Erasmus+ project TE(A)CHADOPT: Teaching students how children with neurodevelopmental disorders adopt and interact with technologies, contract no. 2024-1-AT01-KA220-HED-000248380

WRITTEN REPORT, Activity 2.5

Challenges and recommendations regarding the observation and evaluation of child-technology interaction

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1 Introduction

The TE(A)CHADOPT project aims to create guidelines for evaluation of child-technology interaction and will teach the research findings to students of different fields. This shall boost accessibility awareness and skills in future technology developers and will hopefully advance the development of technologies that are better tailored to the wants and needs of children with neurodevelopmental disorders. An important prerequisite for the development of guidelines is the identification of challenges that can occur when observing and evaluating how children with neurodevelopmental disorders interact with technologies and potential ways to overcome these challenges. .

2 Method

To create a compilation of challenges and recommendations related to the evaluation of child-technology interaction, we relied on challenges and recommendations from the articles identified in our systematic literature review on evaluation of child-technology interaction (Activity 2.4) as well as from the guidelines of our previous Erasmus+ projects EMBOA and SMART. Based on our experience in the therapy of children with neurodevelopmental disorders, we discussed potential further challenges that could occur and tried to find ways to overcome as many identified challenges as possible.

2.1 Challenges and recommendations from systematic literature review of Activity 2.4

The process began with a detailed analysis of the key findings from the systematic literature review on evaluation of child-technology interaction (Activity 2.4) that formed the foundation for a structured online brainstorming workshop. During this Preparation Phase for the workshop, all TE(A)CHADOPT team members were asked to add challenges and recommendations from Activity 2.4 to a shared online whiteboard in the Canva tool. The team members were encouraged to group the identified challenges and recommendations in order to form clusters of similar challenges and recommendations.

2.2 Workshop

An online collaborative brainstorming workshop was conducted on September 16, 2025. The workshop brought together 10 consortium members who cover a broad range of expertise: They have experience with technologies, recording intervention sessions, analysing interaction behaviours, and/or intervention of children with neurodevelopmental disorders. Participants joined the meeting remotely via Zoom and used Canva's whiteboard tool to facilitate dynamic interaction and a visual representation of the brainstorming results; see Figure 1. All participants were familiar with this procedure from the previous Activity 2.3 of the TE(A)CHADOPT project.

The workshop was divided into four distinct phases (i. e., three silent phases, one discussion phase) to encourage independent and collective contributions: During Silent Phase 1, the participants were asked to individually add challenges and recommendations from the previous Erasmus+ projects EMBOA and SMART. Six people (all members of the EMBOA project) were allocated to focus on EMBOA and four people (two of them members of the SMART project) were allocated to focus on SMART. This phase lasted 30 minutes. During Silent Phase 2, the participants read all challenges and recommendations added during the Preparation Phase and during Silent Phase 1. This phase lasted 15 minutes. During Silent Phase 3, all participants were asked to assign all challenges and recommendations to one of five thematic groups: child-related challenges and recommendations, methodological challenges and recommendations, challenges and recommendations related to implementation in therapy, technology-related challenges and recommendations,

Fig. 1. Compilation and grouping of challenges and recommendations during the brainstorming session using Canva's whiteboard tool.

and additional challenges and recommendations. In addition, the participants were encouraged to group similar challenges and recommendations within a thematic group. This phase lasted 40 minutes. The subsequent discussion phase involved critically evaluating the proposed grouping of challenges and recommendations. This phase lasted 30 minutes. The collaborative use of Canva's whiteboard tool enabled iterative refinement, resulting in a preliminary version of grouped challenges and recommendations that informed the basis for the compilation of challenges and recommendations provided in this report. For some of the reported challenges the authors of the original papers already added a recommendation, for others not. Many recommendations reported in the original papers do not refer to a concrete challenge. This leads to a number of isolated challenges, isolated recommendations, and challenges with concrete recommendations that need to be further grouped and combined to result in our final challenges and recommendations compilation.

2.3 Construction of challenges and recommendations compilation

Two authors (Katrin Bartl-Pokorny, Florian Pokorny) who participated in the workshop summarised the challenges and recommendations gathered in the whiteboard and suggested a first version of the challenges and recommendations compilation. They combined similar challenges and recommendations to avoid redundancy. They merged isolated challenges and isolated recommendations where possible so that the total number of isolated items reduced to a considerable extent. During this process, the five thematic groups were reduced to three groups, i. e., child-related challenges and recommendations, methodological challenges and recommendations, and challenges and recommendations related to implementation in therapy to reduce redundancy. Subgroups were added to ensure better readability. The resulting draft of the challenges and recommendations compilation was reviewed by the other consortium members. Each member was encouraged to add recommendations to challenges for which no recommendations could be found in the previous steps (i. e., isolated challenges). In this step we could greatly benefit from our interdisciplinary expertise.

The following section comprises the final version of the created challenges and recommendations compilation.

3 Challenges and recommendations compilation

The tables below present the identified challenges along with their corresponding recommendations, if available. Recommendations that address two or more challenges are marked with an asterisk (*). For some challenges no recommendation has been found (field for corresponding recommendation stays empty) and some recommendations do not correspond to a concrete challenge (field for corresponding challenge stays empty).

3.1 Child-related challenges and recommendations

Initial engagement and familiarisation	
Challenge	**Recommendation**
Refusal of interaction with technology [1, 5, 11, 12, 16, 18, 21, 22, 26, 27, 35, 36, 40, 60, 69, 78, 81, 87–91, 93, 101–103, 112, 114]	• *Familiarisation sessions can help children to overcome children's reservations [19, 36] • *It can be helpful to add an introductory session where the children can interact freely and get themselves familiarised with the technology and also with the researcher/experimenter [49] • Report familiarisation sessions and sessions that failed - All the cases of an interaction failing should be reported along with the cause [19] • Use autism-friendly color palettes and introduce irritating colors (red, yellow, white) slowly [87] • Consider to avoid sharp movements, flashes, loud sounds, or fast animation [87]
Some children are hesitant in first interaction with the technology/need more time to start interacting [22, 36, 48]	• *Familiarisation sessions can help children to overcome children's reservations [36] • *It can be helpful to add an introductory session where the children can interact freely and get themselves familiarised with the technology and also with the researcher/experimenter [49]
Child prefers well-known activities and has problems to change routine and to introduce new activities/technologies [12, 15, 91] Especially older children need more time to adapt to new technology [15]	Add introductory sessions where the new technology is an adjunct to the familiar activity, to promote familiarisation

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Children may refuse wearable devices on their arms or lapel microphones used to collect data [3, 36, 87] TECH2	• *Familiarisation sessions can help children to overcome children's reservations [36] • Consider to use other wearable devices that can be embedded within the child's clothing or shoes [3] • Select devices based on comfort for the child and device setup effort [19] • Consider material of wearable devices (look and feel) and offer a choice between two devices if possible

Motivation, interest, and engagement during intervention	
Challenge	**Recommendation**
Child is not interested in the technology at all or only interested in a few selected activities [8, 11, 26, 114]	• Allow children flexibility in choosing and organizing their preferred activities; this may empower them and lead to more engagement [109] • Activities should be playful [71] • Plan activities in advance, but adapt the plan on the run, whenever necessary, and follow the child's needs [19] • *Creating more game variability and personalisation [27, 100, 115] • *A psychopedagogical profile for each child helps to understand the child's interests and needs [6, 99] • *Investigate new design elements for technologies [16] • Provide clinical psychologists with new tools to attract and sustain children's engagement [66]
Activities with limited action of the technology [16, 27] and long breaks in between [16] resulted in reduced interest	Constraint patterns enable the therapist to pace the flow of activities and to shape the children's behaviour, promoting and regulating the collaboration experience [109]
Certain expressions or activities of the technology might result in disengagement from interaction; e. g., robot's sad face [24]	• Consider avoiding sad or negative faces in robots, rather use a positive or neutral face • Use alternative reward mechanisms such as singing, verbal or nonverbal cues of the robot to engage the child again

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Children prefer more energetic tasks, physical activities, or interpersonal interaction [27]	• *Creating more game variability and personalisation [27, 100, 115] • Creating games/activities where the technology is an adjunct to the physical activity (giving instructions, providing rewards, encouragement)
Child ignores the technology's instructions [1, 11, 13, 35, 81, 99]	• Minimise the number of instructions, simplify them • If possible, use gamification to present the instructions • Include interactive nature to instruction phase • Multimodal communication of instruction (verbal, pictogram, video)
Study participants show high variability in their interaction behaviour (some are engaged, some refuse interaction, some are afraid,...) [115]	• *Creating more game variability and personalisation [27, 100, 115] • *A psychopedagogical profile for each child helps to understand the child's interests and needs [6, 99]
Child was only interested at the beginning of the interaction or during the first sessions (novelty effect) [15, 21, 100]	• More variations in game graphics (e. g., evolving game screens and characters) and used materials [71, 72] • Add more scenarios or activities [115] • *Creating more game variability and personalization [27, 52, 100, 115] • Use multimodal feedback (visual, auditory) to keep children engaged [67]

Attention and concentration	
Challenge	**Recommendation**
Child is intolerant of feedback delay during drag-and-drop or pointing actions [27]	Allow control of feedback timing

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Child has difficulties to interact with the technology or to stay engaged due to limited attention span [1, 4, 8, 11, 12, 15, 18, 27, 33, 78, 81, 83, 85–88, 90, 96, 98, 99, 105, 112]	• Interventions must be short [71, 99] • Customise the intervention time [27] • Limit the number of tasks [49] • Carefully select the technology as it can influence the attention span [99] • *Tasks should be offered gradually increasing the difficulty level which also helps the child to sustain engagement [27, 71, 114] • Favorite song playing in the background helped a child to maintain concentration [27] • *Consider diverse activities and diverse difficulty levels following the child's symptoms, and select the most suitable level for each child [27, 105] INT4
Child has difficulty to concentrate due to many distractions [15]	• *Provide a safe and non-distracting environment for a child [19] • *Minimise technological complexity of observation [19] • Allow for customization of technology distractions (options for clean background or black high contrast, background music options including on/off, feedback sounds on/off, etc.)
Child is distracted especially in case of multiple recording devices [56]	• *Provide a safe and non-distracting environment for a child [19] • *Minimise technological complexity of observation [19] • Limit number of devices; consider using a single device to capture multiple modalities, e. g., a camera to record facial expressions and voice [19]
Child needs more breaks than planned to stay concentrated [18]	
Children spend little time on the introductory part of the tutorial [112]	• Provide additional supports and hints built into the software [112] • Interactive verification steps could be added to ensure that the children get the instructions they need [112]

Cognitive and instructional challenges	
Challenge	**Recommendation**
Child needs lots of help and prompting to be able to interact with the technology and perform tasks [2, 11, 18, 27]	• *Information presented must be very precise and adapted for each child [99] • *Keep the language simple [27] • Provide multimedia digital prompts [27] • *Consider diverse activities and diverse difficulty levels following the child's symptoms, and select the most suitable level for each child [27, 105] INT4
Children don't understand task or concepts, the activity is too difficult/exhausting for them [2, 8, 44]	• *Tasks should be offered gradually increasing the difficulty level which also helps the child to sustain engagement [27, 71, 114] • Provide more granularity in the difficulty levels to match the different range of abilities [27] • It should be possible to control the complexity and tailor it to the needs of the individual child [114] • Flexible approach needed, where technology can react autonomously, but also the therapist can guide it according to the child's needs [116] • Choose appropriate stimuli [19] • *Information presented must be very precise and adapted for each child [99] • *Multimedia material could be supported by pictograms of augmentative communication and audio [99] • *A psychopedagogical profile for each child helps to understand the child's interests and needs [6, 99] • Implement multimodal cues, e. g., small icons alongside text, to improve the experience for children with lower literacy or greater cognitive challenges [13]
Children show very slow progress [99]	Consider more interaction sessions with the technology [3, 99]

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Children have difficulties to operate the technology (e. g., navigating through interface, placing tangible objects on screen) [72, 88, 110]	• Use of tutorials prior to game play to help optimise children's independence [72] • Consider clear and relevant interface elements for navigation [110] • *Information presented must be very precise and adapted for each child [99] • *Each movable or touchable interface element needs to be of a certain minimum size to be useful [110] • Carefully select digital material, physical elements, and scenarios so that it neither distracts nor overloads the child [99] • Increase the screen size [52]
Although children understand how to navigate through the technology, they seem to find the navigation process cumbersome/obsolete [112]	• Do not use a didactic approach, if possible gamify the navigation process • Consider the design (e. g., attractiveness) of navigation elements
Children have difficulties with suspension of reality (players can choose how close the activity should be to objective reality) [26]	• Allow personalised game elements (upload photo of child?) • If robots are used: With these children use robots that more closely resemble real beings (people/animals)

Challenging behaviour	
Challenge	**Recommendation**
High level of child's impulsiveness results in difficulties with goal-directed actions during interaction [11]	
Child intentionally responds inappropriately to technology [11]	If the child does not want to play, end the session
Children show heterogeneous profiles in their symptoms and challenging behaviour can vary from one individual to another [3]	• *Consider diverse activities and diverse difficulty levels following the child's symptoms, and select the most suitable level for each child [27, 105] INT4 • Implement micro applications that can be controlled so that they match the child's needs and the therapeutic goals [110]

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It can happen that children do not handle the technology or parts of the study equipment with care [36, 110]	• Technology needs to be robust, solid, and fixed in place to endure use [110] • *Each movable or touchable interface element needs to be of a certain minimum size to be useful [110]
Child needs to stop interaction earlier than planned [37]	
Hyperactive behaviour results in frequent random choice selections and repetitive speech patterns [18]	*Add "calm down" features to the technology that can help when children are "stuck" emotionally (e.g, an option that leads them in a 1-minute meditation exercise) [112]

Sensory and emotional factors	
Challenge	**Recommendation**
Some children who are reluctant to interact with technology get stressed, irritated, angry, or aggressive [36, 40, 116]	
Child misunderstands emotional expressions [106]	Consider how emotions could be better displayed on the technology [106]
Sensory sensitivities (e. g., sound level too high for the children) can cause problems to get or stay engaged in interaction [36, 37, 40, 50, 69, 76]	• Perform a sensory or preference assessment prior to the start of the study [50] • Choose alternative devices if needed [50] • Consider to redesign the technology so that it works with a reduced sound level [37]
Child does not like technology's appearance [107]	• *Familiarisation sessions can help children to overcome children's reservations [36] • *Some extra accessories might be useful, such as covering parts of the technology with a colored scarf
Child is afraid of technology [1, 3, 50, 60, 115]	• *Familiarisation sessions can help children to overcome children's reservations [36] • *Start with rewarding activities such as singing • Show the child that the technology does not harm • *Some extra accessories might be useful, such as covering parts of the technology with a colored scarf

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Children show irritability [13, 16, 35, 36, 40, 60, 81, 99, 102, 103, 110, 112]	• *Familiarisation sessions can help children to overcome children's reservations [36] • *Start with rewarding activities such as singing • *Some extra accessories might be useful, such as covering parts of the technology with a colored scarf • If irritation is too severe, that particular piece of technology, such as a smart watch might be removed and left out during the session
Performance of the child highly depends on variables in their lives (e. g., how they slept, what happened in the school just before the activity) [4]	*Multiple sessions; add a before-session question (to caregivers or therapists) on whether anything special happened before the session that might influence the participant's behaviour [36]
Performance of the child highly depends on their actual emotional state [99]	*Multiple sessions; add a before-session question (to caregivers or therapists) on whether anything special happened before the session that might influence the participant's behaviour [36]
Children are often frustrated if the technology is not working as expected or if the actual gameplay was not going the child's way [112]	*Add "calm down" features to the technology that can help when children are "stuck" emotionally (e. g., an option that leads them in a 1-minute meditation exercise) [112]

Motor and verbal challenges	
Challenge	**Recommendation**
Child has difficulties to interact with the technology due to limited verbal skills [2, 4, 16, 33, 81–83, 86–88, 90, 91, 93, 96–99, 101, 104, 105, 112]	• *Consider diverse activities and diverse difficulty levels following the child's symptoms, and select the most suitable level for each child [27, 105] INT4 • *Multimedia material could be supported by pictograms of augmentative communication and audio [99] • Technology should be simpler and more explicit collaborative in its mechanics [101] • *Provide activities with different levels of difficulty to match the children's needs [105] • *Keep the language simple [27] • Technology should be able to respond to alternative communication voices (AAC devices)

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Children have too little motor control to interact with the technology [26]	• It should be possible to control the complexity and tailor it to the needs of the individual child [114] • Choose appropriate stimuli [19] • Technology should be accessible to alternative access methods (switches, eye gaze)

3.2 Methodology-related challenges and recommendations

Composition of study group	
Challenge	**Recommendation**
Sample too homogeneous/specific, e. g., all participants were male [11, 107], only participants with IQ above average [17], no milder forms of autism included [4], participants recruited from single centre and coming from literate and urban families [14]	Investigate more diverse samples [4, 6, 17, 18, 27, 38, 53, 62, 96] • Investigate larger age groups [65, 79] • Investigate more varied situations [38] • Importance of using special cases like twins and siblings in research due to the control advantages they offer [94]
Sample too heterogeneous [36, 42, 92], e. g., with regard to ASD [40, 113, 115] or language disorder as a secondary condition [8] Large differences in the participants' skill levels - difficult to establish a balanced control and experimental group [5] Participants' initial vocabulary levels varied, with some having high baselines and others low, which could influence their performance and the observed changes throughout the study phases [18] Inclusion of children with dual diagnosis, e. g., ADHD and ASD [91]	• Add inclusion criteria and ask preliminary questions [36] • Consider gender, disorder severity, and developmental age for the construct of the study and the control groups [19]
Imbalanced sample, e. g., more males than females in context of ASD [88, 95], more children with ASD than controls [88]	• Data augmentation can be utilised to increase the sample size of underrepresented classes • Cases with a significantly low number of samples can be removed from the automated analysis, but considered as special cases
Selection bias [42], e. g., due to voluntary participation [26] and participants'/families' interest in robots [47]	Identify individuals without initial interest in robotics and develop ways to foster interest in robotics and physical computing [47]

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Participant characteristics are not reported	Report participant characteristics and be as detailed as possible [19]
Finding suitable children as some of them were not permitted to play video games due to therapy restrictions [12]	
Some participants had prior exposure to the learning applications [11]	• If the number of such participants is significantly high, consider them as another group for comparison • If the sample size is big enough, these participants could be removed from the sample set and analysed separately
Lack of information on prescribed medication for participants [47]	Request information on prescribed medication for participants [47]

Study design	
Challenge	**Recommendation**
Small sample size [1–16, 18, 20–32, 34, 36, 38–42, 44, 45, 47, 50, 51, 53, 60, 63, 69, 78–90, 92–94, 96–102, 105–108, 110, 111, 113, 115, 116]	Investigate larger samples [6, 11, 16, 18, 22, 24, 38, 40, 59, 61, 62, 81–83, 85, 89, 90, 92, 93, 96]
No control group [2, 4, 10, 22, 39, 71, 113, 115]	Add control group [10, 22, 23]
No control for cognitive and verbal ability for within-group correlations [24]	
Short implementation/treatment period [53, 107] Only one session [25, 106]	• Longer studies/sessions [5, 22, 27, 34, 51, 53, 61] • More frequent studies [5, 22] • Multiple sessions/longitudinal studies [4, 6, 11, 18, 25, 59] INT5 • Perform short- and long-term user experiments [22]
Study is restricted to one country; cultural and language differences cannot be addressed	Perform cross-country study [22, 23]
Optimal intervention conditions are unknown for a certain target group/an individual child	Conduct experiments to determine optimal length of sessions, the number of words that should be trained per session, the optimal age for using robots, the means of interaction, efficient ways of personalising, and efficient ways of combining various elements [39]
Exploratory study only [63]	

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Lack of comparison of different technologies	More studies could be performed with diverse robots to investigate possible effects of appearance, gender, interaction capabilities, etc. on the acceptability rate and children's performance in imitation tasks [95]
Raters, e. g., of eye contact [107], or anxiety and behaviour [50], were not blind to participant treatment, or to setting [43]	
Study did not account for potential confounding factors such as cognitive function or attention deficits, which could influence participants' engagement and responsiveness to the activities [18]	
Disposition-of-the-day bias [36]	*Multiple sessions; add a before-session question (to caregivers or therapists) on whether anything special happened before the session that might influence the participant's behaviour [36]
Balance between scientific rigor and practical implementation	Explore methodologies that balance scientific rigor with practical implementation [14]
	Investigate role of parental involvement to refine interventions and optimise their impact [6, 26]
	Reproduce the experiments with real robots instead of avatars [65]
Software with proprietary classification algorithm and limited transparency on methodological details [42]	
	Teachers' use of protocols should be facilitated; educators' positive acceptance may spread evidence-based practices [58]
The benefits of a technology over traditional intervention approaches are unclear	Compare developed technology (platform) to typical reciprocal imitation training programs [40]
	More detailed analyses of the benefits of robot therapy for specific aspects of ASD including gender differences [22]
	Further explore the role of touch-sensory inputs in communication development [68]

Measurement, assessment and reliability	
Challenge	**Recommendation**
Low interrater reliability [2]	Add training sessions for the raters
Academic tests given only once during baseline [11]	• Use of multiple baseline academic tests in broader intervals [11] • Valuate improvements in cognitive skills with a neuropsychological assessment [27]
Lack of pre-assessment using validated tests [18]	Add baseline assessments
Misalignment between self-reported metrics and parents'/therapists' observations [42]	
Experts not included in study set up	Broader study set up with neuropsychologists and tutors [27]
Difficulties in scoring test items, because clear distinction between each level of item was not specified [26]	
Diagnosis technology: difficult to differentiate between autism and similar disorders [10]	Investigate also children with other disorders [10]
Participants are showing interest for intervention (game) with different expressions [12]	Validation of behaviours by the therapist according to the participant's reaction when they show their interest in other activities [12]
There is not a gold standard for measuring child-robot interaction [8]	Parents' evaluation of the child-robot interaction enriches the instruments for measuring and offers different point of view [8]
Limited availability of datasets	Create an openly available and well described dataset for future studies [19]
Little evidence that increased physical imitation leads to improved socialization [20]	Include social responses such as attention, engagement, and joint behaviour, which have been suggested as primary measurements for effectiveness of technology (socially-assistive robot) in children with autism [20]
	Test augmented reality 3D models in varied materials or colors, or let participants identify modelled objects in real-world settings to assess how well children generalise learned vocabulary [18]

Environmental and contextual factors	
Challenge	**Recommendation**
Changes of setting/equipment during study, e. g., switched robot half way through study [107], new emotion added during study [107]	
Hawthorne effect (people behave differently when knowing they are observed) [36]	Use hidden cameras [83]
Context effect (environment and circumstances of observations influence participants) [36]	• Set up sessions in known environments, e. g., therapeutic centers rather labs [36] • Encouraged technology (Kaspar) familiarisation sessions before the actual measurements [36]
Study conducted in a single environment, e. g., school - potentially not generalisable to other settings, e. g., home [6]	• Various settings should be investigated [6] • Replication of study in everyday environment is needed to check any potential differences due to specific contexts [26]
Study conducted in school environment [41]	Outcomes of study should be verified under laboratory conditions [41]

Technological considerations	
Challenge	**Recommendation**
Technology does not fit the therapeutic goal [19]	*It is neither the child nor the therapy that should be adjusted to fit technology, but vice versa [19]
Lack of accessibility and usability of technology (robots) due to, e. g., single-language design, responding to voice of a single adult only as a result of training, control app could not be efficiently used by children [26]	Develop customised adaptations for technology accessibility and usability, and test efficacy of adaptations in better supporting playfulness [26]
Lack of rich and user-friendly interface of (VR) technology for non-verbal communication [54]	• Children (with ASD) should be provided with more opportunities to lead and codesign social interaction event and setting [54] • Examine technology design and impact on enhancing the learning transfer to daily-life dispositions and behaviors [54]

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Provided virtual environments were relatively simple and did not fully simulate the complexities of real-life interaction [110]	
Limitations regarding technology (robot [57]), e. g., limited flexibility of (robot) behaviour restricting interaction fluency [100], lacking modulation and expressiveness of robot's intonation/prosody [21], lacking verbal communication abilities of robot [40], limited range of robot's emotions [21], limited movements of robot [21], restricted number and location of active degrees of freedom in the robot's face [40], lacking ability of robot to adapt behaviors to the specific needs of patient [21]	• Technology (robots) should be more autonomous and functional [22, 23, 58] • Design adaptive systems delivering challenging though accessible tasks, i. e., increasing the challenges as the participant's skill increases [27]
Pacing of task - slow image loading disrupted flow of session, which caused lost of interest or choosing first available response option before awaiting full scenario [13]	• More adaptable pacing or guidance within task for participants who struggle with self-regulation [13] • Robust technology is recommended; reduce reliance on internet speed, etc.
Time lag between Wizard of Oz control and executed behaviour made the reactions less spontaneous or even unsuitable for some activities [21]	
Possible modification of effect of electronic screen media by participants' level of intellectual functioning [50]	
	Improve technology to capture child's attention towards mobile activities [15]
Limited customisation of technology to individual abilities with respect to the timing and speed of movements can be challenging for individuals with higher levels of disability [44]	*It is neither the child nor the therapy that should be adjusted to fit technology, but vice versa [19]
Used technology (learning platform) did not have cameras and, thus, cannot analyse looking pattern while interaction [17]	Augment technology (learning platform) with cameras [17]
Used technology (robot) did not allow to share emotional state but only to comment on others' emotional states [21]	

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Used technology (robot) could not express agreement or disagreement to create reciprocal social interaction [21]	• If this is due to the physical limitations of the technology, alternative ways to express these can be utilised • If the technology could not express agreement automatically, Wizard of Oz can be employed • The researcher/therapist can give the agreement/disagreement instead of the technology, with simple verbal/nonverbal cues
	Digital media can be beneficial for therapeutic intervention as it can provide everyone with more opportunities, including those with disabilities [55]
Specific technology became obsolete in the course of project as it did not gain traction in its market [44]	
	Clinicians and educators should adapt LEGO robotics programs for youth with disabilities and include knowledgeable staff in robotics and disability [64]
Limited physical behavioral representations due to the virtual characteristics (of the robotic platform) [51]	Carry out an in-person user study to exploit the benefits of an embodied interaction with hardware (a robot) rather than a virtual character [51]
	Combine augmented reality with social stories and computational thinking games to provide a clear visual structure and flexible teaching framework, helping children with ASD improve social reciprocity [62]

Data collection and observation	
Challenge	**Recommendation**
Only one camera angle - child not always in the camera's focus [4, 100]	• If possible, use multiple cameras with different angles • Exploit multiple modalities
Analysing touch events using videos is inherently inaccurate [7]	
Limited availability of observational channels - none of the analyzed modalities (facial expressions, eye gaze, vocalizations, physiological signals) was available the entire time, for some, availability is really low [36]	• Implement missing data-strategies • Multimodal observation [66] CH3

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Automatic detection systems should be more accurate	Combine gaze and pupil data to improve automatic detection systems [65]
Automatic detection routines are prone to noise and therefore depend on verification by experienced assessor, e. g., w.r.t. touch detection [7]	W. r. t. touch detection, algorithm can be enhanced by identifying the peak touch event in any given series of touch events instead of its event onset [7], and additional type and pressure detection using machine learning [7]
Instrumentation effect (using different instruments in groups/locations) [36]	Record all sessions with the same equipment [36]
The more complex the environment and the more sophisticated the equipment, the more technical problems might arise, including device placements [36] The more sensors a robot has, the more expensive the production and the more complex run-time processing are [36]	• *Minimise technological complexity of observation [19] • Technology (robot) should be simple and predictable [59]
Not all potentially-relevant physiological parameters were assessed [22]	• Multimodal observation [66] CH3 • Larger variety of appropriate biomarkers and tighter control of potential extraneous variables [22]
Data fusion from different channels [19]	Consider type of activity, child condition, and context [19]
Recording levels may not be well adjusted	Check recording levels etc. in advance [19]
Wrist wearable alone may not be able to capture the movements of other body parts (e. g., leg) [3]	Consider to use additional devices
Not all observational channels may provide useful data during the entire observation [19]	Monitor data quality, remove time windows when symptoms are not visible [19]
Audio recordings may contain voices of people other than the child [19]	Child's speech must be distinguished from other sounds [19]
Voice of child may not be well captured [19]	• Reduce noise sources [19] • Close positioning of microphone to child [19] • Avoid speech overlaps of parent and therapist and of parent and child [19] • Use voice activity detection algorithms [19]
Reproducibility of studies	Be precise to describe devices, channels and modalities, be aware of distinction between those - distinguish between life activities, observation channels, and modalities [19]
Scoring by a single observer [100]	Scoring should be confirmed by a second rater [100]

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Annotation is very time-consuming	Integrate automated, AI-based behavior analysis to reduce manual coding and improve measurement accuracy [96]
Integration of results from different modalities may be challenging [19]	• Pay attention to synchronisation [19] and modality-specific inconsistencies [19] • Annotate events that could influence data quality, such as room entries, extra noise, atypical child behaviour, empty battery of a device, etc. on the run or in post-processing [19]
Limitations of facial expression recognition algorithms [40]	• Enrich facial expression database by gathering approved data from typically developing children [40] • Adaptation of facial expression recognition algorithms to the specificity of the possibilities of expression of children with ASD using artificial intelligence [99]
Suboptimal placing of technology, e. g., humanoid robot was not on the same eye level as the participants, causing difficulties during the observations [80]	In this case, such as the robot's hat partially blocking the cameras, alternative methods to extract visual information should be considered
Robot did not always face the child whose name it called [106]	Use human tracking method [106]
Observation is subjective	Use objective devices (eye-tracking, facial coding) for measurement [61]
Observational orientation was not systematically validated and is, thus, not representative [45]	
	Use a validated predictive model [24]
Potential low volubility of children with neurodevelopmental disorders during interaction – reduced possibility to extract (emotion) information from this modality [19]	Be aware that some modalities work better for some disorders whereas other modalities work better for other conditions; adapt your setup to the respective condition of interest
	Deeper analysis of the spatial configuration and characteristics to observe the impact of the play space on playfulness [26]
Adaptation time and interval with the provided technology not controlled [46]	
Children often look sideways or down when speaking which hinders recording of the face [19]	Use a little game involving the technology, e. g., tell the child "the robot cannot see his/her face like this."
Baseline differences between children with autism and controls [19]	Record individual baselines for some signals [19]

Individualisation	
Challenge	**Recommendation**
Lessons tailored to each participant, rather than implemented exactly the same for all participants [2]	
App selection was based on individual learning goals as opposed to behaviour and process skills [11] Graphical interface, feedback and content of apps may have well influenced participation and learning [11]	
Designing a single technology (game) for a group of children [74]	Each child needs to be treated individually; provide different types of games for different problems [74]
Complexities in conducting experimental intervention studies in classrooms: participants were undergoing different forms of learning in parallel to study; follow-up phase of study lacked experimental control and the academic scores may have been confounded by other learning interventions [11]	
	Allow personalisation and augmented reality integration to improve motivation and real-life generalisation [67]
	Explore more dynamic and adaptive difficulty mechanisms within augmented reality activities to further personalise and optimise learning experiences for children with ASD [18]
	Customise technology interface to cater to the requirements of children with autism/the unique dynamics of the social skill group and conduct usability study, followed by clinical efficacy randomised controlled trial [21]
It was practically impossible to keep the planned linear scenario order [36]	
Use of images and content suggested by pilot testers (two adult subjects), while one-to-one personalization could indeed provide different results [27]	
	Replicate experiments with more relaxed discontinuation criteria to allow for a more comprehensive understanding of individual learning trajectories [1]

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	Explore which children could benefit most from specific types of interventions [22]

Engagement and interaction design	
Challenge	**Recommendation**
Virtual teacher was unfamiliar to children, which might have influenced their responses [110]	Either analyse this as a nativity effect, or give a demo session for familiarisation
Children might feel alone without familiar people	Therapist or parents of children with ASD should accompany them while playing with application, depending on symptoms [12]
	Various interaction partners, such as parents and peers, for a more comprehensive assessment of ASD children's social joint attention behaviours [110]
	Keep child interested and engaged in interaction with technology (robot) [36]
Richness of session with technology (robot) dependent on teacher's knowledge about (robot's) repertoire/possibilities [98]	Teachers should be made familiar with possibilities of technology (robot) in advance [98]
	Provide a greater play vocabulary, which would have enabled a more extensive repertoire of communicative functions, such as commands, suggestions, refusals, questions, responses, funny and unexpected utterances, and feedback items [38]
Fixed/limited set of images for a story telling task might have caused spontaneity of social communication to be lost [17]	Increase the choice of objects presented to users [17]
	Give children clearly defined roles when trying to get them to collaborate and work together, i. e., participant A will put together the blocks in a sequence, and participant B will scan and press the button [4]
Difficulties to understand technology's expressions	Make gestures that do not have an impact on children more expressive or change them to gestures that are easier to recognise [52]

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Participants completed tasks on the research computer, under the observation of the researchers, which might have caused discomfort or distraction [46]	

Ethical considerations	
Challenge	**Recommendation**
	Protect the child's rights [19]
	Be considerate with the use of terms that refer to children - use inclusive language, pay attention to wording about the children so as not to imply that one individual is superior to another on the health condition or disorder [19]

3.3 Challenges and recommendations related to implementation in therapy

Child-related factors	
Challenge	**Recommendation**
It is possible that not every child benefits (to the same extent) from technology-supported intervention [20]	• Each child has the right to get the best therapy available [19] • Benefits and limitations of a technology should be compared to other approaches [2] • *Combine digital technologies and traditional support [77]
Children's interaction with the technology reduced over time [106]	• Designing appropriate verbal and non-verbal communicative functions for the technology is essential to help the children build a relationship with the technology [106] • *Investigate new design elements for technologies [16] • Try different reinforcers (e. g., non-verbal rewards like physical interactions, edible incentives, technology's verbal praise) to enhance the children's learning process [1] • Social skills training scenarios and reward systems that are more elaborate and customised to individual subjects' needs, interests, and social abilities [107]
	Negative feedback in case of mistakes should be provided together with clear cues as to how to proceed [109]

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Risk of addiction to technology or permanent attachment [14, 83]	• Limit the duration of the intervention [83] • Educating parents and practitioners on how to use technology (i. e., limiting technology for 15-30 minutes) [88] • *Combine digital technologies and traditional support [77]
Risk of dropping out of therapy early [14]	• Consider to offer some (regular) rewards for participants • Keep in close contact with the participants • *Creating more game variability and personalisation [27, 100, 115]
Time-limit can result in frustration of children [109]	A time-limit can be a motivating factor, but the therapist should be able to extend the time simply if needed [109]
Fully automatic functions could result in disappointment [106]	Add an option for manual input of information on user interface to avoid disappointment (e. g., to vary displayed number if this is preferred by the child) [106]

Parental considerations	
Challenge	**Recommendation**
Critical attitude of parents towards technology used for intervention purposes in general or regarding certain parts or features of the technology (e. g., regarding appearance or benefit of technology) [113–115]	• *Professionals should make a greater effort to raise parents' awareness about the benefits of using technology for intervention purposes [113] • Experts from different fields should perform systematic studies on the appearance and functionality of technologies used in interventions [114] • It is important to allow the child to refrain from the interaction at any point [19] • *Combine digital technologies and traditional support [77] • *Investigate new design elements for technologies [16] • Consider to avoid robots-only scenarios due to lack of human-touch and human values [73]
Parents may have high expectations regarding the functionality of technologies [114]	Introduce additional scenarios to teach more skills (e. g., numbers, colours, labeling pictures, addition, subtraction, gaze behaviour) [1, 2, 75, 114]

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Parents may not follow the therapists' instructions regarding the use of a technology [113]	*Professionals should make a greater effort to raise parents' awareness about the benefits of using technology for intervention purposes [113]
The purpose of the technology-supported intervention may not be obvious for some parents [115]	*Professionals should make a greater effort to raise parents' awareness about the benefits of using technology for intervention purposes [113]
App usage at home was driven by parents and not child most of the time [113]	• Perform a demo session with parents • The app usage might be included in the daily chore charts and rewarded

Technology and intervention	
Challenge	**Recommendation**
High costs of technologies[1]	*Provide easy-to-access and cost-effective games for autistic children [67]
Difficult to develop a single technology that fits for all children with a certain condition [1]	• Collaborations with therapists can help to tailor stimuli to the individual developmental levels of children [1] • Close cooperation with the target users to identify a set of game scenarios that is attractive for children, useful for therapists and technically feasible for developers [9, 70] • Tailor interventions to the individual learning needs and paces of children [6] • Usability tests with the support of special-needs teachers at school, and with regular training, to investigate the effectiveness of technology (web platform) in supporting cognitive functions [27]
Therapy institutions have limited resources (time, space, teachers) to experiment with technologies [1]	• Educate professionals who provide services for children with neurodevelopmental disorders by providing specific courses with regard to technologies [8] • *Provide easy-to-access and cost-effective games for autistic children [67]

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Technical issues of the technology [93]	• *Provide easy-to-access and cost-effective games for autistic children [67] • Technologies shall be robust and intuitive built in tech support/problem solving • Provide easy-to-access technological support
Space requirements of the technology [93]	Consider space requirements prior to purchase and implementation
Needed time to set-up the technology [93]	Needs to be built in to session time
The speech generated by the technology can be off, too low or too quick for a child [98]	• Adjust the speech settings (e. g., sound level) to the child's needs [36, 98] • Allow different voice options
	Task must be reliable, consistent, and predictable [109]
Novel elements are introduced too quickly so that child is overburdened	Introduction of novel elements must be done in a gradual and controlled manner [109]
	Implement more actions and new activities from everyday life [113]
Technology only incorporated a pre-determined set of cards and had no option to add further cards [109]	Involve the children in discussions aimed at proposing their own solutions and provide a solution for incorporating them into the technology [109]
Risk of infection (e. g., COVID-19)	Disinfect hardware after each therapy session [114]

4 Conclusions

This report summarizes Activity 2.5 of the TE(A)CHADOPT project which focuses on gathering challenges and recommendations regarding the observation and evaluation of how children with neurodevelopmental disorders interact with technologies. The findings are based on a systematic literature review, the insights from two former Erasmus+ projects, and the interdisciplinary expertise of the project consortium. Most identified challenges are related to the symptoms of the children with neurodevelopmental disorders, including for example a limited attention span, limited verbal communication skills, or sensory sensitivities. The observation of child-technology interaction should be multimodal, yet involve a minimal number of devices to avoid distractions or anxiety. Recording settings should be carefully controlled and data quality should be continuously monitored. When evaluating child-technology interactions, it is crucial to involve more than one annotator, verify the meaning of the child's expressions with someone familiar with the child, and remain cautious of potential misclassifications by automated methods. Technologies designed for children with neurodevelopmental disorders need to be robust, user-friendly, and adaptable - not only in terms of features and appearance but also regarding the type and complexity of the activities. It is strongly recommended to tailor the technology, activities, observational tools, and duration of the interventions to each individual child: What proves effective for one child may be inappropriate for another – and vice versa.

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