Empowering Children with ADHD/ASD within Intelligent Environments

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Enabling neurodiverse children to have control of their surrounding space could improve their well-being by allowing them to adapt it to their needs. Intelligent Environments (IEs) are now part of our everyday lives. For example, smart homes are already a reality and there is an abundance of tools that enable even non-technical users to define their behavior. This not only affects adult users, since children are also expected to live inside such environments; thus, they should be given agency to manipulate them. Previous work on programming and children mainly focused on neurotypical children as programmers of IEs. In contrast, we aim to investigate the opportunities and challenges of enabling children with ADHD and/or ASD to use MagiPlay, an AR serious game for dictating the behavior of IEs by defining rules. These populations benefit greatly from routines, predictability, and regulated home conditions, which MagiPlay could help to establish, along with feelings of control, independence, and motivation. Our goal is to extend MagiPlay in a way that improves the quality of life of children with ADHD and/or ASD. To that end, we plan to follow a methodology that includes children and their families in the design process, so as to ensure that their needs are carefully considered.

CCS Concepts: • **Human-centered computing → Participatory design**; **Interactive systems and tools**; *Mixed/augmented reality*.

Additional Key Words and Phrases: Intelligent Environments, Children Programming, ASD, ADHD, Co-design, Gamification

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1 INTRODUCTION

Allowing children with autism spectrum disorder (ASD) and attention deficit hyperactivity disorder (ADHD) to control their Intelligent Environment (IE), could not only contribute towards improving their well-being, but would also give

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them a sense of control over their lives. IEs include artifacts made intelligent with computing power [46], and proactively, but sensibly, support people in their daily lives [3]. In the case of domestic life, the adoption of commercial smart home devices is rapidly increasing [19], while sophisticated tools allow end-users to configure and control them according to their needs and preferences [22, 48, 49]. The majority of smart home solutions and their accompanying tools target adults in the age group of 25-50, who usually buy, install and use IoT devices in their homes [7, 17, 43, 50]. Nevertheless, considering that people within that age-range are often parents who already have at least a couple of smart artifacts in their homes [24], their children are also expected to interact with these artifacts on a daily basis [34]. Currently, there is limited research that regards children as end-users of IEs and of systems allowing their programming [38, 44], while, to the best of our knowledge, the area of neurodiverse children programming their intelligent surroundings remains unexplored. Until now, pertinent research has mainly focused on neurodiverse children learning to program [18].

In general, enabling children to actively participate in the management of their intelligent surroundings can enhance feelings of responsibility and independence, similarly to when they help with other household activities [13, 26]. At the same time, it might make them feel in control of their environment, and permit them to design routines that accommodate their daily activities. Such benefits could also be important for children with ASD and/or ADHD. In particular, enabling children on the autism spectrum to program their environment could potentially help mitigating challenging situations by evading their exposure to overstimulating conditions [39] (e.g. bright lights), avoiding unpredictable circumstances [20] (e.g. alarms setting off when the child is present), and framing their daily routines [37]. Structuring their routines and following a specific daily program is also important for children with ADHD [11], since it can help manage its behavioral symptoms [5, 21, 28, 32]. These routines could be facilitated by creating rules that either dictate the environment to minimize distractions when the child performs important tasks (e.g. "Turn off the music when I sit on my desk to study"), or initiate appropriate interventions for re-engaging the child's attention to a specific activity (e.g. "When I stand up from my desk for more than 5 minutes during study time, then make the desk lamp blink for 5 seconds"). MagiPlay (Figure 1) is a serious Augmented Reality (AR) game targeting children aged 7-12 years that provides a child-friendly and fun approach for programming their surroundings, while enhancing their computational thinking skills [44, 45]. AR has been successfully utilized to help children with ASD to stay focused [16], and enhance their social skills [27], and children with ADHD to enhance their reading and spelling skills [8, 47], and improve their attention and retention [1, 4]. Given the promising aspects of MagiPlay for neurotypical children, and the benefits of AR, we aspire to investigate potential extensions that would transform the game into a meaningful tool for children aged 7-12 years with "mild-to-no" or "moderate" ASD and/or ADHD, allowing them to create rules that support their well-being and improve the quality of life of the entire family.

2 MAGIPLAY: A SERIOUS AR GAME ALLOWING CHILDREN TO PROGRAM IES

MagiPlay enables children to create trigger-action rules for smart artifacts of their intelligent surroundings. Using tablets, they can move around the environment, collect smart artifacts they wish to program by pointing at them with the device's camera, and use them as the "ingredients" of a rule. Children can build rules by connecting virtual 3D LEGO-like bricks on a virtual baseplate, superimposed via AR over a flat surface. Every rule is composed of one or more triggers (i.e. an event that might occur), and one or more actions (i.e. the step that should follow): when TRIGGER(S) then ACTION(S). MagiPlay offers three gaming modes: (i) "follow the game plot", where children complete levels by creating the dictated rules - depending on the level difficulty, they collect experience points and "unlock" more artifacts to use; (ii) "free exploration", where they can freely interact with available artifacts in order to build rules of their preference; and (iii) "collaboration", where two or more players can work together to build a rule in a synchronized

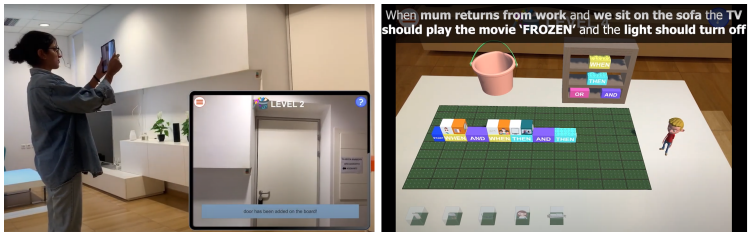

Fig. 1. Creating a rule with MagiPlay: (left) capturing the smart door artifact, (right) the AR baseplate with the 3D bricks

environment. After successfully creating a rule in any of the aforementioned gaming modes, children can simulate or deploy it in the IE. Context-sensitive help is provided via a 3D animated character, aiming to facilitate the rule creation process by helping players either on demand or automatically, by inferring when a player is "confused".

3 MAGIPLAY FOR CHILDREN WITH ADHD AND/OR ASD

The study (N=15) by Stefanidi et al. [45] showed that children aged 7-12 can comprehend the concept of IEs, and that, if provided with appropriate tools, such as MagiPlay, they can dictate their behavior in a fun and engaging way, by creating appropriate rules. Interestingly, this study sparked the idea that MagiPlay could also support children with disabilities such as high-functioning autism, since one of the participants was a child diagnosed with ASD, which we were informed of after the study by the parents. Thus, we started exploring whether enabling children with ASD and/or ADHD to program their surroundings could contribute towards improving their well-being, considering that ADHD is one of the most common comorbid disorders in individuals with ASD [23], and that both populations benefit from being in control of their surroundings and from a predictable, structured environment [25].

ADHD symptoms include inattention, hyperactivity, and/or impulsivity [14], indicating that children are prone to inadvertently deviate from important activities. Enabling them to create rules that will help them to avoid unwanted behaviors (targeting impulsivity and hyperactivity), minimize distractions (targeting inattention and hyperactivity), and reset their attention (targeting inattention) by themselves, would not only help them stay focused, but could also offer a sense of responsibility, independence and control over their own lives. For example, "When I study, then turn off the music, lock my smartphone and turn off the TV" could be a rule aiming to minimize learning distractions, as academic impairments [29] are common consequences of ADHD. Additionally, children with ADHD are reported to often have high levels of emotional difficulties, such as poor self-regulation of emotions and problems coping with frustration and stress [41, 51]. Thus, supporting them to relax (e.g. via breathing exercises [9, 40]) is often a challenging goal. Therefore, including children's wearables in the rule creation process could be a meaningful next step (e.g. "When my heart rate exceeds 90bpm, then play my favorite calming song"). Since routines have been embraced as an effective part of managing the behavioral symptoms associated with ADHD [5, 28, 32, 33], promoting household routines may help reduce both internalizing and externalizing behaviors for children with ADHD, and encourage family cooperation and connectedness [21]. For example, consider the following rule aiming to facilitate a child's bedtime routine "When it is time for bed, then turn off my PC and make my electronic toothbrush blink".

Regarding children with ASD, they can exhibit intense responses to overwhelming situations [2]. Enabling them to manipulate their surroundings could help with their need to feel in control [36], minimize uncertainty and unpredictability [20], and avoid over-stimulation [39]. For example, as children on the spectrum can be particularly sensitive to lights, sounds, and other stimuli [53], pertinent rules could be created, e.g. for dimming the lights in a room when the

child enters. Regarding their need for predictability [31], dictating the environment to silence notifications or alarms when the child is present in a specific room (and e.g. redirect them to the parents' personal devices), could help reduce anxiety and avoid triggering particularly challenging situations. Children with ASD also crave order and routines to make sense of the world [15, 53], while safety can be a concern, e.g. for those who wander or are drawn to water [53]. A system like MagiPlay could help children create rules that address such issues, as helping them cope with uncertainty could contribute to easing some of their symptoms [31].

We see opportunities of using MagiPlay for assisting children with ADHD and/or ASD in maintaining daily routines, whose importance has been established [10, 12], as well as promoting their well-being by creating an appropriate home environment (e.g. less distractions). Independent living could also be supported, while children would feel of help in the family context, similarly to when they help around with other household activities [13, 26]. Positive byproducts of using a system like MagiPlay also include fostering computational thinking skills (while maintaining increased engagement due to gamification [35]), cultivating creativity, and promoting socialization by showcasing the created rules to others.

4 CHALLENGES & FUTURE DIRECTIONS

We aspire to extend MagiPlay to enable children with ADHD and/or ASD to create rules that cater to their daily needs and improve their well-being. This constitutes a challenging process, since ADHD, ASD and their comorbidity entail different user requirements [6, 42]; co-design would help us to elicit these requirements through an appropriate and well-established approach. In addition to determining whether children from the target population can effectively use a system like MagiPlay, using AR technologies and the paradigm of trigger-action programming, we expect to identify potential modifications or additional features, whose introduction will increase the system's usability and usefulness. As a first step, we have conducted a literature review of assistive technologies for children with ADHD and/or ASD. Next, we aim to to inquire how children with ADHD and/or ASD are making sense of the rules that they need to build to support themselves, and if parental support is required. The latter will underline the extent up to which parents should be active participants of the programming process. In particular, if they should be able to: (i) define game levels, by setting the rules that their child should create, (ii) support the rule creation process, even if they are not present in the same room as the child (i.e. remote collaboration), and (iii) set real-life rewards (e.g. visiting a playground), which are particularly appealing to children with ADHD [30]. Furthermore, we would like to explore whether systems similar to MagiPlay can foster imaginative play to support children with ASD, who are often found lacking in imagination and pretend play during early childhood [52]. Finally, our endeavor may pave the way for future studies that will focus on developing smart objects that expose their functionality in a child-friendly manner, keeping in mind that both neurotypical and neurodiverse children will also be their programmers (e.g. a smart oven should permit a child to monitor its current state, but not stop its active timer). To summarize, we believe that this workshop could help us gain valuable insights on how to conduct co-design sessions, including both neurodiverse children and their families, so as to explore these questions, uncover new challenges or even potential pitfalls (e.g. system misuse, safety concerns).

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REFERENCES

[1] Nor Azlina Ab Aziz, Kamarulzaman Ab Aziz, Avijit Paul, Anuar Mohd Yusof, and Noor Shuhailie Mohamed Noor. 2012. Providing augmented reality based education for students with attention deficit hyperactive disorder via cloud computing: Its advantages. In *2012 14th International conference on advanced communication technology (ICACT)*. IEEE, 577–581.

[2] American Psychiatric Association et al. 2013. *Diagnostic and statistical manual of mental disorders (DSM-5®)*. American Psychiatric Pub.

[3] Juan Carlos Augusto. 2007. Ambient intelligence: the confluence of ubiquitous/pervasive computing and artificial intelligence. In *Intelligent computing everywhere*. Springer, 213–234.

[4] Diego Avila-Pesantez, Luis A Rivera, Leticia Vaca-Cardenas, Stteffano Aguayo, and Lourdes Zuñiga. 2018. Towards the improvement of ADHD children through augmented reality serious games: Preliminary results. In *2018 IEEE Global Engineering Education Conference (EDUCON)*. IEEE, 843–848.

[5] Russell A Barkley. 1998. Attention-deficit hyperactivity disorder. *Scientific American* 279, 3 (1998), 66–71.

[6] Peter Börjesson, Wolmet Barendregt, Eva Eriksson, and Olof Torgersson. 2015. Designing technology for and with developmentally diverse children: a systematic literature review. In *Proceedings of the 14th international conference on interaction design and children*. 79–88.

[7] Marketing Charts. 2017. *Who Owns Smart Home Technology?* Retrieved April 13, 2021 from https://www.marketingcharts.com/industries/technology-63952

[8] Giuseppe Chiazzese, Eleni Mangina, Antonella Chifari, Gianluca Merlo, Rita Treacy, and Crispino Tosto. 2018. The AHA project: An evidence-based augmented reality intervention for the improvement of reading and spelling skills in children with ADHD. In *International Conference on Games and Learning Alliance*. Springer, 436–439.

[9] Michael E Clark and Richard Hirschman. 1990. Effects of paced respiration on anxiety reduction in a clinical population. *Biofeedback and Self-regulation* 15, 3 (1990), 273–284.

[10] Samuele Cortese, Stephen V Faraone, Eric Konofal, and Michel Lecendreux. 2009. Sleep in children with attention-deficit/hyperactivity disorder: meta-analysis of subjective and objective studies. *Journal of the American Academy of Child & Adolescent Psychiatry* 48, 9 (2009), 894–908.

[11] Oystein Dale and Lisbet Grut. 2015. Mainstream ICT Can Support Children and Adolescents with ADHD and/or Autism in Their Everyday Activities. *Studies in health technology and informatics* 217 (2015), 679–684.

[12] Julia F Dewald, Anne M Meijer, Frans J Oort, Gerard A Kerkhof, and Susan M Bögels. 2010. The influence of sleep quality, sleep duration and sleepiness on school performance in children and adolescents: A meta-analytic review. *Sleep medicine reviews* 14, 3 (2010), 179–189.

[13] Louise Dunn, Wendy J Coster, Gael I Orsmond, and Ellen S Cohn. 2009. Household task participation of children with and without attentional problems. *Physical & Occupational Therapy in Pediatrics* 29, 3 (2009), 258–273.

[14] Fifth Edition et al. 2013. Diagnostic and statistical manual of mental disorders. *Am Psychiatric Assoc* 21 (2013).

[15] Melinda J Emery. 2004. Art therapy as an intervention for autism. *Art therapy* 21, 3 (2004), 143–147.

[16] Lizbeth Escobedo, Monica Tentori, Eduardo Quintana, Jesus Favela, and Daniel Garcia-Rosas. 2014. Using augmented reality to help children with autism stay focused. *IEEE Pervasive Computing* 13, 1 (2014), 38–46.

[17] Community for Businesses in Latin America and the Caribbean. 2019. *WHOS BUYING HOME AUTOMATION DEVICES?: ConnectAmericas*. Retrieved April 13, 2021 from https://connectamericas.com/content/who\T1\textquoterights-buying-home-automation-devices

[18] Christos Galeos, Kostas Karpouzis, and George Tsatiris. 2020. Developing an educational programming game for children with ADHD. In *2020 15th International Workshop on Semantic and Social Media Adaptation and Personalization (SMA*. IEEE, 1–6.

[19] Christine Geeng and Franziska Roesner. 2019. Who's In Control? Interactions In Multi-User Smart Homes. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. 1–13.

[20] Marie Gomot and Bruno Wicker. 2012. A challenging, unpredictable world for people with autism spectrum disorder. *International Journal of Psychophysiology* 83, 2 (2012), 240–247.

[21] Abbey N Harris, Laura Stoppelbein, Leilani Greening, Stephen P Becker, Aaron Luebbe, and Paula Fite. 2014. Child routines and parental adjustment as correlates of internalizing and externalizing symptoms in children diagnosed with ADHD. *Child Psychiatry & Human Development* 45, 2 (2014), 243–253.

[22] Steven Houben, Connie Golsteijn, Sarah Gallacher, Rose Johnson, Saskia Bakker, Nicolai Marquardt, Licia Capra, and Yvonne Rogers. 2016. Physikit: Data engagement through physical ambient visualizations in the home. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. 1608–1619.

[23] Jina Jang, Johnny L Matson, Lindsey W Williams, Kim Tureck, Rachel L Goldin, and Paige E Cervantes. 2013. Rates of comorbid symptoms in children with ASD, ADHD, and comorbid ASD and ADHD. *Research in developmental disabilities* 34, 8 (2013), 2369–2378.

[24] Bojan Jovanović, Ivana Vojinovic, Damjan Jugović Spajić, and Nikolina Cvetićanin. 2021. *45 Fascinating IoT Statistics for 2021: The State of the Industry*. Retrieved May 5, 2021 from https://dataprot.net/statistics/iot-statistics/

[25] Sally A Koblinsky, Katherine A Kuvalanka, and Suzanne M Randolph. 2006. Social skills and behavior problems of urban, African American preschoolers: Role of parenting practices, family conflict, and maternal depression. *American Journal of Orthopsychiatry* 76, 4 (2006), 554–563.

[26] Mary Law, Dana Anaby, Rachel Teplicky, Mary Alunkal Khetani, Wendy Coster, and Gary Bedell. 2013. Participation in the home environment among children and youth with and without disabilities. *British Journal of Occupational Therapy* 76, 2 (2013), 58–66.

[27] Runpeng Liu, Joseph P Salisbury, Arshya Vahabzadeh, and Ned T Sahin. 2017. Feasibility of an autism-focused augmented reality smartglasses system for social communication and behavioral coaching. *Frontiers in pediatrics* 5 (2017), 145.

[28] Eric J Mash and David JA Dozois. 2003. *Child psychopathology: a developmental-systems perspective.* Guilford Press.

[29] Greta M Massetti, Benjamin B Lahey, William E Pelham, Jan Loney, Ashley Ehrhardt, Steve S Lee, and Heidi Kipp. 2008. Academic achievement over 8 years among children who met modified criteria for attention-deficit/hyperactivity disorder at 4–6 years of age. *Journal of abnormal child psychology* 36, 3 (2008), 399–410.

[30] Robert J McInerney and Kimberly A Kerns. 2003. Time reproduction in children with ADHD: motivation matters. *Child Neuropsychology* 9, 2 (2003), 91–108.

[31] Louise Neil, Nora Choque Olsson, and Elizabeth Pellicano. 2016. The relationship between intolerance of uncertainty, sensory sensitivities, and anxiety in autistic and typically developing children. *Journal of Autism and Developmental Disorders* 46, 6 (2016), 1962–1973.

[32] National Institute of Mental Health. 2008. Attention deficit hyperactivity disorder (ADHD).

[33] National Institute of Mental Health. 2016. *Attention-Deficit/Hyperactivity Disorder (ADHD): The Basics.* Retrieved April 12, 2021 from https://www.nimh.nih.gov/health/publications/attention-deficit-hyperactivity-disorder-adhd-the-basics/index.shtml

[34] Marc Prensky. 2008. Programming is the new literacy. *Edutopia magazine* (2008).

[35] Pier JM Prins, Esther Ten Brink, Sebastiaan Dovis, Albert Ponsioen, Hilde M Geurts, Marieke De Vries, and Saskia Van Der Oord. 2013. "Braingame Brian": toward an executive function training program with game elements for children with ADHD and cognitive control problems. *GAMES FOR HEALTH: Research, Development, and Clinical Applications* 2, 1 (2013), 44–49.

[36] Amon Rapp, Federica Cena, Romina Castaldo, Roberto Keller, and Maurizio Tirassa. 2018. Designing technology for spatial needs: Routines, control and social competences of people with autism. *International Journal of Human-Computer Studies* 120 (2018), 49–65.

[37] Roseann C Schaaf, Susan Toth-Cohen, Stephanie L Johnson, Gina Outten, and Teal W Benevides. 2011. The everyday routines of families of children with autism: Examining the impact of sensory processing difficulties on the family. *Autism* 15, 3 (2011), 373–389.

[38] Mazyar Seraj, Cornelia S Große, Serge Autexier, and Rolf Drechsler. 2019. Smart homes programming: development and evaluation of an educational programming application for young learners. In *Proceedings of the 18th ACM International Conference on Interaction Design and Children*. 146–152.

[39] Pawan Sinha, Margaret M Kjelgaard, Tapan K Gandhi, Kleovoulos Tsourides, Annie L Cardinaux, Dimitrios Pantazis, Sidney P Diamond, and Richard M Held. 2014. Autism as a disorder of prediction. *Proceedings of the National Academy of Sciences* 111, 42 (2014), 15220–15225.

[40] Hye-Sue Song and Paul M Lehrer. 2003. The effects of specific respiratory rates on heart rate and heart rate variability. *Applied psychophysiology and biofeedback* 28, 1 (2003), 13–23.

[41] Tobias Sonne and Mads Møller Jensen. 2016. Chillfish: A respiration game for children with adhd. In *Proceedings of the TEI'16: Tenth International Conference on Tangible, Embedded, and Embodied Interaction*. 271–278.

[42] Latha V Soorya and Danielle Halpern. 2009. Psychosocial Interventions for Motor Coordination, Executive Functions, and Socialization Deficits in ADHD and ASD. *Primary Psychiatry* 16, 1 (2009).

[43] Benjamin K Sovacool and Dylan D Furszyfer Del Rio. 2020. Smart home technologies in Europe: a critical review of concepts, benefits, risks and policies. *Renewable and sustainable energy reviews* 120 (2020), 109663.

[44] Evropi Stefanidi, Dimitrios Arampatzis, Asterios Leonidis, Maria Korozi, Margherita Antona, and George Papagiannakis. 2020. MagiPlay: An Augmented Reality Serious Game Allowing Children to Program Intelligent Environments. In *Transactions on Computational Science XXXVII*. Springer, 144–169.

[45] Evropi Stefanidi, Maria Korozi, Asterios Leonidis, Dimitrios Arampatzis, Margherita Antona, and George Papagiannakis. 2021. When Children Program Intelligent Environments: Lessons Learned from a Serious AR Game. In *Proceedings of the 20th ACM International Conference on Interaction Design and Children*. conditionally accepted for publication.

[46] Biljana L Risteska Stojkoska and Kire V Trivodaliev. 2017. A review of Internet of Things for smart home: Challenges and solutions. *Journal of Cleaner Production* 140 (2017), 1454–1464.

[47] Crispino Tosto, Tomonori Hasegawa, Eleni Mangina, Antonella Chifari, Rita Treacy, Gianluca Merlo, and Giuseppe Chiazzese. 2020. Exploring the effect of an augmented reality literacy programme for reading and spelling difficulties for children diagnosed with ADHD. *Virtual Reality* (2020), 1–16.

[48] Khai N Truong, Elaine M Huang, and Gregory D Abowd. 2004. CAMP: A magnetic poetry interface for end-user programming of capture applications for the home. In *International conference on ubiquitous computing*. Springer, 143–160.

[49] Blase Ur, Elyse McManus, Melwyn Pak Yong Ho, and Michael L Littman. 2014. Practical trigger-action programming in the smart home. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. 803–812.

[50] Lionel Sujay Vailshery. 2021. *Smart home device ownership by age U.S. 2017.* Retrieved April 13, 2021 from https://www.statista.com/statistics/799584/united-states-smart-home-device-survey-by-age

[51] Peter M Wehmeier, Alexander Schacht, and Russell A Barkley. 2010. Social and emotional impairment in children and adolescents with ADHD and the impact on quality of life. *Journal of Adolescent health* 46, 3 (2010), 209–217.

[52] Lorna Wing and Judith Gould. 1979. Severe impairments of social interaction and associated abnormalities in children: Epidemiology and classification. *Journal of autism and developmental disorders* 9, 1 (1979), 11–29.

[53] Lior Zitzman. 2021. *Sensory-Friendly Home Modifications for Autism and Sensory Processing Disorder.* Retrieved April 11, 2021 from https://www.bigrentz.com/blog/sensory-friendly-home-modifications-autism-sensory-processing-disorder?amp