, as showcased in paper P II. These observations are in line with previous work that emphasised the need for creating a shared understanding in care coordination for children [456]. Our findings, in that respect, further highlighted the connection between empowerment and well-being in this context. Paper P II identified specific paths to empowerment for ADHD children which, among others, included the support of their autonomy, agency, satisfaction, as well as feeling included and accepted within their care ecosystems (see Figure PII.3), which are all concepts that link to well-being. In particular, this thesis has already discussed how literature has linked autonomy and agency to both well-being and empowerment (for an overview see Table 2.1). Moreover, satisfaction links to emotional and psychological well-being, and inclusion and acceptance to psychological and social well-being [290, 291].

Concurrently, the aforementioned findings from paper P I, which emphasise the shortage of technologies targeting multiple members of children's care ecosystems, conflict with their complex and multifaceted roles, highlighting the need for more collaborative technologies. Moreover, findings from both papers P I and P II show that the majority of existing technologies are intervention-driven, aiming to address symptoms, which might lead to technologies becoming chores for some children. This resonates with findings by Spiel et al. [542], who noted a similar trend in autism technology research, favouring symptom-focused interventions over empowerment-driven approaches. Therefore, based on our findings, investigating how to design technologies that are driven by ADHD children's interests and needs in order to empower them and support their overall well-being is crucial, along with exploring technologies that allow both individual and collaborative use.

At this point, it is important to reflect on the methods that this dissertation used to identify the roles and needs of ADHD children and their care ecosystem with respect to technology, thus addressing **RQ1**. First, it should be noted that our literature review in paper P I specifically focused on HCI publications. Given the multidisciplinary nature of research on ADHD, including e.g. psychiatry and medicine, this focus led to excluding relevant research based on publication venues, which could potentially enrich our understanding of ADHD children's interactions with technology. However, reviewing the entire literature available on the subject was beyond the scope or purpose of this review. Moreover, despite the multi-stakeholder nature of our interview study in paper P II, interviewing a select group of participants, who all came from countries within Europe, may not fully represent the diverse experiences and needs within the worldwide ADHD community. Nevertheless, it allowed us to acquire rich insights into the lived experiences of multiple care ecosystem stakeholders, including ADHD children, parents, therapists, and teachers residing in four countries within Europe.

Overall, addressing **RQ1** highlighted the need to engage with both ADHD children and their care ecosystem in technology design and evaluation. It also showed that current technological solutions provide limited support for integrated engagement among multiple members of the care ecosystem, affecting the daily experiences of ADHD children. Thus, there is a need for technologies that support the complex and layered roles within the care ecosystem, as well as their diverse interests. The present thesis addressed the above aspects by adopting a more holistic approach, considering the interconnected but also varying needs and roles of all ecosystem stakeholders. Moreover, this work actively involved them throughout the design and evaluation of the proposed technologies. This comprehensive perspective guided the design of the technologies studied in papers P III, P IV, P V, and P VI, addressing **RQ2** and **RQ3**, elaborated upon below.

4.3 RQ2: Empowerment through Technology: Affording Power-to and Power-over

The second research question focused on the aspect of empowerment, investigating how to design technologies to empower both ADHD and neurotypical children, affording them both *power-to* and *power-over* [467]. This approach aimed to actively design for the varying needs of both children (neurotypical and with ADHD) and their care ecosystem, and explore how to navigate power imbalances between children and their caregivers within technology design and use, nurturing children's agency. Since the power imbalances between adult caregivers and children exist both in the case of neurotypical *and* neurodivergent children, while being more pronounced for the latter group, this thesis investigated how to design empowering technologies for *both* neurotypical and ADHD children.

Table 4.1 Explanation of which features of the technologies designed in papers P III, P IV, P V, and P VI supported empowerment and how, as well as whether this affords users power-to or power-over. Unless otherwise specified, "users" refers to both children and members of their care ecosystem.

Papers	**Features**	**Explanations**	**Empowerment Support**
P III	Tangibility	Allows use by various age groups as well as equal access, encouraging collaboration.	Affords users *power-to* feel connected by engaging in joint interactions.
P III	Real-time feedback of users' actions	Leads to mutual awareness and control and facilitates communication and collaborative interactions.	Affords children *power-over* their interactions with their grandparents, instead of (only) the other way around, as the mutual awareness and control provide children with the certainty and safety to take control and assume leading roles during playtime.
P IV, P V, P VI	Individual recording and reviewing of experiences and emotions	Allows individual emotional expression, as well as to individually reflect on experiences and emotions through the act of recording or reviewing them.	Affords users *power-to* emotionally express, and reflect on emotions and experiences through technology usage, with the help of facilitating aspects, e.g. emojis in P V, P VI, and externalising their states in a creative manner (i.e. through drawing) in an immersive environment (VR) in P IV.
P IV	Collaborative recording and reviewing of experiences and emotions	Allows collaborative emotional expression and reflection, with an emphasis on perspective-taking. Supports mutual awareness and control, ensuring that both users engaged in the activity can actively determine its outcome, nurturing their agency.	Affords users *power-to* engage in collaborative emotional expression and reflection. Also, affords users *power-over* the outcome of the joint activity (e.g. the mutual drawing in P IV).
P V, P VI	Sharing recorded experiences and emotions as well as reactions to them	Allows to collaboratively reflect on shared experiences and emotions, stimulating conversation and reflection both during the technology use as well as after, in real-life interaction scenarios.	Affords *power-to* share emotions and experiences in an indirect manner, in users' own time, and facilitates transparent communication. Affords users *power-over* their interactions with others, ensuring their voices are not only heard but also acknowledged, e.g. enabling children to initiate discussions on important to them matters with the support of technology, thereby enhancing their agency.
P V, P VI	Allowing to choose if and with whom to share personal data	Allows users to make decisions within their technology use and be in control of their choices and of their own data.	Affords users *power-over* their interactions with the technology and over their own data, by directly being in control of how to use the technology.

Table 4.1 demonstrates how the technologies proposed in this thesis are connected to empowerment, addressing **RQ2**. This table not only identifies but also elaborates on the various technology features that are proposed in this thesis to foster empowerment, linking them to the specific papers which contributed those findings. It represents an integral component of the "puzzle" of **RQ2**, offering a comprehensive perspective on how technology design can be strategically employed to enhance empowerment, particularly in the context of designing for neurodivergent individuals. Nevertheless, it should be noted that not all participants' interactions with the technologies designed in this thesis necessarily constituted empowering experiences. Specifically, the dynamics observed between one grandparent-grandchild pair while using MagiBricks illustrate this point. The child, feeling empowered by the system, assumed the leader role while playing with his grandfather, e.g. instructing him what to do and what they should build with the smart toy bricks, which, however, was not the case for the grandfather. Notably, the child frequently overlooked his grandparent's suggestions during their playtime with the regular toy bricks, reducing the opportunities for shared moments of connectedness. Furthermore, while using MagiBricks, the child monitored his grandfather's constructions closely, often dictating actions and critiquing mistakes, which may have impacted the quality of their interaction. Therefore, we can see that even though the aspects described in Table 4.1 *can* lead to empowerment, engaging with technologies does not necessarily benefit all individuals uniformly. This "gap" in who benefits from technologies usually refers to the unequal access to technologies [577], or differences in the ability to utilise technology effectively among those who have access [229]. Our findings show the importance of considering how the use of technology might affect family members' empowerment to different degrees, demonstrating how this might especially be the case in collaborative settings of use, where an individual's experiences depend not only on the technology itself but also on their interactions with their co-users. Ultimately, this reflection urges a deeper investigation into how and whether empowerment through technology can be "equitably distributed" among all users. This becomes particularly relevant in collaborative use settings involving diverse groups or family dynamics, to ensure that users have equitable opportunities for both power-to and power-over in their interactions with technology and with each other.

Overall, in addressing **RQ2**, this thesis contributes the following findings. First, this thesis proposes not only designing technologies for ADHD children that afford them "power-to" [467], by enabling them to accomplish new things e.g. by supporting their emotion regulation skills, thus supporting their *autonomy*. It also proposed to afford them "power-over" [467], by designing "empowering experiences" [491] that go "beyond symptoms" (P II), driven by their interests and needs, and establishing their *agency*. This work argues that this can allow them greater control over their technology use and can even support them to take leading roles in their interaction with older care ecosystem members within their joint technology usage, adding to the discussion about power imbalances between the "all-knowing" adults and the "all-learning children" [142]. Moreover, this research has demonstrated that actively involving children and their care ecosystem in the design and evaluation of technologies can empower them by affording them power-over, as their voices and needs get to actively shape the creation of technologies, in line with Schneider et al.'s [491] notion of "empowerment through the design process" and extending that to empowerment through participation in the *evaluation* process as well. Furthermore, this work has shown that another way that technologies could grant children "power-over" is to actively include choices that children get to make as part of their interactions with technologies, fostering their ability to exercise control and make decisions, thus nurturing their sense of agency (e.g. children being able to choose whether to share their data with others in MoodGems and REMEMO).

Therefore, this thesis has demonstrated that designing "beyond symptoms" and designing technologies that actively include decision-making can lead to technologies that can deliver "empowering experiences" *and* power-over. This extends the understanding built by Schneider et al.'s [491] conceptualisation of empowerment, which only associated "empowering experiences" with power-to, showing how it can also be linked to power-over as well.

4.4 RQ3: Impact of the Proposed Technologies on Well-being

Based on the conceptual basis built in paper P II, key aspects for supporting the well-being of children and their care ecosystems included: i) supporting the interactions and communication between children and members of their care ecosystem, ii) allowing children and their care ecosystem to express their experiences and emotions, both in individual and collaborative settings, and iii) allowing children and their care ecosystem to reflect on their experiences and emotions, both in individual and collaborative settings. It should be noted that there is no standard method to assess well-being in children [437]. As elaborated in the Background chapter of this thesis (chapter 2), I deconstructed the concept of well-being to core concepts that are positively linked to it and aimed to design for those in order to support the overall well-being of children and their care ecosystem. This has been the primary method for studying the impact of this thesis' proposed technologies on well-being. Additionally, in the field study with REMEMO, we employed the Middle Years Development Instrument (MDI) [493], a self-report questionnaire designed for children older than 10 years, which gathers data on their thoughts, feelings, and experiences. By aggregating specific measures from the MDI, we can compute the "Well-Being Index". The primary goal of administering this questionnaire was to acquire insights into the children's backgrounds and enhance our understanding of their interactions with REMEMO and the other participants, helping us to contextualise our findings. Therefore, in addressing **RQ3**, this thesis designed and evaluated different types of technologies employing these concepts (papers P III, P IV, P V, P VI), with the goal to investigate how they can support the well-being of children and their care ecosystems.

Table 4.2 provides a detailed overview of the features that the technologies designed in this thesis employed and how these specifically contributed to supporting well-being [1]. In particular, for each feature, I explain how it supports well-being based on the working definition of this thesis, and therefore detailing how each feature, present in one or more of this thesis' designed technologies, can support psychological, emotional, and/or social well-being [290, 291].

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[1] In order to avoid repetition, the explanations of each feature are available in Table 4.1. Here, in Table 4.2, I focus on how these same features supported well-being, while the previous Table showed how they supported empowerment.

Table 4.2 Explanation of which features of the technologies designed in papers P III, P IV, P V, and P VI supported well-being and how. Unless otherwise specified, "users" refers to both children and members of their care ecosystem. Please note that the similar impact on well-being of the features "tangibility" and "real-time feedback" stems from the fact that they both support collaborative interactions.

Papers	**Features**	**Well-being Support**
P III	Tangibility	Supports emotional well-being by delivering an engaging and satisfactory activity and by encouraging collaborative interactions, psychological well-being by nurturing relationships, and social well-being by increasing feelings of connectedness and belonging.
P III	Real-time feedback of users' actions	Supports psychological well-being by encouraging collaborative play, which nurtures relationships, and social well-being, since this collaborative play increases users' feelings of connectedness and belonging.
P IV, P V, P VI	Individual recording and reviewing of experiences and emotions	Supports psychological well-being as it can lead to reflection, which can increase positive self-perception by reminding users of positive aspects of their lives, e.g. a child recording moments when they had fun, as well enhancing effective daily life management, e.g. serving as a cathartic exercise or personal tool for problem-solving and perspective taking.
P IV	Collaborative recording of experiences and emotions	Supports psychological well-being by supporting healthy relationships, e.g. through the joint engagement in the activity, emotional well-being by supporting satisfaction, e.g. when perspective-taking leads to conflict resolution or argument mitigation, and social well-being by allowing for a meaningful joint activity that can support feelings of connectedness, e.g. by spending quality time together.
P V, P VI	Sharing recorded experiences and emotions as well as reactions to them	Supports psychological well-being by supporting healthy relationships e.g. by strengthening relationships through fun, transparent and/or fun communication, emotional well-being by supporting satisfaction e.g. in the cases where users receive positive feedback, and social well-being by supporting feelings of connectedness through this exchange, e.g. by understanding each other's emotions and perspectives.
P V, P VI	Allowing to choose if and with whom to share personal data	Supports psychological well-being, as allowing users to have control over their own data and choices within their technology interactions can nurture their agency, which can be connected to positive self-perception and satisfaction, as users are empowered to make their own choices. Moreover, agency links to well-being [8, 507].

However, we need to acknowledge the risks, challenges, and complexities of integrating technologies into the lives of children, both ADHD and neurotypical, and their care ecosystem. For instance, studies have already shown that the continuous notifications that we receive on our smartphones can cause inattention and hyperactivity in the general population [311] – which was, for instance, a driving reason for us not to implement any notification system in our field study with REMEMO. Moreover, research has demonstrated the vulnerability of ADHD children specifically to “problematic” technology use [608], for instance exhibiting more addictive behaviours with respect to video games [357]. This consideration was reflected in our study with MoodGems, where some parents and children participants appreciated the prototype exactly because they perceived it as some type of digital furniture, different from traditional screens, and therefore not as a system that would exacerbate technology use. The challenge here is to balance the engagement and benefits of technologies to well-being, with their potential to incur unwanted negative consequences.

Further reflecting on the risks of technology use, which can be counteractive to children’s well-being, it should be noted that “digitising” our interpersonal interactions, e.g. through increased use of social media, can result in less focused in-person conversations and diminish the sense of presence in face-to-face interactions [17] thereby undermining deep engagement and empathy in relationships [17]. These negative outcomes can impact the development of social and emotional skills [438], which are vital for the development of children [149, 237]. While the prototypes proposed in this dissertation were carefully designed in order to support emotional expression and reflection and to foster interaction within the technology usage, the effects of long-term integration of these technologies, e.g. throughout one’s childhood, have not been studied. Additionally, while participants’ interactions with all the designed technologies in our studies were overall positive and were shown to support their well-being, there were a few instances of unintended consequences arising from their use. In particular, in the field study with REMEMO, the ability to share posts within the broader care ecosystem caused conflict, when a mother participant shared a post about her daughter’s low performance in mathematics. Although the post was well-intended, praising the daughter’s resilience and maturity, the daughter’s discovery of this shared information led to a breach of trust and subsequent conflict with her mother. This aspect of user expectations and trust dynamics shaping participants’ interactions with technologies is discussed in detail in the pertinent paper P VI. This underscores the complexity of multi-stakeholder technologies, particularly when personal data sharing is involved, highlighting the intricate challenges of both designing *and* using such systems. The need to carefully design such technologies is therefore underscored, reflecting “our need to address accountability, responsibility and ethics” as researchers and designers [177, p.22], and emphasising the complexities of navigating diverse stakeholder perspectives throughout the technology lifecycle.

Overall, in addressing **RQ3**, this thesis contributes the following findings. First, this work has shown that designing for children’s empowerment by actively involving them and their care ecosystem as co-designers, evaluators, and users of technologies can lead to technologies that support their overall well-being as well. This is evident as the same features that were employed which fostered empowerment, visible in Table 4.1, supported well-being in the ways visible in

Table 4.2. Moreover, this dissertation has demonstrated how a range of different technologies, including VR, physical situated displays, and mobile applications, which allow for emotional expression and reflection through recording and sharing of emotions, can contribute to the well-being of children and their care ecosystem. Furthermore, I have shown how our findings on how technologies that provide real-time feedback about their state and users' interaction with them allow for mutual awareness and control in joint playful activities between children and their care ecosystem can support social well-being, by fostering a sense of connectedness and belonging.

Therefore, based on our findings, this thesis proposes that future technologies aiming to support well-being and empower both ADHD and neurotypical children and their care ecosystem could employ the key features of Table 4.2. However, the degree of the individual effect of these features on well-being has not been established based on this work. Nonetheless, this work has demonstrated how different combinations of these features can support well-being, and I have detailed how each of these features can support both well-being (Table 4.2) as well as empowerment (Table 4.1).

CHAPTER 5

From Findings to Insights

This thesis has demonstrated how we can design a range of technologies, supporting diverse outcomes that can improve well-being and support empowerment. Additionally, I have shown how the designed technologies can facilitate various interactions within children's care ecosystems. This regards both communicating caretaking information among caregivers in a transparent and immediate manner, but also affectionate and fun communication and playful interactions. Below, I engage with key implications that stem from this work. First, I critically reflect on the extent to which the proposed strategy of "designing beyond symptoms" is a suitable approach across different scenarios. To that end, I examine it under a lens that goes beyond HCI, touching on the fields of psychology and sociology, among others. I also contemplate the application of this thesis' approach with different neurodivergent populations and discuss the involvement of both ADHD and neurotypical children in this research. Subsequently, I evaluate the impact of adopting a care-ecosystem-based approach throughout this thesis. I elaborate on the challenges and opportunities of involving these multiple and sometimes diverse perspectives and propose that technologies that seek to navigate this and support well-being and empowerment for children and their care ecosystem could provide opportunities for both individual and collaborative usage.

5.1 Designing Technologies Beyond Symptoms: a Best of All Worlds Approach?

This work has broadened the agenda on technologies for ADHD children and their care ecosystems, showing how we, as researchers and interaction designers, can go beyond developing technologies focusing on symptoms, to engaging children themselves. This engagement is twofold; it regards both actively involving children in the technology creation process, allowing their voices and interests to contribute in shaping technologies, as well as in the technology use, enabling them to reflect on their emotions and experiences and thus actively participating in supporting their well-being. While it is still important for research to develop diagnostic and intervention tools, this thesis adopts a different framing and shows how to design technologies so that children become more aware, empowered, and engaged in their own well-being through and within their technology use. The research in this dissertation has demonstrated how this conceptual framing can be beneficial, as it can result in technologies that satisfy diverse needs, including both ADHD and neurotypical children, as well as those of their caregivers. It has shown that the technologies that are built based on this approach can be based on neurodivergent interests and needs while at the same time supporting ADHD children with aspects that they might struggle with, such as emotion regulation, which might be more of a key motivator for technology use by parents or therapists. Thus, this approach has the potential to deliver a “best of both worlds” scenario, both catering to neurodivergent interests *and* supporting ADHD-related challenges.

5.1.1 Reflecting on our Approach Beyond HCI

Here, I reflect on our approach of “designing beyond symptoms” in a context beyond HCI research. First, this approach aligns with positive psychology, as similar to how Seligman [499] aimed to “develop interventions that build the enabling conditions of life, not just interventions that decrease misery” [499, p.233]. Similarly, the aim of this research is to enhance overall well-being instead of only treating symptoms. We focus on recognising and fostering strengths, for instance, by engaging ADHD children in co-design sessions to influence technology design, instead of solely attempting to ’correct’ symptoms. Concurrently, our approach finds grounding in literature across a variety of fields, including medicine, psychiatry, sociology, and clinical psychology [242]. Scholars in those fields have debated the use of the so-called “social model of disability” versus the “medical” one. “The medical model focuses on individual pathology and attempts to find ways of preventing, curing or (failing these) caring for disabled people” [355, p.86]. Conversely, “the social model locates disability not in an impaired or malfunctioning body, but in an excluding and oppressive social environment” [355, p.88]. Relating this back to HCI research, Spiel et al. [543] already criticised how the medical model fails to support neurodivergent individuals, their agency, and interests in the context of playful technologies.

Importantly, although the social model can empower people with disabilities, it can be challenging to accept the idea that one’s disability is solely a result of societal factors [242], especially for people with certain conditions where medical interventions may be necessary for well-being and livelihood [332]. In particular, people can feel this implies that their individual challenges “should be ignored” [242]. This directly reflects the aforementioned perspective that I do not argue for the elimination of symptom-based approaches, but rather call for more work that employs the proposed “design beyond symptoms” strategy, which is largely underrepresented in current approaches and technological solutions. This integrated approach resonates with the views of feminist disability scholar Liz Crow [119]. While critiquing the medical model, Crow proposed a renewed social model, recognising that a condition’s negative impacts could independently hinder one’s social interactions, and acknowledging that medical intervention could play a beneficial role in mitigating these effects.

The models discussed above have been developed to address a broad concept of disability. This thesis rather focuses on neurodiversity, which addresses the notion of neurological differences, and particularly on designing technologies for ADHD children, distinguishing these from tools aimed at supporting individuals with physical disabilities. Below, we discuss the application of our “designing beyond symptoms” approach to other neurodivergent populations.

5.1.2 Application of our Approach to other Neurodivergent Populations

In considering this thesis’ broader implications beyond focusing on children with ADHD, I reflect that even though our proposed approach of “designing beyond symptoms” proved to be a suitable and beneficial approach in the context of this thesis, I do not claim that these benefits necessarily generalise to other neurodevelopmental diagnoses. In particular, further research is needed to explore how and to what extent the same benefits (i.e. leading to technologies that are both driven by neurodivergent interests and support symptom management and other caregivers' wishes) extend to other neurodivergent populations, such as children with autism. Several of the ADHD children who participated in our studies also had co-morbid diagnoses, such as high-functioning autism, and while both therapist and parent participants across studies with different systems pointed out the expected usefulness and benefits of the developed prototypes for different populations beyond ADHD children, further work is needed to actually investigate the implementation of this approach with different populations. Nevertheless, the potential of applying our approach to other groups was further corroborated by the feedback from therapist participants about how such technologies could help build empathy and emotion regulation skills for all children. Concurrently, previous work on technologies for autistic individuals has also advocated for technologies that support their agency and are driven by their own interests and needs and not only neurotypical expectations [542, 543]. This further underscores the value of investigating how the approach of this research and the proposed technologies can support different neurodivergent populations, such as children with autism. Nevertheless, the value of therapeutic approaches for supporting neurodivergent individuals should not be undermined, both in the context of traditional therapy as well as regarding the variety of technological solutions that can support neurodivergent people with specific symptoms (e.g. see [57, 103, 205]).

5.1.3 Involvement of both ADHD and Neurotypical Children in our Studies

This thesis engaged both neurotypical and ADHD children in the various studies, given its goal of investigating how to design for diverse needs, in order to empower and support the well-being of children and their care ecosystems. In that respect, given that the power imbalances between adult caregivers and children are existent both in the case of neurotypical *and* neurodivergent children, while being more pronounced for the latter group, this thesis investigated how to design empowering technologies for *both* neurotypical and ADHD children.

It should be noted that throughout our studies in papers P II through P VI, we did not identify any distinct differences regarding *the impact* of technologies that could be generalised as being specific to ADHD or neurotypical children. While this research did not conduct any comparative analysis, this is in line with our findings in paper P II, which formed the conceptual basis for the technologies investigated in the subsequent papers. Specifically, throughout the multi-step, multi-stakeholder approach employed in P II our aim was not to compare the ADHD and neurotypical participant groups but to understand how technology design can empower children, both with ADHD and neurotypical. However, there was a notable distinction *in the methodology* that we employed in that respect. In particular, while both groups actively participated in and enjoyed the co-design activities, we had the therapists of the ADHD children present during their sessions. The aim of this was to provide additional support and guidance and to help children stay focused on the task. Our method, in that respect, is in line with previous work with neurodevelopmentally diverse children, which emphasised how including children's caregivers could help mitigate challenges in their participation [41].

Apart from this distinction in the two groups' participation, our findings that technologies facilitating the recording, sharing, and reflection on experiences and emotions could empower children and support their well-being applied to both groups, based on the analysis of not only the children's participation but also the therapists'.

We also did not observe specific differences in our findings in the rest of the papers where various technologies were explored with different constellations of participants, including both ADHD and neurotypical children. It should be noted, however, that not all the technologies have yet been studied with ADHD populations (i.e. MagiBricks and TeenWorlds). Moreover, it should be clarified that not all the data acquired were the same, especially when referring to interview data we collected from families with ADHD children, where they emphasised specific struggles they faced in their everyday experiences. However, those aspects significantly varied within our samples of ADHD families. Therefore, without further analysis, no definitive conclusions can be drawn. Interestingly, one participant pair in TeenWorlds comprised of a teenager and their parent disclosed that they were neurodivergent towards the end of the study – but without specifying their neurodevelopmental diagnoses. Given that we did not separately analyse this pair, we cannot speak to a different effect of TeenWorlds on them compared to other participants.

Overall, involving both ADHD and neurotypical children, along with members of their care ecosystem, in different constellations throughout our studies allowed us to gather rich and diverse data. While no comparative analyses were conducted in this thesis, our findings have demonstrated the potential of the proposed technologies to support the well-being and empower both ADHD and neurotypical children. It is part of future work to investigate MagiBricks and TeenWorlds with ADHD children and their care ecosystem.

5.1.4 Implications for Future Research

Overall, this thesis proposes that "designing beyond symptoms" can be a beneficial approach towards supporting the interests, needs, and well-being of ADHD children, and can result in empowering technologies that afford both ADHD and neurotypical children power-to *and* power-over. I call on future research to investigate the applicability of this approach to other neurodevelopmental diagnoses, such as autism. At the same time, I acknowledge that technology use can come with risks and complications, and emphasise that the methods employed in this thesis and the proposed technologies are not meant to be considered "*the* solution" to all challenges that neurodivergent and neurotypical children and their care ecosystems might face. Nevertheless, future work could employ "designing beyond symptoms" as an approach, creating and investigating alternative technologies beyond those that this thesis proposed and their impact on both neurotypical and neurodivergent children's well-being, as well as on the well-being of their care ecosystem. A starting point for the latter could be engaging with other concepts that are positively linked to well-being, e.g. creativity, and designing to support those.

5.2 A Care Ecosystem-based Approach towards the Design, Evaluation, and Use of Technologies

Throughout this dissertation, a key consideration has been children's care ecosystems, given their catalytic role in children's everyday experiences and overall well-being [227, 427, 494]. Both children and members of their care ecosystem have been actively involved throughout the studies conducted in this thesis. To illustrate, this research investigated their role in technology design, evaluation, and use as detailed in paper P I. Furthermore, they assumed the roles of active informants in paper P II, which helped to build the conceptual basis for the design insights that guided this work, and as co-users of the designed technologies in papers P III, P IV, P V, and P VI. In this way, this work has broadened the research agenda around well-being technologies, especially for ADHD children, by adopting a care ecosystem-based approach. Unlike many existing studies, this thesis has involved an extensive range of care ecosystem members such as peers, therapists, and teachers, both as users and in the design and evaluation processes. This multidimensional inclusion builds on the principles outlined by Forlizzi [175], who advocated for shifting from user-centred to stakeholder-centred design. Building on this, the present thesis not only incorporates various stakeholders in technology design and evaluation but also focuses on creating multi-user technologies. These technologies satisfy and adapt to the diverse needs and interests of these stakeholders through tailored interfaces or by allowing both individual and collaborative usage, thus addressing them in a comprehensive manner.

Drawing from our experiences of involving diverse constellations of care ecosystem stakeholders in the various studies of this thesis, we acknowledge that this endeavour brings significant advantages as well as challenges. In the sections below, we critically reflect on both, providing an analysis of different outcomes and insights gained from engaging with these multiple stakeholders in the context of this thesis.

5.2.1 Recruitment & Rapport

A primary challenge of the multi-stakeholder approach adopted in this thesis was recruiting these diverse and often vulnerable and hard-to-reach stakeholder groups to participate in our studies. These challenges are well-documented in the literature, with previous studies underlining the difficulties in acquiring access to ADHD children and their care ecosystems [533, 606], and more generally, in recruiting various family members for research participation [79, 326]. Especially when seeking to engage multiple perspectives, as in our case involving multiple care ecosystem stakeholders, recruitment emerges as a key issue, necessitating consent from numerous individuals to participate [638]. Consequently, we as researchers need to allocate significant time to develop and maintain sustainable relationships with participants [638]. Beyond the time required from the researchers' side, participants themselves need to allocate significant time resources, especially in the case of longitudinal studies. This requirement can pose a challenge for stakeholders already managing tight schedules, such as families with (ADHD) children, potentially becoming a barrier to participation altogether. Concurrently, my PhD started in 2020, in the middle of the COVID-19 pandemic, which in itself posed significant barriers to accessing participants. Another key consideration in that respect was that COVID-19 disproportionately and significantly impacted children with ADHD and their families [419].

In general, engaging with diverse and vulnerable populations in studies requires unique considerations to ensure the well-being of both the participants and the researchers. As Henderson [235, p.167] highlighted, “sending out a survey to people whom you will never meet is much different” from working with marginalised or under-served groups, and researchers can “change as a result of the process of research”. She further underscored the importance of establishing rapport between researchers and participants, which is “easier said than done” [235, p.165]. Throughout the course of this thesis, I managed to establish meaningful connections with participants across the world, including families, professionals, and therapy centres participating in our studies. This in itself posed both a challenge, given the considerable struggle my co-authors and I faced with finding stakeholders willing to participate, as well as a great benefit. I personally feel honoured to have forged these relationships with unique and wonderful individuals, and privileged to have been able to gather insights from their worlds.

5.2.2 Navigating Diverse Perspectives

Another aspect that presented us both with a challenge and a unique opportunity was acquiring and reconciling the multiple and often divergent perspectives of these multiple stakeholders. A characteristic example from our studies is that of children and therapist participants being excited about the possibility of keeping their recorded data for themselves with MoodGems and choosing if, whether, and with whom to share them. Therapists particularly commended this feature as an agency-supporting aspect for ADHD children, with the potential to “give them back some control”. However, some parents –albeit not the majority– were very adamant in their positions that they wanted to be able to bypass the system and still see all the data their children recorded with the system, even suggesting that the system could give the illusion of privacy without that being the case in reality. This points to particularly difficult to navigate dynamics and considerations, showing how it can be challenging to reconcile these very contradictory points of view of the various stakeholders.

At the same time, this brings to the forefront the question of when it might be more appropriate to *not* involve *all* care ecosystem stakeholders. Apart from the fact that it is evidently easier to not include such a diverse range of perspectives, as it reduces the effort and time required for recruitment, decreasing the number of stakeholders involved can also streamline decision-making, which might be necessary in time-critical situations or when resources are limited. Nevertheless, this can also lead to negative repercussions. These may include a lack of comprehensive understanding or acceptance of decisions made in the technology design by users, or the undermining of its effectiveness over time. Notably, based on our findings not all points of divergence in perspectives might present the same degree of difficulty to navigate. For instance, the contradicting opinions of some participants in REMEMO regarding receiving notifications from the system could be addressed by embedding this as a customisable setting within such technologies. On the other hand, conflicting opinions regarding whether the application should allow therapists to share their own posts in REMEMO with children is another example of a more difficult to navigate aspect. This becomes particularly relevant if and when such technologies are translated from research prototypes to commercial digital tools, as this could raise ethical and legal issues, e.g. as “patient” information might be transferred through such technologies. This highlights the importance of forging synergies between researchers and policymakers, in order to navigate these multifaceted aspects.

Previous HCI research across different domains has highlighted the existence of tensions and conflicting perspectives in designing for specific populations. For example, previous HCI work around online health communities has found that informational and socio-emotional needs may sometimes align but can also clash, leading to conflicting priorities and expectations [392]. More specifically regarding ADHD children and their caregivers, Cibrian et al. [106] identified tensions and challenges when trying to design applications for wearable technology supporting children with ADHD. Highlighting that researchers should consider the needs of both children with ADHD and their caregivers, their results point to tensions between self-regulation and co-regulation. This refers to balancing the needs for regulation within the family while fostering ADHD children’s independence to regulate themselves.

Viewing the challenges of multi-stakeholder research through a broader lens highlights the inherent complexities of qualitative family research [228, 638]. Previous studies have demonstrated the value of capturing diverse perspectives within family dynamics, especially when these perspectives might be conflicting [638]. Research involving neurodivergent populations, for example, emphasises the importance of respecting and integrating these varying viewpoints, which can enrich the research outcomes and lead to more inclusive technology designs [414]. The role of the researcher is pivotal in navigating these complexities. By adopting a “bird’s eye” view, researchers can synthesise different accounts to understand where perspectives align or conflict, thereby managing to balance these views effectively [228, 365]. Thus, it is crucial to incorporate the perspectives of various family members into research [638], or more broadly, of the care ecosystem stakeholders. Doing so is a vital step in capturing “the meeting ground of multiple realities” [318, p.189] that coexist within a child’s care ecosystem.

In this thesis, actively involving diverse care ecosystem stakeholders from the outset not only mitigated complex dynamics but also provided significant insights into technology design for these users. In particular, this inclusive process allowed us to form an understanding about how to design technologies that would be accepted by both (ADHD) children *and* their caregivers, who often have distinct motivations and interests with respect to technology use. This was emphasised in the findings of paper P II and is in line with literature that has noted the divergent views among researchers, parents, and children about children’s technology use in general [54, 316, 445, 455], which is a common family conflict [379]. Designing technologies that might be accepted by both children and caregivers directly connects to this thesis’ proposed approach of “designing beyond symptoms”, which allows deriving design implications for technologies that are driven both by neurodivergent interests, so they do not “become a chore” for children(P II), but at the same time can also address aspects with which caregivers need support, such as helping children with emotion regulation.

Furthermore, this care ecosystem-based approach allows deriving broader insights that would not have otherwise been possible. This is supported by family research that has shown that involving multiple stakeholders, such as both children and their parents, yields information that could not have been obtained by involving only one family member [638]. In more detail, and in the context of this work, the considerations around policy implications when integrating systems like MoodGems in clinical contexts, which are important for future research to consider, arose exactly because of this intersection of different stakeholders from various environments (see home, versus therapy contexts). At the same time, distinct considerations also arose when we deployed REMEMO with ADHD and neurotypical children, their parents, and their therapists. In particular, there were several tensions and challenges identified when bridging those different "worlds", which are detailed in paper P VI, e.g. illustrating how some therapists struggled to integrate using the app into their already overloaded schedule at work, for instance, due to back-to-back sessions with other children. This suggests that there are structural changes that might be needed in order to facilitate the integration of digital tools within already defined environments, such as a therapy centre that operates in a specific manner.

Overall, while it remains challenging to navigate the diverse perspectives that arise when involving multiple stakeholders, it can lead to rich and multifaceted insights. Acknowledging that these multiple perspectives might arise before conducting a study is perhaps one way of being prepared as researchers to assume this "birds eye" view. This could potentially allow us to create a comprehensive narrative based on our participants' accounts [228, 365], while carefully considering their diverse needs.

5.2.3 Different Stakeholder Constellations for Multifaceted Insights

Importantly, the studies in this thesis investigated different constellations of care ecosystem stakeholders. From involving two care ecosystem stakeholders (children and their grandparents in MagiBricks) to engaging all key members (children, their families, therapists, and teachers in the design of REMEMO), the studies conducted in this PhD provided rich insights by exploring various constellations of these stakeholders. For instance, these insights included uncovering differences in the interactions with TeenWorlds and its effectiveness based on whether teenagers used it together with other teenagers or their parents. Additionally, our findings pointed to varying user expectations regarding the same technology; for example, in REMEMO, some users preferred to log only positive experiences, whereas others wanted to track both positive and negative ones with the technology. This underscores the importance of developing flexible and customisable technologies to accommodate diverse user needs, aligning with previous work which emphasised the importance of flexibility, particularly for self-tracking technologies [24]. It should be noted that, while we designed REMEMO for and with all identified key care ecosystem stakeholders, we were not yet able to evaluate it with one of these groups (teachers). Nonetheless, engaging with the rest of the stakeholders allowed us to build an understanding of how the various care ecosystem members, as well as children themselves, are impacted by such a technology. This included the identification of both positive outcomes, e.g. the application being able to support their well-being and strengthen their relationships, as well as challenges, e.g. how existing communication barriers sometimes remained and affected the use of this application.

Moreover, these different constellations across the studies allowed us to uncover that TeenWorlds "worked better" for one stakeholder group, i.e. teenagers interacting with their parents, but did not work as effectively for another, i.e. teenagers interacting with teenagers. Overall, this meant that teenagers interacting with their parents were able to reach deeper levels of reflection than those interacting with their peers, based on both our qualitative and quantitative analysis. To illustrate, our results revealed significant differences in perspective-taking between the two types of pairs, as measured by the Interpersonal Reactivity Index-Perspective Taking (IRI-PT) subscale. Notably, the increase in perspective-taking was more pronounced among parent-teenager pairs than teenager-peer pairs, suggesting that teenagers did not enhance their perspective-taking abilities as effectively when paired with other teenagers.

Therefore, investigating the same technology with different user groups can yield rich insights into the necessary adjustments required to meet the diverse needs of various user types. This underscores the potential for future research to explore additional configurations of care ecosystem stakeholders beyond those examined in this thesis. It also shows the need to design technologies that provide different support opportunities when interaction with technology requires scaffolding for different stakeholder groups. For instance, while we found that in TeenWorlds, many teenager pairs needed the scaffolding to achieve reflection, in the study with MagiBricks, we saw that younger children had the scaffolding of the feedback that the system provided. In particular, having mutual awareness and control during the shared playtime in MagiBricks through the systems' multimodal feedback empowered even younger children to assume leading roles in their interactions with their grandparents. Concurrently, the grandparents were further supported by the system's tangibility and familiarity.

Thus, this calls for future research to investigate how such systems, offering opportunities for emotional expression and reflection, can support a variety of users. To illustrate, future work should explore how systems like TeenWorlds can facilitate emotional expression and well-being across different care ecosystem constellations and age groups. This is particularly important for younger children and neurodivergent groups like those with ADHD, who might need even more support to navigate emotionally loaded situations, and may require varying degrees of scaffolding to achieve reflection. Moreover, integrating therapists as facilitators could help ensure a supportive environment for these interactions. Nonetheless, this constitutes both a design opportunity and a tension, as children and especially teenagers' needs to establish their agency should be considered. Ultimately, balancing children's independence with appropriate scaffolding from caregivers remains a critical area for development, as evidenced by prior work with ADHD children and their caregivers [106, 523].

5.2.4 Designing for both Individual and Collaborative Use

Another aspect of the employed care ecosystem-based approach refers to the usage of the designed technologies. In particular, a key design recommendation stemming from this work is to design technologies that allow for both individual and collaborative use. Research efforts conducted in parallel to the work in this dissertation echoed this suggestions, emphasising the importance to balance opportunities for individual and joint use, e.g. for self and co-regulation within ADHD families [522, 523]. Our findings, and especially the integrated understanding gleaned from paper P VI where multiple care ecosystem stakeholders used REMEMO in real-life settings, in both individual and collaborative ways, point to the potential of such technologies to navigate the complex perspectives of diverse stakeholders. In particular, this work proposes that such technologies have the potential to allow for varied ways of use, based on users' preferences, interests, and needs, which could potentially mitigate potential diverging opinions that formulate at the time of the design of technologies.

Below, I elaborate on cases where each of these usage modes (individual and collaborative) was found to be particularly beneficial. Drawing from our findings, I propose that individual usage scenarios are beneficial for individual reflection, externalising and regulating one's emotions in an independent manner, and problem-solving. Therefore, future research that aims to foster autonomous emotional expression that supports agency and emotion regulation could include individual aspects of use. On the other hand, allowing collaborative use within technology interactions can support communication and strengthen relationships. Collaborative use can also be suitable when users require support, e.g. teenagers requiring scaffolding for effective reflection by their parents in TeenWorlds. Thus, future research that seeks to support the interactions between children and their caregivers should consider integrating collaborative usage aspects. Based on our findings, this has the potential to foster their interactions both *within* the technology use cycle, e.g. by providing feedback to each others' logged data while using a system, or also *outside* the use cycle, e.g. as the shared data between users can serve as a conversation starter for in-person discussions. Moreover, I argue that when combining individual and collaborative usage, users can be empowered to make choices about the way they use the technology, echoing our previous findings about the important role of decision-making in users' interactions with technology to afford them both power-to and power-over; for instance, children having power over their decision whether to share their self-tracked data with others, thus transitioning from individual to collaborative use.

Furthermore, the individual or collaborative nature of the interaction can be fostered by the design choices. For instance, tangible artefacts encourage collaboration and joint usage [338, 356, 584], which for example was the case with MagiBricks. On the other hand, a mobile application such as REMEMO can invite both individual and collaborative use, as mobiles are associated with both individual interactions and with messaging apps for interacting with others. Thus, REMEMO being available on mobile devices could have further contributed to the notion that users can decide whether to share their self-tracked data in the application. TeenWorlds, in the meantime, combined an individual and joint experience, presenting a more structured approach as participants first interacted individually and were then guided to interact in a joint setting. This suggests that different kinds of technologies (e.g. mobile, tangible, VR) can be employed to shift the focus and intentions of the users between individual and collaborative modes of usage.

5.2.5 Implications for Future Research

Overall, following this care-ecosystem based approach can procure important benefits and lead to the design of meaningful technologies that satisfy diverse user needs. However, there are still various challenges involved and satisfying *all* users' motives remains a complex and demanding task. The studies of this dissertation have identified tensions between supporting children and establishing their agency, as well as between satisfying the varying stakeholders' needs and how to navigate directly contradicting views. This thesis proposes that a way towards navigating those multiple perspectives is to continuously engage the various stakeholders, both as designers and users of technologies, and to design technologies that allow both individual and collaborative use. Combining these with multi-stakeholder tailored interfaces could help balance diverging expectations and needs and empower users to actively exercise control within their technology usage. At the same time, this thesis emphasises the need for future research to delve deeper into navigating divergent stakeholder perspectives in children's care ecosystems. It suggests that a first step could be forging synergies between researchers and policymakers in order to navigate this complex design field, harnessing the existing opportunities to meaningfully support both ADHD and neurotypical children and their care ecosystem, while actively identifying and addressing potential challenges by continuously engaging with these stakeholders.

CHAPTER 6

A Model for Children and Care Ecosystem Well-being & Empowerment Supported through Technology (CWEST)

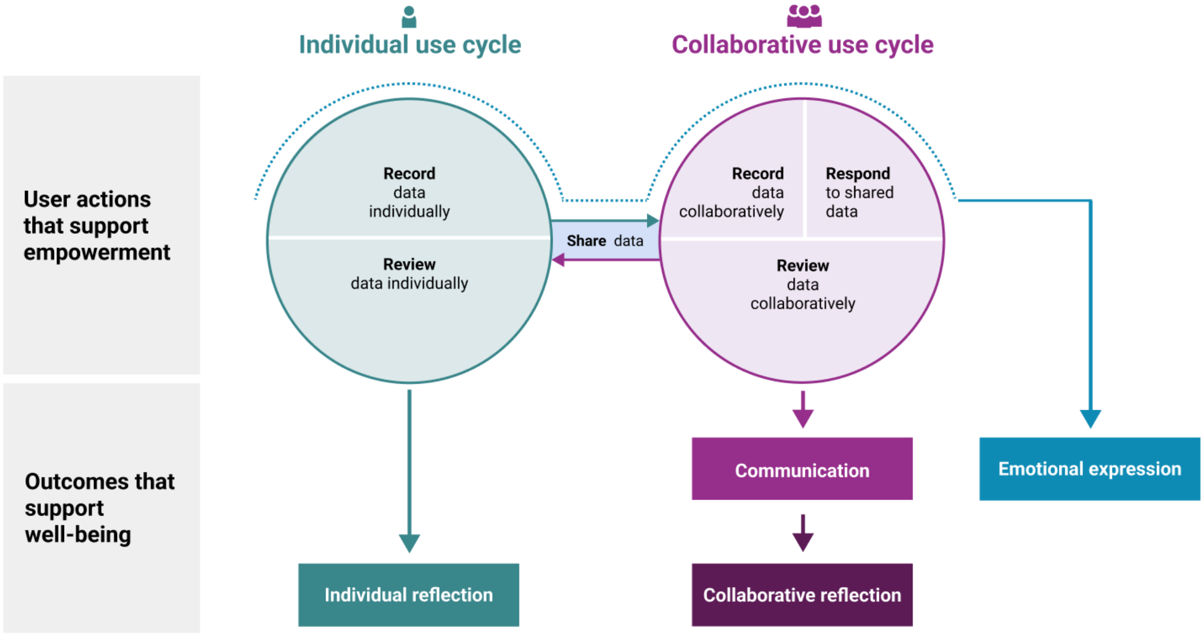

Fig. 6.1 The "Children and Care Ecosystem Well-being & Empowerment Supported through Technology" model (CWEST). It demonstrates how children and their care ecosystem can engage in individual and/or collaborative use cycles with technologies that allow recording and reviewing data, as well as sharing and responding to shared data in collaborative use cycles. These actions can support users' empowerment (upper part of the Figure) (granting them "power-to" and/or "power-over", see Table 4.1 for further explanations). Users can select which and how many of these actions to engage in each time they interact with the technology. The model also illustrates how these actions are connected to outcomes that foster well-being (bottom part of the Figure): individual reflection, communication, collaborative reflection, and emotional expression. Here, "data" refers to logged activities and emotions, and can be one's own data or other's data that have been shared.

The findings of the studies included in this thesis showed that technologies that allow both children and members of their care ecosystem to express and reflect on their emotions and experiences by digitally recording them, and which provide them with the option to share their recordings among each other, could support their well-being and empowerment. Importantly, these technologies would be desired by both the caregivers and the children. Based on the findings from the studies encompassed in this dissertation, and particularly from papers P II, P IV, P V, and P VI, this thesis proposes a model of supporting well-being and empowerment for children and their care ecosystems through the processes of emotional expression, communication, and individual and collaborative reflection using technology. The proposed *Children and Care Ecosystem Well-being & Empowerment Supported through Technology* (CWEST) model is illustrated in Figure 6.1, and extends this dissertation to offer a theoretical contribution [617].

The need for this model stems from two key factors. First, it arises from the importance of conceptualising our findings on how emotional expression, communication, and both individual and collaborative reflection can be linked to specific user actions facilitated by technology, supporting both empowerment and well-being. Second, specifically regarding the concept of reflection, the need for such a model comes from our involvement of *both* caregivers and clinicians *as well as* of children in the collaborative reflection process. In particular, I aim to extend previous work that has included *only* caregivers and clinicians in that respect (see the "collaborative reflection process" by Marcu et al. [353]) or engaged *only* children as the stakeholder that is supported to reflect with the help of therapists (see the "Safety, Connection and Reflection" framework by Loke et al. [335]). This extension is based on the benefits of involving ADHD and neurotypical children in reflection processes, both individually *and together* with their care ecosystem, as this thesis has demonstrated. To that respect, this newly proposed model aims to illustrate the steps that are involved in this process, based on the findings of the studies included in this dissertation. Overall, the model shows how children and their care ecosystem can engage in individual and/or collaborative use cycles with technologies that allow specific user actions which can support their empowerment (upper part of Figure 6.1), autonomously choosing the actions that they wish to engage in during their technology use, and how these actions are connected to specific outcomes that support well-being (bottom part of Figure 6.1).

In the following, I explain how this model was constructed, I provide a description of its aspects, and I explain how researchers can use it for designing technologies that support well-being and empowerment for children and their care ecosystems. Finally, I elaborate on the aspect of reflection, which plays an important role in the model, and juxtapose the model to relevant prior conceptual work in the domain of well-being.

6.1 Constructing the Model

Here, I explain how I constructed the CWEST model, elaborating on the aspects it is comprised of and how each was derived from the work included in this thesis. On a high level, the CWEST model demonstrates how children and their care ecosystem members can be empowered to individually or collaboratively record experiences and emotions using a technology, thus emotionally expressing themselves, and review and share them with each other. It also shows how this process can foster communication and lead to reflection, thus supporting their well-being. Importantly, the model was constructed based on the findings of studies that actively involved both children, ADHD and neurotypical, and various constellations of their care ecosystem members. The aspects that form the model are marked with bold font below to allow the reader to easier connect the explanations with Figure 6.1.

As a starting point, the findings from the interviews conducted in paper P II highlighted the aspect of supporting **communication** among the care ecosystem members and the child

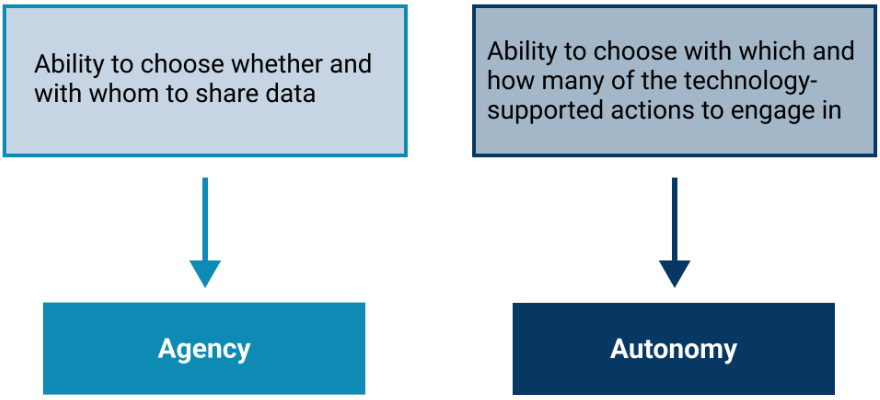

Fig. 6.2 This figure emphasises how two key processes of the model connect to autonomy and agency. It illustrates that allowing users to choose whether and with whom to share their data while using technologies can support their agency, and that enabling them to choose with which and how many of the technology-supported actions they engage can support their autonomy.

as a key action for fostering the child's empowerment and well-being. Additionally, based on the remaining studies reported in paper P II, we found that enabling children with ADHD and their care ecosystem to **express their experiences and emotions** and **reflect** upon them, could also foster their well-being. Based on the above, the studies reported in papers P IV, P V, and P VI, each implemented the actions of **recording**, **reviewing**, and **sharing** one's own experiences and emotions as well as others', as well as interacting with each other through **responding to the shared data** in various types of technological prototypes, including VR and mobile applications, and physical displays. These technologies were studied with different constellations of children (ADHD and/or neurotypical) and members of their care ecosystem (e.g. parents, therapists, or peers), and in different usage scenarios (individual or collaborative). Those studies showed that allowing children and their care ecosystem to individually engage in those actions can facilitate **emotional expression**, and **individual reflection** (i.e. self-reflection), thus supporting their well-being. Moreover, those actions support empowerment, as they afford users power-to perform these actions [15], these "new possibilities" [467], thus fostering their autonomy. Additionally, they empower users by granting them power-over their interactions with technologies, for instance by allowing them to select whether and with whom to share their data, in that way nurturing their agency as they have control over their decisions [254] (see Figure 6.2 for a visualisation, and Table 4.1 for a detailed overview of all the aspects that support power-to and power-over in our designed technologies). This forms the **individual use cycle**. Concurrently, collaboratively engaging in those actions could support joint **emotional expression**. Additionally, by **sharing data** and **responding to the shared data** and thus engaging in active **communication** between them, users can also **collaboratively reflect** on both their own and others' data together. This then forms the **collaborative use cycle.**

The above served as an explanation for the construction of the model. Below, I describe its aspects and how it can be used by researchers and designers in the domain of technologies for children and their care ecosystem.

6.2 Description of the Model

Based on the construction of the model explained in the previous section, here I describe it in detail, elaborating on each aspect and its connections. The model conceptualises how technology can support well-being and empowerment of children and their care ecosystem. In particular, it consists of user actions that can empower children and their care ecosystem (see upper part of Figure 6.1) and connects these to outcomes that support well-being (see bottom part of Figure 6.1), encapsulating these actions within individual or collaborative use cycles of a technology. In that way, it illustrates the relationship between empowerment and well-being in the context of this thesis, and in particular how empowerment can lead to well-being in technologies that allow users to perform specific actions. Moreover, users have the autonomy to choose when interacting with a technology that is based on the CWEST model, whether they wish to engage in an individual use cycle, a collaborative one, or both. In each case, they can autonomously decide if and how many of the actions within each use cycle they perform – in other words, they are free to engage in the number and type of actions they choose, while still being able to use the technology. This is an empowering aspect in itself, affording them power-to choose how they interact with the technology, thus fostering their autonomy (see Figure 6.2). Naturally, when users use a technology for the very first time, they have to perform a record action, in order to initially have some data inside the system (either individually or collaborative), unless another user has already shared data with them, in which case they can engage in any of the available actions, as then there is already a resource of data in the system.

Below, I describe the individual and collaborative use cycles in more detail. First, for the individual use cycle, the process entails individually recording one's data with the technology and reviewing them at a later time, or individually reviewing shared data that the user received from someone else. These actions can lead to individual reflection. Sharing data is what connects the two use cycles: in order to transition from an individual use cycle, especially in the first time of use, a user has to share their data, or has to receive data from someone. Another way to enter the collaborative use cycle is to initially record data in the technology collaboratively with another user. Apart from this action, the collaborative use cycle entails reviewing data that has been shared or received together with others, and responding to shared data within the technology. By reviewing and responding to each other's data, users can engage in communication and collaboratively reflect on them. Thus, this process overall can support the collaborative reflection on both own and others' data. Moreover, recording data either individually or collaboratively, as well as responding to shared data, can support emotional expression, linking the two types of use cycles with a common outcome that supports well-being.

6.3 Using the Model

The CWEST model serves not only as a lens to understand the work conducted in this thesis. It also illustrates how the core concepts of emotional expression, communication, and reflection can be connected to each other within technology use and how they can lead to well-being in that setting. Thus, the model can be used by researchers and designers in the domain of technologies that seek to support well-being and empower children and their care ecosystems. In particular, they can use the model to position already existing technologies designed for these populations, mapping the features of their systems to the aspects that comprise the CWEST model. This could show how existing technologies that were not necessarily framed with well-being or empowerment as a goal have the potential of supporting users in that respect, or show aspects that can be enhanced, in case there is a wish to alter a system to support these goals. For instance, existing technologies that enable family members to track and view each other's logged activity and/or emotions could be enhanced by integrating explicit data-sharing functionalities. This could promote greater agency by allowing children more control over their data, thus mitigating privacy concerns [430], while enabling parents to use the technology more transparently. For example, parents could choose to share sensitive information only with older children, amongst themselves, or not at all, which could address a common tension in family informatics where parents might wish to omit sharing certain data to shield their children [213, 429], or feel uncomfortable with systems that automatically share such data with the entire family [522].

Additionally, researchers could use the model as a basis and extend it by including new aspects, and demonstrating how the newly developed technologies support empowerment and/or well-being. For instance, while the studies of this thesis involved *manual* logging of data, future work could investigate the extent to which the CWEST model is applicable to technologies that allow *automated* tracking and logging of data. While not yet implemented, findings from our study with MoodGems, where we discussed the potential to have *semi-automated* tracking of data based on participants' preferences and needs, point to this direction.

Researchers can also employ the CWEST model to create new technologies based on its aspects. To illustrate, below I present a brief example of how the model can be used to inform the design of a new smartwatch and smartphone system that aims to support the well-being of children and their care ecosystem. In order to facilitate connections to the model's illustration in Figure 6.1, I mark the aspects of the model with bold font below. When designing such a technology, the researcher may consider the different aspects of the model, and ensure that their application accommodates all of them. In this way, the model can inform the user journey and heuristic evaluations of the system. The system's general functionality could e.g. be mood tracking and sharing among a child, their siblings, parents, and grandparents, with the initial goal to support long-distance relationships within families – as for instance, sharing everyday life data is a commonly used technique by technologies for intergenerational connectedness (e.g. [48, 73, 90, 101]). Employing the **record data individually** aspect of the model, the system could allow the users to track their mood by presenting them with a selection of emojis and pre-determined colours that represent specific moods to choose from (e.g. like in the zones of regulation [312]). This would allow quick and on-the-go tracking, since a smartwatch can be worn in different contexts, and smartwatches are commonly used for personal and health tracking (e.g. [12, 84, 391, 523]). Utilising the **review data individually** aspect, the system could allow users to review their recorded data on their personal smartphones, thus entering the **individual use cycle**. At the same time, once a user shares their data, the other users' smartwatches could faintly vibrate and show the emoji that the user selected, surrounded by the selected colour. This would then correspond to the **share data** aspect of the model, entering the collaborative use cycle. After individually reviewing that data, the smartwatch could allow the receiving user to tap on the screen and quickly **respond to the shared data**, thus engaging in communication while using the technology. If the users that live apart then decide to phone each other based on the information they received, or discuss their exchanges via the system when they meet again and revisit some of those exchanged moods (engaging in **reviewing data collaboratively**), they can engage in not only **communication**, but also in **collaborative reflection**. Therefore, while the technology's main goal was to support intergenerational communication and connectedness, mapping each user action to the CWEST model highlights its potential to also support family well-being and empower users through these interactions.

6.4 The Model as Part of a Reflection Ecology

Given the prominent role of reflection as an aspect in the CWEST model, and as a core concept in this thesis which links to well-being, this section elaborates on the use of the term within the model, based on the findings of the user studies of this thesis. It also discusses the levels of reflection that participants in our studies reached using our proposed technologies, based on Fleck and Fitzpatrick's framework of reflection [171].

First, it should be noted that our findings indicate that a technology affording users the actions visible in the model can facilitate reflection at different times after deciding to engage with it: before, during, and after recording data. For instance, in our study with REMEMO, some participants reported already deeply thinking about what they were going to record before actually logging it in the application, especially prompted by the title-giving of their post. Moreover, besides the reflection that occurred for some participants during their recordings within the technology use e.g. collaboratively reflecting on how they felt during a conflict in TeenWorlds, some participants engaged in reflection after technology use, e.g. thinking back on their posts to find solutions to an issue they recorded in REMEMO. This support both during and after technology use is also the case for another outcome that fosters well-being in the model: communication. In particular, the findings of our studies demonstrated that the processes visible in the model can support communication both during and after technology use. An example of the first is MoodGems and REMEMO allowing indirect communication between users through responding to each other's shared data within the technology; while an example of the second is how the reviewing of others' data facilitated in those two systems can serve as a conversation starter, e.g. encouraging in-person communication about topics that the child shares with their caregivers using the technology. In REMEMO, this for instance allowed a mother and daughter participant pair to engage in a calm conversation about a previously heated discussion topic, after they had interacted about it while using REMEMO.

Furthermore, it should be noted that, while communication can result from users engaging with any number of the three actions inside the collaborative use cycle, it does not necessarily lead to collaborative reflection. Similarly, engaging with the actions inside the individual use cycle does not always lead to individual reflection. Reflection can be a challenging activity and often does not occur automatically, but needs to be encouraged [525]. In line with this, and given that the model includes reflection as an outcome that supports well-being, I specify that the individual and collaborative reflection processes in the model refer to users reaching a deeper understanding. Employing Fleck and Fitzpatrick's framework which categorises the outcomes of reflection in five levels [171] ("R0: Description", "R1: Reflective Description", "R2: Dialogic Reflection", "R3: Transformative Reflection", and "R4: Critical Reflection"), in the model users engage in individual and collaborative reflection by reaching *at least* the second level, i.e. R1. This is supported by our studies, where users achieved varying degrees of reflection based on this framework [171], overall ranging from R0 to R3. For instance, in TeenWorlds those ranged from participants not reporting a reflective experience, thus only reaching R0, while still finding the experience enjoyable and beneficial for fostering interpersonal relationships, to R2, where they uncovered new strategies for communication and conflict resolution, such as the value of active listening and expressing feelings. "Only" reaching R0 in the example above is an example of the previously discussed aspect that some teenagers required more scaffolding in order to successfully reflect, while other participants were able to reach deeper levels of reflection, i.e. R2. As another example, in our study with REMEMO, while the majority of users seemed to engage in either R1 or R2, our findings show that some users even reached the fourth level of reflection R3, leading to a change in their understanding of an event. This is evident in the example of a mother participant who used REMEMO as a "cathartic exercise" and for problem solving, by recording the experience in the app, reflecting on it, and finding a solution and then recording it, thus changing her understanding of the situation, according to her.

6.5 Situating the Model within Existing Literature

Below, I discuss how the CWEST model builds on or differs from existing models in HCI literature that connect to it, either because they conceptualise reflection, or because they visualise some aspects of the relationships between children, caregivers, well-being, and technologies. Please note that this is not meant to be an exhaustive list of all available frameworks that employ one or more of the aforementioned concepts. Rather, this section's aim is to situate our proposed model within existing literature, by juxtaposing the proposed model with key examples drawn from literature.

First, examining the specific aspects that comprise the CWEST model, it is relevant to reflect on Epstein et al.'s [154] "lived informatics model of personal informatics", and Bentvelzen et al.'s [43] "Technology-Mediated Reflection Model". The first specifically focuses on how users decide to track and select a tool, how they use it to collect, integrate, and reflect as part of tracking and acting, and also include possible lapsing and resuming to track. The second describes conditions and barriers for reflection on personal data, consisting of a temporal and a conceptual cycle of reflection, in order to identify the possible obstacles a user might face when using a system for reflection. With respect to these models, the CWEST model regards the processes that begin *after* a user has chosen a specific technology to use. It focuses on the subsequent actions and outcomes that occur during their engagement with that technology each time they use it. Thus, unlike the models by Epstein et al. [154] and Bentvelzen et al. [43], which incorporate a “lapsing” aspect, the CWEST model concentrates on the dynamics of actual technology usage. It details how users independently decide which actions to engage in, whether in an individual or collaborative use cycle, or both. This in turn results in outcomes which include not only reflection but also emotional expression and communication.

Moving to a high-level examination of the CWEST model that goes beyond a specific aspect but rather focuses on the inclusion of children and their caregivers in the design of technologies, the “Children in the Centre” (CiC) Framework by Kärnä et al. [282] considers children with “special needs” and their families. It aims to guide researchers in multidisciplinary research and design collaboration and in including children with “special needs” into the design and development processes of technologies. This framework consists of five levels, and involves four specific stakeholder groups: children, their families, tutors, and researchers from special education and computer science, aligning with our approach of involving multiple care ecosystem stakeholders. The CiC framework also seeks to challenge the conventional clinical perspectives of viewing children with “special needs” only as subjects of interventions or consumers of technology, shifting the narrative away from a problem-focused one [582]. This echoes this work’s approach of “designing beyond symptoms”. A key difference with the CWEST model lies in the purpose of the CiC framework compared to it. The CiC framework’s main focus is on how various care ecosystem stakeholders can be involved into the design and development processes of technologies for children with “special needs”. While this aligns with the method employed in the studies of this thesis, which ultimately led to the construction of the proposed model, the CWEST model itself has a different focus. Namely, it regards the actions that transpire while using a technology, rather than showing how the various stakeholders can be considered in its design – which in our case, was a prerequisite for designing technologies that support diverse stakeholder needs and interests. Nevertheless, similar to how the CiC framework can inform technology design for children with “special needs”, the CWEST model can inform the design of well-being technologies for both neurotypical and ADHD children, as well as their care ecosystem, by illustrating empowering user actions and linking them to specific well-being supporting outcomes (see section 6.3 above).

Relevant to the proposed model, primarily due to its support of reflection for children, is also the “Safety, Connection and Reflection” framework by Loke et al. [335]. It illustrates how therapists can scaffold reflective experiences for social emotional learning in children with “serious emotional behaviour issues”, based on their needs: safety, relatedness, empathy, and social resilience. Similar to the CWEST model, this framework is meant to guide the design of technologies that support children. However, while the CWEST model engages with reflection as one of multiple outcomes that link to well-being, across different contexts (e.g. home, therapy), this framework specifically targets technologies to support safety, connection, and reflection in scaffolding social emotional learning towards improved emotional behaviour for children in a therapeutic setting. Moreover, in Loke et al. [335]’s framework the therapist plays a key role in shaping the experience of reflection for the child, while the model proposed by this thesis demonstrates how the child can engage in reflective experiences both individually and collaborative, together with not only therapists but also other care ecosystem members. At the same time, Loke et al. [335] emphasised that caregivers must also be aware of their own emotions, to scaffold the reflective experience for children. Building on this, the CWEST model explicitly includes the engagement of not only professionals but also other members of the care ecosystem with their own emotions, alongside the child.

While the aforementioned frameworks actively engaged children, either conceptually as technology designers and users [282] or as the subjects which are supported to reflect [335], the following two models present the key difference that they do not engage the children as active users; they rather focus on their caregivers. In particular, Marcu et al.'s [353] model of the "collaborative reflection process" outlines the processes by which care teams iteratively work together towards decision making and treatment goals for children with "behavioural needs". The collaborative reflection process by Marcu et al. [353] consists of a short-term inner loop and a long-term outer loop. The inner circle of this process in particular includes recording data, reflecting on the data both individually and collaboratively, and corroborating interpretations of the data with others. The CWEST model provides a different approach to collaborative reflection, detailing how that occurs when children and their care ecosystem are the intended users of the technology, and when the data is not only patient-related data, but also include e.g. emotions. While the goal of the collaborative reflection process as proposed by Marcu et al. [353] is to improve the efficiency and effectiveness of children's treatment teams, collaborative reflection in the CWEST model is a goal that can be achieved when users engage in actions within the "collaborative use cycle" (see Figure 6.1), and is an outcome linked to communication and to the well-being of both children and their caregivers. Similar, to Marcu et al.'s [353] model, the CWEST model is tightly linked to some form of communication: in our case, transparent, indirect, fun, and/or affectionate communication, based on our findings, and in theirs, to corroborating patient-related information among the caregivers. Thus, expanding on Marcu et al. [353]'s notion of collaborative reflection, the CWEST model contributes to our understanding of how children and their care ecosystem can both individually and collaboratively record, review, and reflect on their data and emotions.

Building on Marcu et al.'s [353] "collaborative reflection process", Richards et al. [456] expanded it by specifying the factors facilitate a continuous progression through its stages. In particular, they showed that distributed care teams need to develop shared understanding to transition through the stages of collaborative reflection. Their "conceptual framework of shared understanding in care coordination" aims to inform future designs of systems that can support information sharing and mitigate barriers to creating this shared understanding. Specifically, their framework includes three common barriers caregivers face in developing a shared understanding in children's care coordination: differences in approaches and motivations, inability to rely on documentation, and information loss during transfer across the care team. It also proposes nine practices that can help in that respect, via two key mechanisms: building relationships across boundaries, and sharing actionable information. The CWEST model presents a way to employ those two mechanisms, applied in a context that goes beyond the sharing of care coordination information among caregivers. For instance, by enabling both children and their care ecosystem to share their data across different contexts (see the aspects that include "record" and "share" in the CWEST model), the sharing of descriptive information can be facilitated, which is a practice for achieving shared understanding based on Richards et al.'s [456] framework.

Similar to Loke et al.'s framework [335], the frameworks by Marcu et al. [353] and Richards et al. [456] both document reflection processes in therapy and intervention-related contexts. In contrast, the approach of this thesis is to support well-being and empowerment through technologies across contexts, and without necessarily focusing on symptoms, treatment, or interventions, thus providing a more integrated understanding of how to incorporate the aspect of collaborative reflection in technology design for this purpose. Overall, the CWEST model adds to HCI researchers' and designers' understanding of individual and collaborative reflection processes when designing "beyond symptoms", not specifically in therapy settings or by professional caregivers, but also for the children themselves and other members of their care ecosystem. It also goes beyond being a model that encompasses reflection as its main aspect, additionally integrating the key aspects of emotional expression and communication, and illustrating how these concepts that can support well-being link to each other through specific user actions that technologies can foster, both in an individual and joint capacity, which can empower users by affording them both power-to and power-over.

CHAPTER 7

Unanswered Questions – Where to Next?

In the context of this thesis, I acknowledge that I do not have answers to all the questions that may arise for the reader. This statement encompasses two related but distinct considerations. First, like all research, this work is subject to certain limitations. Second, the process of addressing the RQs of this thesis has generated additional questions, opening up promising avenues for future work. Therefore, the following sections discuss limitations of this work, followed by suggestions for future research.

7.1 Limitations

I acknowledge that the studies in this thesis have certain limitations. First, I recognise the small number of participants, especially of ADHD children, across the studies included in this dissertation. Participant recruitment, especially of ADHD children and their care ecosystem, was one of the core challenges during my PhD, and is a well-known challenge in literature [79, 326, 533, 606]. Nevertheless, the number of ADHD children included in our studies is still in line with recommendations from seminal work on research methods in HCI with a focus on studies with people with "disabilities" [322]. Additionally, the employed care ecosystem-based approach, involving not only ADHD children but also members of their care ecosystem, allowed us to acquire rich data across our studies, often amounting to total participant numbers well above the average of 12 participants, common in HCI studies [75].

Moreover, I recognise the need for longitudinal field studies with the remaining technologies –MagiBricks, TeenWorlds, and MoodGems – beyond REMEMO, to better understand their long-term effects on empowerment and well-being. The field study with REMEMO provided valuable insights on how multi-stakeholder technologies that allow for emotional expression, reflection, and communication across care ecosystem stakeholders can foster well-being. However, it remains an open question how the benefits of involving vulnerable populations, such as neurodivergent children and their caregivers, especially in longitudinal studies, outweigh the challenges and burdens faced by both participants and researchers.

Furthermore, the list of core concepts that link to well-being employed in this thesis is not exhaustive. For instance, creativity is another construct that is positively linked to well-being [98], which was not explored as a core concept in this thesis. In particular, creativity is one of the key therapeutic elements in arts therapies [387], which have been found to have positive effects on children's well-being in general [82, 366, 388] and specifically on children with ADHD [287, 643]. Studies have highlighted the importance of creativity for self and emotional expression [153, 387] and problem-solving [153]. Nevertheless, it could be argued that even though creativity was not one of our core concepts, it was indeed employed in the technologies that were designed in this thesis. In particular, playing with MagiBricks arguably involves creativity due to the building of structures, and drawing in TeenWorlds also involves artistic expression and creativity. Moreover, creativity can also be part of interacting with REMEMO, as users can draw as part of recording their experiences. In any case, this thesis does not suggest that the investigated concepts are the only core components of well-being, nor that focusing on these is the only way to design for children's well-being. The goal was not to find and investigate an exhaustive list of concepts related to well-being, but rather to explore how to design different types of technologies based on some core concepts drawn from literature and our own findings that formed the conceptual basis for the technologies we designed. Thus, this thesis does not propose one unique technological solution; instead, it posits that the identified features based on the employed approach can be used by future researchers and implemented in other types of technologies, whose impacts on well-being and empowerment can then be investigated. Moreover, the effect of the core concepts individually has yet to be investigated, as the technologies investigated in this thesis employed a combination of them.

Finally, we did not involve all the care ecosystem stakeholders in all the studies, but rather investigated various constellations of them. The reasons for (initially) choosing these constellations for each system vary and are described in the Transition sections in Part II before the pertinent publications. Nonetheless, it was precisely studying the proposed technologies with these diverse constellations that allowed us to acquire unique insights, which are detailed in section 5.2.3.

7.2 Future Work

The insights of this thesis give rise to several exciting directions for future research. First of all, regarding the core concepts that are positively linked to well-being and/or empowerment which this thesis employed (i.e. reflection, emotional expression, autonomy, and agency), future studies could try to determine how they each impact the results when employed in technologies. Moreover, future work could investigate how other concepts that are positively connected to well-being can be employed in the journey of designing empowering technologies for the well-being of neurotypical and neurodivergent children and their care ecosystem.

With respect to the care ecosystem stakeholders, future research could investigate the technologies proposed by this thesis with different user constellations, after carefully applying considerations in order to effectively support the needs that diverse groups might have. For instance, since our findings demonstrated the need for implementing additional scaffolding for teenagers interacting with their peers to successfully support reflection when interacting with TeenWorlds, future work could implement this in the technology and conduct further studies with the refined version of TeenWorlds, investigating its impact on not only teenagers interacting with their peers, but also with their siblings or other family members. Moreover, in the future, we plan to study the use of the technologies we designed with more care ecosystem stakeholders, e.g. recruiting teachers to participate in field studies with REMEMO.

At the same time, this work points to several opportunities to design technologies that employ the concepts of emotional expression, reflection, and communication to foster the well-being of not only ADHD children and their care ecosystem, but also other neurodivergent populations. Although I do not claim that our findings necessarily generalise to other neurodevelopmental conditions, both therapist and parent participants across our studies with different systems pointed out the expected usefulness and benefits of the developed prototypes for different populations beyond ADHD children. Additionally, several of the ADHD children who participated in our studies also had co-morbid diagnoses, such as high-functioning autism. Therefore, further research is necessary to explore the impact of the proposed technologies and the broader implementation of the "designing beyond symptoms" approach across different populations.

Furthermore, future work could examine the extent to which the proposed CWEST model for children and their care ecosystem is applicable to technologies that allow automated tracking of users' activities; or, more broadly, whether other user actions could be included inside the individual and collaborative use cycles and in which outcomes these would result. Future research should also investigate the long-term impacts of technologies that follow the CWEST model. This entails both conducting longitudinal studies with the technologies that this thesis proposed, as well as with new ones that can be designed based on the model. It also includes investigating how – and whether and in which cases it makes sense – to foster long-term engagement with such technologies. This leads to the next and final suggestion for future endeavours to explore how and if the proposed technologies should change and adapt as children get older, and what specific factors might influence this decisions (e.g. changing relationships within the care ecosystem, diagnosis progression), and which technology features would need to be adjusted (e.g. need for more agency and autonomous decisions versus scaffolding requirements).

7.3 A Closing Note on Ethics

I acknowledge the many considerations associated with conducting studies with vulnerable populations, such as ADHD children and their caregivers. As a whole, the work undertaken in this PhD serves as proof of both the challenges and the benefits associated with such endeavours. Before elaborating on this further, I clarify that, in this thesis, I define "vulnerable" populations as groups that are at a higher risk of incurring harm or exploitation due to their specific circumstances or conditions [519]. This can differ from "marginalised" populations, referring to groups that have been systematically disadvantaged or excluded from mainstream social, economic, and cultural life [64]. Notably, there is overlap, as there are situations where vulnerable groups are also marginalised. Nevertheless, this research primarily addresses vulnerability in terms of the increased care and ethical considerations required when engaging with participants who have specific needs due to their neurological differences. For instance, we have already discussed how ADHD children were disproportionately affected by the COVID-19 pandemic [419] and how ADHD families can face additional challenges in their everyday experiences [565].

Reflecting on advantages of doing research in this domain, the present thesis underscores the importance of involving (neurodivergent) children and their caregivers in the design of technologies, echoing previous work [41, 325]. The work conducted in this PhD has demonstrated how actively involving both neurotypical and ADHD children and multiple care ecosystem members is possible and can lead to positive outcomes. Those include the design of technologies that can support their well-being and empower them, and which can address the interests and needs of diverse stakeholders. Importantly, we applied a range of measures in our studies in order to ensure the well-being of our participants, such as inclusive design and safety and considerations of long-term impact.

In particular, all user studies in this thesis received prior ethical clearance from University ethics boards, in line with the Declaration of Helsinki (P II: HSG-EC-20220302; P III ERB Review Bèta S-21606, P IV: HSG-EC-20230605, P V and P VI: HSG-EC-20230406). Additionally, we implemented measures such as the presence of therapists during co-design sessions with ADHD children, and offered children and parents the choice regarding parental presence during the studies, ensuring comfort and respect of family dynamics across our studies. Moreover, we involved therapists throughout our studies with ADHD children, even in studies with systems where they were not the initially envisioned target users, such as MoodGems. This was instrumental in uncovering ethical and safety considerations about the use of well-being technologies at home, for instance when discussing negative emotions within ADHD families.

Furthermore, it is important to critically reflect on the long-term impacts of field studies on participants, particularly focusing on the implications after their conclusion, when a technology that might have been part of participant's routines is removed from their lives. To ensure the well-being of our participants in the study with REMEMO, we transparently communicated the end date of the application's availability. The importance of this transparency was highlighted by a therapist's concerns about the permanence of data logged in the application. In particular, given that REMEMO is not commercially available, the therapist was initially reluctant to log her sessions with a child primarily with REMEMO, for fear she might eventually lose access to this information when the project was over. To mitigate such concerns, we engaged in ongoing communication with participants throughout the study, which helped manage expectations and foster trust between researchers and participants.

However, this thesis also demonstrates that certain aspects remain difficult to navigate and require critical discussion, both within the research community and beyond; for example in the case of policy implications that arise when embedding digital tools in the homes of families or in therapy settings. Continuous dialogue with researchers, policymakers, and the vulnerable populations themselves is essential to address challenges associated with their engagement. These challenges often include the considerable time and effort required from researchers to recruit hard-to-reach and vulnerable populations, and from participants, who may have already tight schedules. Both of these were a key challenge throughout this PhD, with significant resources having been allocated to reach and recruit participants. Concurrently, we need to respect the agency of participants while ensuring that their participation does not exacerbate existing burdens. This tension was reflected in our field study with REMEMO, especially with one family who insisted on their wish to participate despite their very limited engagement with the application, attributed to their facing increased challenges in their everyday lives and significant shortage of time. Overall, this thesis emphasises the need for further discourse and reflection within the research community to balance these factors and to safeguard the well-being of vulnerable participants during and after their involvement in research.

CHAPTER 8

Conclusion

This thesis engaged with ADHD and neurotypical children as well as key members of their care ecosystems, including siblings, parents, teachers, and therapists, with the goal to explore the design of technologies that can empower them and support their well-being. It investigated how to design technologies that can afford users both *power-to* and *power-over* [467], seeking to design for the diverse needs of care ecosystem stakeholders (children and their care ecosystem members). It also explored how to navigate power dynamics between children and their caregivers within technology design and use, nurturing children's agency. Since the power imbalances between adult caregivers and children are existent both in the case of neurotypical *and* neurodivergent children, while being more pronounced for the latter group, this thesis investigated how to design empowering technologies for *both* neurotypical and ADHD children.

Through a series of studies, this work conceptualised, designed, developed and evaluated a range of different technological prototypes which aimed to support diverse needs, interests, and interactions among children and their care ecosystem. Thus, this thesis delivers artefact contributions, by designing and developing such technologies, as well as empirical contributions, by investigating their impact on the empowerment and well-being of children and their care ecosystem. Overall, this thesis approaches the topic from a variety of angles and contributes insights into how such technologies can be designed. The findings of this work have demonstrated that children can be afforded both power-to and power-over by engaging them and their care ecosystem in the design and evaluation of technologies and by designing "empowering experiences", for instance by including active decision making as part of their interaction with technology. Concurrently, this dissertation has shown that designing for children's empowerment by actively involving them and their care ecosystem as co-designers, evaluators, and users of technologies can lead to technologies that support their overall well-being as well. In other words, this thesis demonstrates that empowering children and their care ecosystem enables different ways to address their well-being. Based on our findings across the studies of this thesis, key features of technologies that can support the well-being and empower both ADHD and neurotypical children and their care ecosystem are proposed: facilitating emotional expression, fostering reflection, supporting active decision-making in technology interactions, and promoting communication, while at the same time enabling individual and joint technology use by various care ecosystem stakeholders. The findings of this thesis culminate in the proposal of the "Children and Care Ecosystem Well-being & Empowerment Supported through Technology" (CWEST) model, which conceptualises how technology can support well-being and empowerment of children and their care ecosystem.

Finally, several challenges when engaging with neurotypical and ADHD children and their care ecosystem in the design of technologies for well-being were identified. Those arise from the vulnerability of some of the involved stakeholders and their multiple and often divergent perspectives, as well as from integrating multi-stakeholder technologies that incorporate the aforementioned features both at home and in therapeutic contexts. Open challenges also include balancing respect of participants' agency and potential burdens of (longitudinal) studies on both participants and researchers.

It is my hope that this thesis inspires future research that supports the well-being of children, both neurotypical and neurodivergent, and their care ecosystems, that includes designing technologies but also goes beyond that, exploring technology use and non-use and how and when each needs to be considered within the setting of empowering children and improving their overall well-being.

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