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Research paper

Co-designing a social robot for child health care

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ABSTRACT

Social robots provide new opportunities to support general child healthcare programs. However, it is still unclear how social robots could be used in this context and how corresponding behaviours should be designed. To ensure satisfying implementations of such new technological solutions, it is essential to include the end-users in the designing process. We have conducted a co-design study at two primary schools based on three complementary, creative methods: Draw-write-and-tell and/or story-writing-and-telling, Theatre play, and Robot avatar programming. A total of 46 children aged 7–12 years old participated in four robot co-design workshops. The drawings, stories and theatre plays were analysed, resulting in evaluations of 10 scenarios as well as 21 new scenarios and 7 main user requirements for social robots providing mental support in general child healthcare. Evaluation of the activities highlight their stimulation of out-of-the-box thinking and the development of creative solutions (i.e. drawings/stories/theatre plays resulted in robot designs, scenarios and requirements), while children's reflections show them being enjoyable for participation. The inputs gathered during these co-design workshops will greatly influence future work on the design and application of social robots in the child healthcare domain.

1. Introduction and related work

Social robots have potential as a tool supporting a child's overall well-being. In general, children tend to react positively to robots, readily engaging in play activities with them (e.g., Bernstein & Crowley, 2008). Moreover, studies show positive indications for the feasibility of social robots in child paediatric and education settings (e.g., Belpaeme, Kennedy, Ramachandran, Scassellati, & Tanaka, 2018; Dawe, Sutherland, Barco, & Broadbent, 2019; Moerman, van der Heide, & Heerink, 2019; Neerincx, Sacchitelli, Kaptein, Van Der Pal, Oleari, & Neerincx, 2016). Specifically, during mental healthcare interventions, children prefer digital features such as videos, limited text, ability to personalize, ability to connect with others, and options to receive text message reminders (Liverpool, Mota, Sales, Čuš, Carletto, Hancheva, Sousa, Cerón, Moreno-Peral, Pietrabissa, et al., 2020). These features could easily be incorporated in a social robot platform.

Social robots are especially acceptable as a tool providing mental support for the child when needed (Neerincx & Luijk, 2020). Medical interventions can be stressful for a child, and a social robot has the potential to reduce a child's stress level (e.g., Beran, Ramirez-Serrano, Vanderkooi, & Kuhn, 2013; Liverpool et al., 2020; Trost, Ford, Kysh, Gold, & Matarić, 2019). The presence of a social robot in the hospital can increase positive emotions and social engagement (Jeong, Breazeal, Logan, & Weinstock, 2018), provide distraction, relaxation and better communication (Moerman et al., 2019) for example by mediating between children and therapist (Zhanatkyzy, Telisheva, Amirova, Rakhymbayeva, & Sandygulova, 2023). As such, a social robot can facilitate the connection between child, child care professional, and parent (Neerincx, Rodenburg, de Graaf, & Masthoff, 2021), especially in specific cases where communication is challenging (i.e., children with autism spectrum disorder (ASD) Giannopulu & Pradel, 2012). Additionally, a social robot can increase engagement and motivation during physical rehab therapy sessions (Butchart, Harrison, Ritchie, Martí, McCarthy, Knight, & Scheinberg, 2021), and improve a child's self-discipline and awareness in treatment sessions of paediatric disorders (Henkemans, Bierman, Janssen, Looije, Neerincx, van Dooren, de Vries, van der Burg, & Huisman, 2017). These factors function as specific aspects of child development and care, important in paediatric as well as education settings.

However, when designing a technical solution for a specific application field such as healthcare, it is vital to include end-users' perspectives (Norman, 2013). When dealing with children, it is challenging to

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include them as co-designers, since children have specific needs, based on e.g., their level of development (Darbyshire, MacDougall, & Schiller, 2005). Using suitable co-design methods is necessary to keep children's engagement and help them design realistic solutions (Ligthart, Henkemans, Hindriks, & Neerincx, 2017; Metatla, Bardot, Cullen, Serrano, & Jouffrais, 2020). In the field of healthcare, some co-design research with children has been carried out on social robots for distraction (Foster, Candelaria, Dwyer, Hudson, Lindsay, Nishat, Pacquing, Petrick, Ramirez-Duque, Stinson, et al., 2023), pain management (Zhang, Broz, Dertien, Kousi, Van Gurp, Ferrari, Malagon, & Barakova, 2022), and mental support of adolescents (Alves-Oliveira, Budhiraja, So, Karim, Björling, & Cakmak, 2022). However, it is still unclear which co-design methods work best for children under 12 years old in designing social robots for mental support in more general healthcare settings. Also, specific implementation scenarios for these kinds of robots are lacking in previous research.

Therefore, in this paper, we present a human-centred co-design study aiming at designing and evaluating social robot behaviours for implementation in the general child healthcare domain, *for* and *with* children. Including end-users in the design of new technologies can increase usability and value of products (Norman, 2013). Children, depending on their age and development, can experience difficulties expressing themselves or may even be unaware of their own needs (Southam-Gerow & Kendall, 2002). Moreover, their attention span for active engagement is limited (Mahone & Schneider, 2012). It is therefore necessary to tailor co-design methods to children, allowing them to choose their own way of expressing and providing insights in their values, needs and situations (Darbyshire et al., 2005).

The contribution of our paper consists of children's evaluations of previously-derived social robot scenarios, as well as new scenarios and user requirements. Additionally, we evaluate different creative co-design methods, tailored to the needs of children.

1.1. Co-design for child–robot interactions

There are different ways of adopting a human-centred design approach. Children can be included in the design process as six main roles: users, testers, informants, design partners, co-researchers, and protagonists (Alves-Oliveira, Arriaga, Paiva, & Hoffman, 2021). In our work, we included the children as design partners, by involving them in the design process of social robot behaviours through creative activities, as well as co-researchers, by letting them evaluate results from previous co-designing activities with parents and healthcare professionals.

To accommodate children's needs, several studies have reported on diverse co-designing techniques to evaluate technologies with children. Simko, Chin, Na, Saluja, Zhu, Kohno, Hiniker, Yip, and Cobb (2021) developed a focus group strategy specifically for children called "Would you rather...?". This questioning stimulated the children with playfulness, humor, and structure, while the researchers were able to gather recommendations from the focus groups. Also Foster et al. (2023) used focus groups for co-designing with children and parents. Lee, Roldan, Zhu, Kaur Saluja, Na, Chin, Zeng, Lee, and Yip (2021) evaluated various co-designing techniques for online settings, including crafting and drawing activities (e.g., bags of stuff, comic-boarding, big paper technique), highlighting the additional value of using creative methods as well as improvisation for collaboration in co-designing with children. Woodward, McFadden, Shiver, Ben-hayon, Yip, and Anthony (2018) studied children co-designing intelligent interfaces by comparing different, collaborative, creative activities such as Cooperative Inquiry, bags of stuff, and big paper. They found that the big props technique (i.e., acting out the system itself) provided the richest data. Henkemans, Neerincx, Oleari, and Pozzi (2016) designed the Co-design for Child–Computer Companionship suite (4C suite), which includes various creative methods to provide the children with different outlets for their thoughts and experiences. These methods consist of draw-write-and-tell, storytelling, and image theatre. Alves-Oliveira, Arriaga, Paiva, and Hoffman (2017) successfully used storytelling as a method in their research in combination with puppeteering techniques as input for the robot behaviours. Metatla et al. (2020) took a more longitudinal approach with a co-design method set consisting of four consecutive workshops with children: (1) getting to know the robot; (2) self-programming the robot; (3) Lo-Fi crafting a robot and a game concept making use of role playing and design fiction techniques; and (4) designing a collective physical game to stimulate collaborative team work. Sanoubari, Muñoz Cardona, Mahdi, Young, Houston, and Dautenhahn (2021) used remote co-design to create a social robot in the context of bullying at school. Creative activities such as brainstorming, sketching, storyboarding, and animating were used. Also Alves-Oliveira et al. (2022) used brainstorming, together with ideation and prototyping, to design a social robot with teenagers for improvement of adolescent's mental health. The final robot-mediated intervention was preferred over the traditional treatment medium. Zhang et al. (2022) used prototyping as well, to design a social robot for pain management. Lindberg (2013) studied participatory design methods for children with cancer, and found that comics were suitable for the children to create realistic information technology designs.

In summary, although a variety of co-design methods have been developed for children, these methods have not yet been evaluated for the general child healthcare domain. Based on these studies, it seems important to combine imagination-facilitating methods, which will give the children different modalities to express themselves (e.g., not only verbal) (Darbyshire et al., 2005). Moreover, a combination of methods may increase the children's engagement level and with that their attention-span, while programming may help in understanding the robot and setting more realistic expectations of its capacities (Ligthart et al., 2017; Metatla et al., 2020). By using block programming tools specifically developed for children, it would be possible to involve them in this aspect of designing social robot behaviours as well.

1.2. Design space: Social robots in child healthcare

In the Netherlands, The Child and Family Center provides general health care for children (e.g., vaccinations, eye tests, check-ups), as well as mental health care services (e.g., family coaching, training sessions at primary schools). This organization is currently exploring the implementation of social robots in their care practices in a practical manner by testing their social robots sporadically in low-risk situations (e.g., waiting room Neerincx, Hiwat & de Graaf, 2021, mass vaccination days), with a specific focus on children aged 7–12 years old. This is not only the main target group of the Child and Family Center, but also considered a suitable age group for the implementation of social robots as a tool for care practices (Neerincx, Rodenburg et al., 2021). For a successful implementation, the Child and family professionals have expressed a need to increase knowledge regarding the risks and opportunities of the application of social robot in children's healthcare practices, as well as advance requirements and implementation strategies based on scientific empirical evidence (Moerman et al., 2019).

Mental care professionals coach and treat children with a variety of (mental) health issues, sometimes with their parents present during the therapy sessions. Care organizations employ professionals with varied expertise and disciplines to cover the diverse needs in children's treatments. Even though we can make these distinctions in child health care, the care provided is tailored to individuals. The challenge is to develop social robot functionalities that add on to the diverse care paths and can be deployed in a more generic way.

Child care professionals express the need for more long-term and specific research as well as concrete social robot applications for child mental support in healthcare settings (Neerincx, Rodenburg et al., 2021). The goal of our overall research project is to bridge this current gap of ecological validity and lacking knowledge of long-term effects by co-designing robot application scenarios with children, parents, and healthcare professionals, as well as systematically test these scenarios

Table 1
An overview of the different creative co-design activities of the workshop.

Activity	Instructions	Modality of expression	Data type
Storytelling	Write a story about a child and a robot at the Child and Family Center (individual).	Verbal	Story + Transcript
Draw-write-and-tell	Draw a child and a robot at the Child and Family Center (individual).	Visual, Spatial	Drawing + Transcript
Theatre Play	Play out one of the following 9 scenarios (or think of one yourself) (group).	Bodily-kinaesthetic, Spatial	Video
Robot Avatar Programming	Program the robot with the online programming tool (group).	Verbal, Bodily-kinaesthetic	Program

with longitudinal studies in real-world contexts. Child professionals are generally not familiar with existing social robot applications and their potential (Neerincx, Rodenburg et al., 2021; Rabbitt, Kazdin, & Scassellati, 2015), and neither are the children themselves. Yet, including the end users in the research and design process is essential to avoid non-adoption or rejection (De Graaf, Allouch, & Van Diik, 2017) and establish awareness of the potentials such robots may offer and identify the relevant user requirements (de Graaf, Ben Allouch, & van Dijk, 2018). A human-centred design approach can help in creating engaging child–robot interactions (Rose & Björling, 2017). The main users involved in our project are child healthcare professionals, parents and the children themselves. In previous work, we carried out focus groups with our adult end-users, which is an appropriate method for co-design purposes (Freitas, Oliveira, Jenkins, & Popjoy, 1998). However, children require other co-design methods given their inadequate capacities to express themselves and limited awareness of their own needs (Southam-Gerow & Kendall, 2002), and their narrow attention span for active engagement (Mahone & Schneider, 2012). Although children have been involved in co-design studies for technology, more specific co-design guidelines for social-robot interactions in general child care settings are still lacking.

For our research, a set of co-design methods tailored to our young target group and application domain is needed, allowing them to choose their own way of expression and that provides insights into their values, needs and situations (Darbyshire et al., 2005). This paper will evaluate the suitability of several co-design methods for children with the aim to develop effective and appropriate child-professional-robot interactions for child (mental) and family care, and will report several scenarios and user requirements that have risen from these co-design sessions with children.

2. Methods

2.1. Selection of co-design activities

For our co-design workshop, it is important to let the children have fun to ensure engagement during this study. Additionally, it is important to give the children different ways of expressing themselves. Therefore, we are planning to implement four different, playful activities. Based on previous research (see Section 1.1 : Alves-Oliveira et al. 2017, Henkemans et al. 2016, Lee et al. 2021, Lindberg 2013, Metatla et al. 2020, Sanoubari et al. 2021, Woodward et al. 2018), we choose to incorporate the following activities in our workshop: (a) Storytelling, (b) Draw-write-and-tell, (c) Theatre play, (d) Robot avatar programming. An overview of all activities, including instructions given, the modality of expression used by the children, and the type of data collected, can be found in Table 1.

After consultation with a child and family care professional, we decided to combine the storytelling and draw-write-and-tell activity, and let the children choose themselves whether they wanted to draw or write. This gives the children even more freedom to express themselves, and shortens the workshop time, which benefits the children's attention span. Also, more general group discussions should be included, to discuss all outcomes with the children.

2.2. Pilot study

To evaluate the proposed co-design activities, we first carried out a pilot study at the Child and Family Center, before organizing the workshops at primary schools. 4 children, aged 8–12 years old, were recruited via emailing employees of the Child and Family Center, asking if they knew any potentially interested children (clients and/or family) who would like to participate in a robot workshop. All participants consisted of family members of healthcare professionals. Two researchers were present to lead the workshop, explain the study, and host the activities. Also, two child care professionals were present to assist the researchers during the activities and to intervene if needed. The researchers, child care professionals, and children evaluated the workshop afterwards together in a group discussion. All activities were evaluated positively and only small improvements were incorporated. First, it was decided to remove the ice breaker activity, since children at the primary school will already know each other. Also, it was decided to split the groups of children at the primary schools into two if the workshop participants would consist of more than 6 children, to stimulate interaction and teamwork, and leave more room for individual expression and assistance when needed. Finally, it was decided to change the robot play time closure activity to robot avatar programming, to add an educative component to the workshop and explore the potentials of children co-designing robot behaviours through programming for the Child and Family Center healthcare and coaching context. For an overview of the pilot procedure, as well as the general procedure, see Fig. 1.

2.3. Participants

A total of 46 Native Dutch-speaking children aged 7–12 years old participated in our co-design study (see Table 2), recruited via their primary school teacher. We chose this age group, since it is the main client group of the Dutch Child and Family Center. Also, based on the related work, this age group is suitable for the creative activities chosen, as well as for robot implementations in general. The children participated as part of their usual Monday morning 'plus'-class, designed for children that can handle extra classwork, of which four classes participated in total. In all cases, parental consent was provided. This was obligatory for the children to be able to participate, i.e. 4 children in total did not receive parental consent and therefore did not participate in the workshop. Also, in the introduction of the workshop, all children were told that they did not need to participate in the workshop activities, that they were allowed to stop the activities whenever they wanted, and that they could refuse being recorded and/or sharing their products with us. In case the children did not want to participate anymore, they could go back to their general class. In the theatre activity, before each play, children were asked if they wanted to participate. The mediator of this activity made sure that every child got the chance to participate, but it was not mandatory. Ethical approval was obtained from the ethics board of our university. The children had no notable previous experiences with social robots (i.e. none of them participated in child–robot interaction studies before, nor ever encountered a social

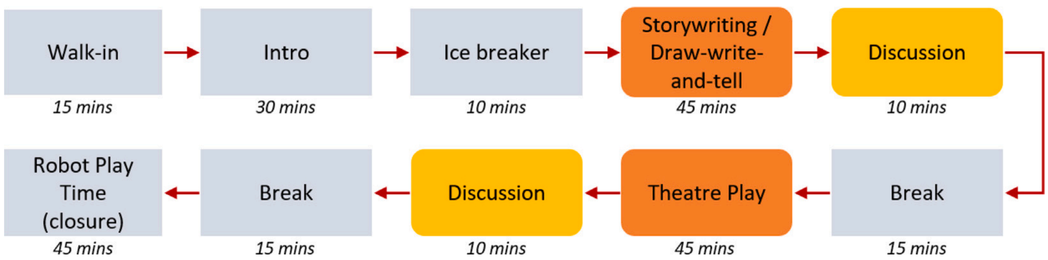


Fig. 1. An overview of the pilot procedure.

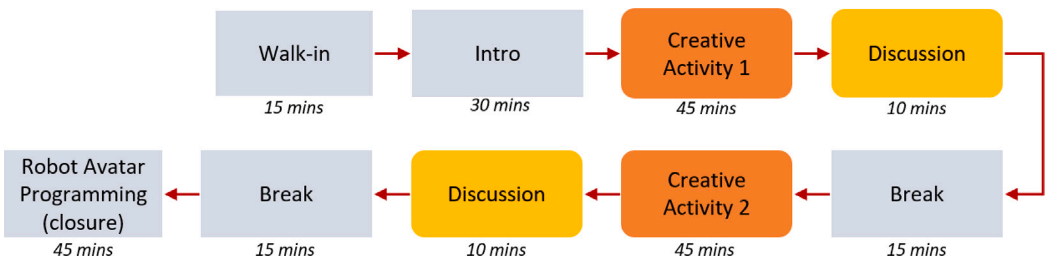


Fig. 2. An overview of the general procedure. Creative Activities 1 and 2 consisted of Storywriting/Draw-write-and-tell and Theatre Play (interchanged between groups).

Table 2
Participant overview. A total of 46 children participated in our study, over 4 different workshops.

Workshop	# Children	Age range
W1	12	8–10 years old
W2	13	10–12 years old
W3	15	7–12 years old
W4	6	7–8 years old

robot in a healthcare/education setting). The previous experiences of the children consisted of social robots presented in popular culture (e.g., movies) and toys.

2.4. Procedure

For a brief overview of the procedure and timeline, see Fig. 2. In each of the sessions, two researchers, two child care professionals, and one teacher were present to guide the session. Each creative activity was led by one researcher and one child care professional, while the teacher was present to assist when necessary and intervene in cases of need (see Table 2).

2.4.1. Walk-in

The workshop started with a fifteen-minute walk-in to check for informed consent. Parents received the information letter beforehand. The children handed in the signed informed consent, since the parents were not allowed in the classroom due to COVID. Parents were told to ask their questions via email beforehand, if they had any. During the walk-in, the children took place at their desks.

2.4.2. Introduction

To give the children more context for the co-designing activities, we started by informing the children about social robots in general during a short PowerPoint presentation. Here, we also checked for prior social robot experiences of the children. After we presented the work of the Child and Family Center. To ensure a safe workshop environment, a few guidelines were set up together with the children: (1) we are nice to each other; (2) we will let each other finish speaking; and (3) we are using our fantasy. The teacher added guideline 4: *We do not make fun of each other*. We explained the children that the discussed scenarios can be fictional. To prevent any misunderstandings, the children were allowed to ask questions at any time during the day. Moreover, the children were explicitly made aware that they could quit the workshop activities any time. The teacher divided the children randomly into two groups for the two activities and brought them to the corresponding locations (two different classrooms).

2.4.3. Creative activities

Simultaneously in two different classrooms, we started the creative activities.

For the *storywriting/draw-write-and-tell activity* (see Fig. 3(a)), we instructed the children to find a spot in the room where they could create a story or a drawing. Both methods required the children to create a scenario where a child arrives at the Child and Family Center and begins to interact with a social robot. This activity lasted for approximately 45 min.

For the *theatre play activity* (see Fig. 3(b)), we instructed the children to act out predefined scenarios (see Section 3 Table 4 for all 10 scenarios). The scenarios were based upon results from previously carried-out focus groups with child care professionals and parents of children with care needs (Neerincx, Rodenburg et al., 2021). All scenarios consisted of three actors: a child, a care professional, and a social robot. Before each play, one of the session leaders asked which three children would like to participate in the play. The three children were then asked to pick one of the ten scenarios printed out on laminated cards, and act out the corresponding scenario. After acting out the scenario, the audience could ask questions and provide suggestions. Then, three other children were asked to act out a new scenario, selected from the left-over cards (i.e., each scenario was only acted out once per group, except for the "Create your own scenario" card). This continued until approximately 30 to 45 min had passed, dependent on the attention and active engagement of the group of children.

2.4.4. Group discussion

After each creative activity, we instructed the children to all go back to the group circle and discuss their products. The group discussions were recorded for analysis. After each explanation, the children, researchers and/or professionals could ask questions about the drawing, story, or theatre play to gain more insights. After each group discussion, a short break of 15 min took place, to let the children have something to eat and drink, or to let the children play outside as they were used to at school. After the short break, the two groups of children switched activities (i.e., the group who did draw-write-and-tell/story writing as

(a) Drawing and Storywriting. (b) Theatre play. (c) Meeting the robot.

Fig. 3. Pictures of the research set-up and different activities.

the first activity, would do the theatre activity, and vice versa). After the second activity, all children returned to the group circle to again discuss the outcomes and experiences of both groups. Again, a short break of 15 min took place.

2.4.5. Closure: Robot avatar programming

After two creative activities in parallel sessions, the robot avatar programming activity allowed children to explore potential behaviours of a virtual robot. Given that the children just completed a module on programming at school, this activity suited the curriculum well. First, the researcher would explain how the tool worked, and then ask the classroom what they would like the virtual robot to say or do. The children were able to suggest different blocks of content, which the researcher would add to the tool. After, the children were allowed to one by one add one block of content to the program on the digital whiteboard. In this way, they together created a program that was run after every child added something to it.

The activity was ended by showing a small, humanoid robot (UB Tech Alpha Mini) and let the children interact with them (see Fig. 3(c)).

2.5. Materials

A PowerPoint presentation was used to visualize information regarding the workshop, projected on a digital whiteboard. The Alpha Mini (Ubtech) was used to introduce the children to a social robot. The social robot was also used as a reward, since the children were allowed to interact with it after the experiment. For the storytelling/draw-write-and-tell activity, writing and drawing materials were present. For the theatre activity, several attributes were used to make the play more realistic and enjoyable (e.g., a robot costume, a hat, a scarf, a necklace). A camera was used to record the workshop and corresponding responses and interactions of the children. For the robot programming activity, an online platform was used (redacted for anonymity reasons).

2.6. Experimental setting

The workshops took place at two primary schools, in four different groups at four different days. The workshop took place in two different classrooms at the corresponding primary school. In these workshops, children brought their own foods and drinks, as they were used to at any other school day. All rooms were decorated with robot-related attributes. For a visual impression of the research set-up and different activities, see Fig. 3.

2.7. Data collection & analysis

Data from both creative activities was collected for analysis with the goal to derive scenarios, robot roles, and user requirements of social robots in the general child healthcare domain. The stories, drawings, and theatre plays of the children, consciously or unconsciously, represent the thoughts and experiences of the children, as well as their perception of robots (Rollins, 2005). The written stories were collected for textual analysis. The drawings were divided into categories and analysed. The theatre plays were recorded and video coded afterwards. Discussions on the children's stories and drawings were recorded and transcribed, to provide additional explanations of their products as well as derive additional robot roles and user requirements.

The data analysis adopted an open and axial coding and grounded theory approach (Habib & Hinojosa, 2015; Walker & Myrick, 2006). First, the drawings, stories and theatre plays were each individually labelled into different scenarios. Then, corresponding robot roles and user requirements were assigned to each scenario, based on the drawings, stories and theatre recordings. Two researchers independently coded 25% of the results and discussed the codes until consensus was reached. These scenarios, robot roles, and user requirements were used as a base to analyse the remaining data. Finally, all results were discussed among the two researchers until full agreement was reached.

3. Results

3.1. Drawings, stories and theatre play: New scenarios

During both creative activities, new use cases and scenarios were created by the children. In the storytelling and draw-write-and-tell activities, the children thought of them individually, while in the theatre activity, the children were collaborating together.

An overview of all newly created scenarios can be found in Table 3, together with the number of times they were created by the child or group of children. It also shows the product type(s) upon which the results were based. Additionally, it shows robot roles and requirements that were found in these scenarios. For more information on the requirements, see Section 3.3. The codes used in the table to refer to the requirements can be found Table 5. In total, 21 new scenarios were created by the children, of which ten emerged from the first activity (drawings and stories), eight from the second (theatre), and three from both.

3.1.1. Collected drawings and stories

Examples of the collected data in the first creative activity can be found in Fig. 4. The most popular scenario to draw or write a story about was a social robot present during a vaccination (S1). An example of such a drawing can be found in Fig. 4(a). In this drawing, it can be seen that the robot is providing the child with mental support by taking on a buddy role. The robot holds the hand of the child, uses soothing phrases (e.g., *"You can hold my hand"*), and hugs the child afterwards.

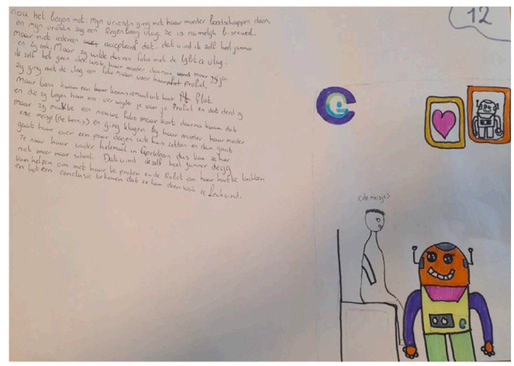
The next most popular scenario was a social robot to help out at school or at home for learning problems (S2). An example of this scenario can be found in Fig. 4(b). In this example, a child can be seen struggling with the amount of homework, stating *"I have a lot of homework"*, where the robot offers to help out by saying *"I will help you"*. Some children mentioned specific cases of learning problems, for example dyslexia, where they thought a social robot could be of use.

Fig. 4(c) shows a child meeting a robot in a waiting room (S5), before an eye test. In this case, the child feels nervous while waiting.

(a) Social robot for mental support during a vaccination.

(b) Social robot helping with homework (educative).

(c) Social robot as a fun distraction in the waiting room.



(d) Social robot for mental health support (LGBTQAI+ related).

(e) Social robot for emotional support (anger issues).

(f) Social robot for sleeping problems.

Fig. 4. Examples of results of the drawing and writing activity.

The robot asks her if she would like to play a game together (*"Would you like to play with me, so it is less scary?"*).

Fig. 4(d) shows a written story about a robot supporting a child struggling with her sexual orientation. The story is told from the perspective of a friend of the child. In this story, the child, who identifies as bisexual, is not supported by her social environment. Her friend suggests a social robot to talk to (S4), so she can realize that (as stated in the story) *"she can do what she likes"*. Another example of scenario S5 can be found in Fig. 4(e), showing a robot providing emotional support. Here, the robot is there for the child when he gets angry. The child states: *"I am angry"*, with steam coming out of his ears. The robot stands next to him, supporting him with his emotion regulation.

Lastly, Fig. 4(f) shows a robot at home for sleeping problems (S7). In this drawing, a child asks for help because she has trouble sleeping (*"Robot, I cannot sleep, please read me a story or sing something"*). Her sister says *"Oh no not again!"*. The robot says that he is going to help her and sings a story for the child, while she falls asleep. The next morning, the child states: *"Mom, I slept great!"*.

3.1.2. Collected theatre examples

Also during the theatre play activity, the children came up with new scenarios. A social robot to stimulate movement and exercise (S13) was acted out twice. For example, in one play, the child and robot do sports together, namely boxing. The child can hit the robot, but the robot is not allowed to hurt the child. In this example, the robot acts as a buddy, exercising together.

Another scenario that was created by two different groups of children, was the scenario of a social robot assisting a teacher at school (S14). In one example, the robot first acted as a tutor, teaching the

Table 3
Summary of newly created scenarios by the children and number of mentions as well as corresponding robot roles and requirements. The requirements are further explained in Table 5. T = Theatre, D = Drawing, S = Story.

	New scenario: Social robot	#	Product	Robot role	Requirements
S1	Present during vaccination	9	D, S	Buddy, mental support, fun distraction, carrying out vaccination	1, 1a, 1b, 1d, 4
S2	To help at school/homework for learning problems	7	D, S	Mental support, educative	1, 2a, 6, 6b, 6d
S3	Present during eye test	6	D	Mental support, carrying out eye test	1, 6b, 5f
S4	For general emotional/mental support	5	D, S	Mental support, distraction, reward	1, 1a, 1b, 2b
S5	In the waiting room	4	D, S	Providing information, distraction, mental support	1, 1d, 3b, 5h
S6	To support child with special needs	3	D, S, T	Mental support, physical support, buddy	1, 3b, 4a
S7	For sleeping problems	3	D, T	Bedtime stories and songs, giving advice (informative/educative), asking questions	6a, 6c
S8	For house keeping	3	D	Technical support	5a, 5, 5f
S9	During general health interventions	3	D	Mental support	1, 1a, 1d, 2a
S10	To read stories	3	D	Educative, entertainment	
S11	As a host at the entrance	2	D, T	Guide	3b, 3e, 5d
S12	Present during hearing test	2	D, S	Mental support, carrying out hearing test	
S13	To stimulate movement and exercise	2	T	Physical education, buddy role	3b, 4, 4a, 5d,5h
S14	To help the teacher at school	2	T	Tutor, buddy	1c, 3a, 3d, 4, 4a, 5a, 6d, 6e
S15	Present at the playground	1	D	Social support	3c
S16	For child struggling with going to school	1	T	Give advice (informative/educative)	5a, 5b, 6a
S17	To increase child's self-esteem	1	T	Positive feedback (improving self-efficacy), mental support, rational feedback	2, 2b, 3, 5b, 5c, 6a, 6b
S18	To solve conflicts	1	T	Mediator, reward	3c
S19	To teach children about technology	1	T	Educative, buddy	1, 3e, 5, 6d, 7a
S20	As a companion and navigation system	1	T	Technical, buddy	3b, 4, 5
S21	As a mediator/leader during a group therapy session	1	T	Mediator, administrative	3b, 3c, 3d

children about robots. The teacher guides the interaction and introduces the robot. Afterwards, the robot plays a game together with the children, where the robot takes on a buddy role.

Also, one group of children came up with a social robot to increase the child's self-esteem (S17). In this scenario, a child feels insecure about her verbal abilities. The robot is used to improve self-efficacy of the child by for example using motivational phrases like *"You can do this!"*. Also, the robot provides rational feedback: *"You are able to say a few words, so you can talk"*. In this scenario, the robot and the parent are working together in increasing the child's self-esteem.

3.2. Theatre play: Scenario evaluations

Besides creating new scenarios, the children were asked in the theatre activity to evaluate nine other different scenarios based on results from previous focus groups with child care professionals and parents (Neerincx, Rodenburg et al., 2021). The evaluated scenarios, including the number of times they were acted out, corresponding robot roles, and requirements, are shown in Table 4. The codes used in the table to refer to the requirements can be found in Table 5.

Since the children could choose a scenario themselves, not every scenario was acted out in every workshop. The scenarios acted out most were the scenarios of a child receiving extra math lessons (ES1), a child finding it difficult to talk about his feelings (ES2), a child that finds it difficult to play with other children (ES3), and a child that needs a vaccination (ES4). One of the most popular robot roles was a social robot as a buddy, which for example occurred in scenario ES1. Here, the robot would do the math lesson together with the child, helping out but not telling the exact answers.

Also, in an example play of ES1, the robot showed positive feedback (*"You got all the answers, yay!"*) and rewards. Rewards were also found in ES2, where the robot stated that the child will receive a reward if he tells what is wrong (*"If you tell me, you will get a present", "If you tell me, I will do everything for you"*). In another example play of ES2, the robot provided mental support, which occurred in 6 scenarios in total. For example, the robot would state *"You can tell me anything"*, and *"You don't have to be afraid"*. Sometimes, the social robot would hug the child for comfort, for example when saying goodbye (ES8).

Also, personalization took place in multiple scenarios, for example ES3, where the robot would ask multiple questions to the child in order to adapt its behaviour to the child's need, such as*"What kind of game would you like to play?"*.

In multiple interactions, the social robot was a fun distraction, e.g., playing a game in the waiting room (ES5), explaining the vaccination in a fun and playful manner (ES4).

In most plays, the robot expressed 'robot-like' behaviour (e.g., rigid movements) and speech (e.g., short factual sentences, monotonous voice).

Table 4
Results of the children's scenario evaluations. The requirements are further explained in Table 5.

	Evaluated scenario	#	Robot role	Requirements
ES1	Child receives extra math lessons. To learn about this, the child takes a test with/on the robot.	5	Positive feedback, reward, buddy, educative, assisting teacher	2, 4, 4a, 5f, 5g, 6b
ES2	Child finds it difficult to talk about his feelings. How can the robot and care provider help?	5	Mental support, reward, personalization, role play, guidance/referral, assisting care provider	1a, 1b, 2a, 3, 3a, 3b, 4a, 5a, 5e, 6b, 7, 7a
ES3	Child is shy and finds it difficult to play with other children. The robot finds this difficult too. How can they help each other?	5	Mental support, buddy, mediator	3a, 3c, 4, 5b
ES4	Child comes to the CJG for a vaccination. The child finds this a bit scary. There is a robot that explains the procedure.	5	Mental support, fun distraction, reward, assisting care provider, personalization	1a, 2a, 4, 5b, 5d, 5h, 6a
ES5	Child did very well on the assignment. Therefore, the child is allowed to choose a fun game to play with the robot.	4	Buddy, reward, positive feedback, personalization	1a, 2, 4, 4a, 5d, 6d
ES6	Child comes to the CJG for an eye test. Here the child has to wait. In the waiting area is a fun robot.	4	Guidance/referral, educative, reward, personalization, fun distraction	1b, 2a, 3b, 4a, 6a, 6b, 7, 7a
ES7	The child comes to the CJG for the first time for a chat with the care provider. The child meets the care provider and the robot for the first time. The child feels a little shy.	4	Mental support, buddy, assisting care provider, fun distraction, personalization, guidance/referral	1a, 1d, 7a
ES8	Child has already been to the CJG a few times. The child and the robot have become friends. Unfortunately, they now have to say goodbye and it is unclear whether they will see each other again.	3	Mental support, buddy, fun distraction	1b, 3a, 3d, 4, 4a, 5b, 5d
ES9	Child must give a presentation at school. The child finds this a bit scary. The child asks the robot for help. What will happen?	3	Mental support, educative	4, 6a, 6f, 7a
ES10	Come up with a situation yourself!	14	See Table 3	See Table 3

3.3. User requirements

From the creative activities, not only scenarios could be derived, but also user requirements (corresponding to the scenarios). An overview of all user requirements can be found Table 5. In this table, the seven different main user requirements are explained by means of expected outcomes and sub-requirements. These requirements are matched with the specific scenarios in Tables 3 and 4.

3.4. Robot avatar programming

Since this activity was only an introduction of block programming in general, and there was not much time left, this activity was simply an exploration of the potentials of introducing block programming in co-designing social robot interactions with children. First impressions show that the children greatly enjoyed programming the robot to dance, and letting the robot say general things such as: *"Welcome at the Child and Family Center!"*, *"We had a lot of fun today!"*. However, also sentences that made less sense were used, for example *"I am nature!"*, *"I want to honk!"*, which they stated was an inside joke. When running the program and watching the virtual robot dance, the children would get out of their seats and dance together with the robot. They therefore seemed highly engaged, even though the robot being programmed was only present on a screen and not physically.

3.5. Children's reflections

After the school workshops, 31 children submitted self-reflections about the workshop as a homework assignment to the teacher, one week after it took place. In these evaluations, they reflected upon the activities and what they learned from them. The teacher initiated this, so the researchers were not involved. Afterwards, the teacher shared the reflections with the researchers. The teacher asked the children to write down which activities they liked the most and why, and what they learned from the workshop. As can be seen in Fig. 5(a), the children stated that they enjoyed the theatre activity the most. However, most children stated multiple activities in their answers. Each activity was mentioned as 'fun' by at least 5 children. The reasons they provided were sometimes referring to personal preferences (e.g., *"I really like drawing!"*, *"Theatre is my thing"*), or self-expression (e.g., *"I liked theatre play because I could use my fantasy, and make it reality"*, *"I liked the drawing activity because I could use my creativity"*). Some children mentioned they especially liked the collaborating together and the costumes during the theatre activity (*"Theatre, because there was*

Table 5
Summary of user requirements. The specific scenarios from which the requirements are derived can be found in Table 3 and Table 4. R = robot, H = healthcare provider, P = parent, T = Teacher, C = child.

RQ	Requirement	Expected outcome
1	R shall be able to provide mental support	C feels supported, comforted, and encouraged
1a	R shall be able to use soothing phrases	Child feels supported, anxiety and stress levels are reduced
1b	R shall be able to hug C	C feels comforted, anxiety and stress levels are reduced
1c	R shall always display kind behaviour	Child feels comfortable in interaction with the robot
1d	R shall be able to fun distraction when needed	C feels entertained, anxiety and stress levels are reduced
2	R shall be able to provide positive feedback/compliments	C feels encouraged and rewarded
2a	R shall be able to reward C when appropriate	Positive reinforcement, C feels motivated
2b	R shall be able to use words of encouragement	C's self-esteem /self-efficacy improves
3	R and H/T/P shall collaborate in helping C	R and H/T/P learn from each other and provide better care for the C
3a	H, T, C, or P shall take the initiative in C-R interaction	Users feel in control
3b	R shall be able to guide C towards the right location/H	Child gets the healthcare that is needed
3c	R shall be able to act as a mediator in situations of conflict	Conflict/tension between C and other C/H/P/T gets resolved
3d	H/T shall explain the robot to C	C understands how R works
3e	R shall be able to ask for help when needed	Human actor can help fixing R if it breaks down
4	R shall be able to act as a buddy	C and R help each other, play and learn together
4a	R shall be able to play a game and/or do exercises with C	Interaction with R is entertaining, rewarding and educative
5	R's behaviour shall be able to match C's expectations	Interaction is pleasant for C, C understands R
5a	R shall express 'robot-like' behaviour (speech, movement)	C understands R
5b	R shall be able to display clear and appropriate emotions	C understands R
5c	R shall be able to give rational feedback	Child learns from the robot
5d	R shall have a robust design	Robot does not brake when a child hits or kicks it
5e	R shall always work	Child easily interacts with R, is not disappointed because R is broken
5 g	R shall be able to display neutral behaviour	Robot is an independent, non-judging party in the child-robot interaction
5h	R shall be able to give short, factual information/commands	C understands what R is saying, and it matches expectations
6	R shall be able to be educative	C learns from the robot
6a	R shall be able to give tips, advice and relevant information (educative)	Child learns from the robot
6b	R shall be able to give C appropriate exercises, assignments and tests	C learns from R in a playful manner
6c	R shall be able to read a story to C	C calms down, educative
6d	R shall be able to help C with education/homework, but not tell the answers	C learns and practices himself
6e	R shall be able to act as a tutor when helping the teacher	C learns from R
6f	R shall be able to act as a multimedia tool in educative settings	C learns from R in different ways
7	R shall be able to adapt its behaviour to C's needs	R learns about the problem/needs of C and adapt its behaviour accordingly
7a	R shall be able to ask appropriate questions to C	R learns what C needs, C feels seen/heard

good collaboration", *"The theatre play, because I liked it with all the suits and that was the only assignment where I could really move and do things myself"*).

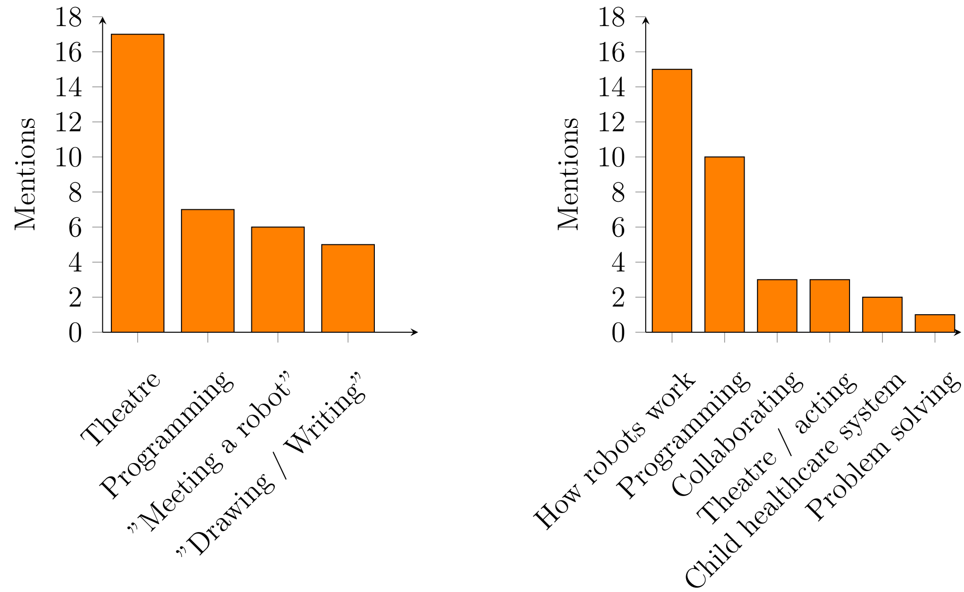
In general, as can be seen in Fig. 5(b), the children stated that they learned mostly about robots at the workshop, although also in this question some children answered with multiple concepts. Some children for example stated they learned about capabilities of robots (e.g., *"That there are many different robots. They can all do things. One can vacuum and the other can sing. One is the size of a child and the other can stand on your shoulder and it can be a robot for something medical or for something else. I found that very interesting"*, *"That robots can't do anything but you have to program everything before they can do anything"*). Ten children specifically stated that they learned about programming as well (e.g., *"That programming is a lot of fun and that it's actually not as difficult as thought"*). Other relevant concepts, such as the healthcare system in general and problem solving, were only mentioned once or twice.

4. Method evaluation

Next to evaluating the pilot study with healthcare providers and children, we evaluated the main study in a meeting afterwards with the researchers. The children's reflections were asked by the teacher as a homework assignment and included for final analysis. The researchers evaluated with the teacher after each workshop. Results of the evaluations are presented in this section. During the co-design workshops, three different creative activities were carried out, namely: (1) storywriting and draw-write-and-tell; (2) theatre play; and (3) robot avatar programming. Moreover, every workshop started with an introduction about social robots and the work of the Child and Family Center as well as an introduction to a small, humanoid social robot (UBTech Alpha Mini). Even though before starting the workshop we carefully thought of a schedule, we anticipated that working with children might require a certain amount of flexibility. Scheduling extra time for changing rooms, setting up, distractions, as well as discussing the schedule with the teacher/childcare professional present, is advisable. For example, during the first workshop (W1), a bird was present in the gym where the theatre activity took place. Not surprisingly, this distracted the children a lot. By scheduling 30–45 min there was enough time to calm everyone down and do the activity anyway.

4.1. Storywriting and draw-write-and-tell activity

The first creative activity included the methods storytelling and draw-write-and-tell (Henkemans et al., 2016), which we combined after consulting a child care professional. Combining the methods fitted the workshop well because some children were not very comfortable with drawing but had a good story instead, or the other way around. The children had 45 min to complete their drawings and stories, which for some children seemed a bit too long. Some children added stories to their drawings, or the other way around, to pass the time before the discussion was started. However, in one workshop, some children were still not done with their drawings, due to insecurities (e.g., they would tell each other that they did not know what to draw, or that they did not like their drawings). Since this only occurred in one group, it seems like the group atmosphere has an influence on this as well. Additionally, some children took inspiration from each other and started to draw the same or similar scenarios. Even though the children came up with individual products, the results were sometimes influenced by each other.



(a) The activities the children enjoyed the most.

(b) What the children stated they learned from the workshop.

Fig. 5. Results of the children's workshop reflections.

4.2. Theatre activity

All theatre activities took 30–45 min. In the theatre activity, 5 to 12 scenarios were acted out, of which on average 2 were made up by the children themselves. At the beginning of each scenario, new children were asked to participate from the audience. In the end, all children participated at least once during theatre play. Most children liked to use the attributes (such as the robot costume) during the plays. The robot costume was easy to put on and fitted all children, which is also advisably as to not exclude anyone. With the teacher as a mediator, making sure every child got a chance to participate, and flexibility in how everything could be carried out all went rather smoothly. For example, the children were allowed to add another role to a scenario or change the scenario to some degree if they wanted to. Children liked ending the theatre activity with one play created all together with a scenario they thought of themselves. This scenario was often less realistic or useful, but a reward for the children themselves. During the theatre play, we also observed some obstacles. For example, sometimes the children found it difficult to know what to do and/or say when playing the robot. This happened around seven times during the theatre play activity. For example, they would state: *"I do not know what to say"*, or, *"I do not know what to do"*. This especially occurred with the youngest group of children (e.g., W4), where often the child forgot what he wanted to act out, or even forgot the robot role had to participate as well. This is probably the reason why in W4, only five theatre plays were acted out. Also, acting out specific scenarios seemed to become a bit boring for the children. After a while (around approximately 30 min, depending on the group), the children seemed more distracted, for example by running around more often. By introducing more scenarios that they could come up with by themselves, and letting all children participate in the same play at once as a closing activity during theatre play, the children were able to relieve some of that build-up energy. As can be seen from the results in Tables 3 and 4, many new scenarios and requirements could be derived from the theatre play (corresponding with results from Woodward et al. 2018). It is however more complicated to analyse and present theatre play results compared to drawings and stories, which are easily shared and interpreted with just one picture.

4.3. Group discussions

Two general discussions took place of both activities, since the activities took place at the same time, splitting the class into two different groups. Especially discussing the drawings and stories was beneficial, to let the children explain their products themselves. Not every child liked to present their work, however by keeping it casual and not putting too much pressure on the child ("Just shortly show your drawing or summarize your story"), every child explained their products.

4.4. Robot avatar programming

We decided to introduce Robot Avatar Programming to the workshop, to explore the possibilities of programming social robots in co-design with children, and to add an educative component to the workshop as well. First impressions show that the children enjoyed programming and learned from it, as stated in Section 3.5. One child also mentioned that it was easier to program a robot than he initially thought. In some cases, programming the robot avatar lead to children understanding the potentials of social robots better, contributing to more realistic expectations. In our workshop, we only scheduled 45 min for the programming activity as well as meeting the robot. Therefore, this activity was mostly about on introducing the children to the programming tool, and time constraints prohibited us to give the children specific assignments to program the robot avatar. In the end, only random content was programmed by the children. By introducing more context to the Robot Avatar Programming activity (e.g., programming the robot from the drawing/story activity), it is expected that more interesting results could be found.

5. General discussion

Although there is an extended body of research on child–robot interaction (e.g., Belpaeme et al., 2018; Dawe et al., 2019), only a few studies focus on social robots in the child healthcare domain, and even less involve primary school children in the design process. This paper describes four creative co-design workshops on the use of social robots for child (mental) healthcare with children aged 7 to 12 years old. With these workshops, we aim at getting insights into potential social-robot interactions for child mental health care situations, as well as evaluating appropriate methods for this specific target group. Results include newly developed use scenarios, a set of requirements, and an evaluation of co-design methods with children.

A first contribution of this paper is a total of 21 use scenarios, as well as evaluations of 9 scenarios derived from previous focus groups with adults (parents and healthcare professionals) collected in a previous co-design study (Neerincx, Rodenburg et al., 2021), including corresponding robot roles and user requirements. The most popular potential social robot scenarios from the perspective of primary school children consisted of a social robot present during a vaccination day, a social robot to help at school, a social robot being present during an eye test, and a social robot for more general emotional support. In general, primary school children view the social robot as a buddy, providing mental support and fun distractions when needed. Also, the social robot can take on an educative role. Therefore, it can be concluded that according to the children, a social robot can be used to assist the child care professional in his or her work, to improve the general mental well-being of the child. Other studies in the field of HCI show the potential of technology in improving the mental well-being of children (e.g., Slovák, Theofanopoulou, Cecchet, Cottrell, Altarriba Bertran, Dagan, Childs, & Isbister, 2018; Theofanopoulou, Isbister, Edbrooke-Childs, Slovák, et al., 2019).

Second, corresponding user requirements were derived from those scenarios and robot roles. Specifically, we were able to derive several requirements from the data, which could be grouped into 7 main user requirements including sub-requirements. A substantial part of our user requirement results further validate previous findings. The most important similarities are: the robot should be able to have a simple conversation with children (including asking questions Abubshait & Wiese, 2017; Breazeal, Kidd, Thomaz, Hoffman, & Berlin, 2005; Tung, 2016); the robot should have a humanoid (or zoomorphic) appearance (Beasley, 2012; Tung, 2016); the robots should be able to read and express emotions (Logan, Breazeal, Goodwin, Jeong, O'Connell, Smith-Freedman, Heathers, & Weinstock, 2019); and the robot should be able to act as a tutor or peer (Belpaeme et al., 2018; Mubin, Stevens, Shahid, Al Mahmud, & Dong, 2013). On top of these, we also identified additional requirements more specific to the child (mental) healthcare domain, such as the robot acting as a mediator in child-professional-parent interactions, and a robot helping in personalizing the treatment of the child.

A final contribution of this paper are the method evaluations of the co-design activities used for the child healthcare domain. Children require special approaches and techniques as research participants. During the theatre activity, the children were less concentrated and wandered off the scenarios many times. This could perhaps be because the scenarios were a bit difficult for them to act out (depending on e.g., the age), or because their attention span was limited. These issues can be resolved by providing the children with more context in the scenarios, or by scheduling more breaks. However, the children still seemed very enthusiastic about the costumes and roles. By being flexible in adding or removing roles, letting the children think of plays themselves, asking the children whether they wanted to participate without forcing them, self-expression and creativity were stimulated. The children collaborated together surprisingly well, even with bigger age differences. The creativity involved in the activities seemed to make them suitable for every child in the broad age group of 7 to 12.

5.1. Limitations and future work

Regarding the scenarios, there is a risk that the children will give answers that they think the researchers want to hear. We tried to deal with this risk by adapting several techniques suggested by Bergen and Labonté (2020), namely indirect questioning, providing assurances (i.e. assuring the children that their creative solutions are never 'wrong'), and probing for more information as well as requesting stories or examples when their presented solutions were unclear or incomplete. Additionally, we added the final evaluation as a homework assignment given by the teacher, to give the children the feeling that the researchers were not involved in this. Of course, it remains a challenge to completely eliminate this social desirability bias (Bergen & Labonté, 2020). Also, in the drawing and writing activity, the children were clearly inspired by each other. It might be the case that children will mimic other children when coming up with 'new' scenarios. For future research, a solution would be to also let them perform opposite scenarios, meaning that the children could play or draw an unwanted scenario, such as a social robot being mean when a child is angry. It would be interesting to see how children would respond to these scenarios.

Additionally, it would be interesting to iteratively improve upon the co-design methods used in this paper, for example by providing more context in the Robot Avatar Programming activity. Since the children were able to come up with relevant social robot scenarios after learning more about the child healthcare context, it is expected that incorporating this context in the programming activity will lead to insightful results as well. One limitation of the participants of this study is that the children are no regular clients of the Child and Family Center (even though the majority experienced vaccinations and/or eye tests at the centre). Clients of the centre were invited to participate, but none of them signed up. It would be interesting to carry out co-design workshops with clients in the future if possible, to see if results will be different. Another limitation regarding our participant pool is the differences in group sizes and participant's age distribution per workshop. Since we carried out the robot workshops at so-called 'plus'-classes at primary schools, each class had a different age distribution and group size on its own. Due to planning the workshops in usual class hours, we were bound to the existing group compositions. However, this ensured the children to already know each other, resulting in a comfortable atmosphere. Also, this resulted in additional interesting insights regarding group size and age differences. An example is that during W4 it was observed that the theatre play activity might have been too difficult for younger children. However, in W3 with bigger age differences, a high amount of collaboration between younger and older children took place, where older children were generally helping younger children with expressing themselves during the theatre play activity. This suggest that collaboration between younger and older children can result in satisfying participation and results of all children. Previous research shows that when co-designing with children, they might experience difficulties with group dynamics and coming up with realistic ideas (Vaajakallio, Lee, & Mattelmäki, 2009). In our workshop, the collaboration of the children was satisfactory (as also evaluated by the children themselves), and most scenarios were realistic. We expect this to be because a clear context including explanations was given (namely, a child, a healthcare professional, and a social robot).

5.2. Conclusion

In conclusion, children see potential in the use of social robots for child mental support in the general healthcare domain. Our participants came up with 21 new scenarios and, in addition, positively evaluated 9 scenarios created by adult end users (Neerincx, Rodenburg et al., 2021). These derived robot roles and user requirements serve as input for guidelines in designing social robot behaviours and applications for child mental support in the healthcare domain. Additionally, this paper provides in-depth insight into suitable methods and contexts for co-designing social robot interactions for child healthcare settings together with children. By providing the children with different ways of expressing themselves (see Table 1), our co-design methods resulted in new scenarios, scenario evaluations, robot roles, and user requirements for social robots in the child (mental) healthcare domain from the perspective of primary school children. The presented and evaluated co-design methods can already be used by other child–robot researcher in the community, while we are currently also developing follow-up design-test activities to further substantiate this set of co-design activities. Finally, our study provides further evidence for the suitability of a mixture of creative methods (i.e., drawing, writing, theatre play, programming) to involve children in the design of artificial intelligence technology such as social robots. Especially theatre play and programming is relevant for co-designing embodied agents such as social robots. Co-designing not only helps in designing for the user, it also helps in making the use and workings of technology such as social robots more transparent to the children themselves. The results of these co-design sessions will, together with previous research with involved adult users (e.g., child healthcare professionals, parents Neerincx, Rodenburg et al., 2021), contribute to designing low-risk applications of social robots in the child healthcare domain, which can then be tested in long-term, real-world settings (e.g., youth coaches at schools, social robots at vaccination days). The end goal is to design social robot interactions which are widely applicable.

Selection and participation of children

Overall 46 children aged 7–12 years old participated in our co-design study. The children in the pilot study were recruited via emailing employees of the Child and Family Center, asking if they knew any potentially interested children (clients and/or family), who would like to participate in a robot workshop. The other children were recruited via their primary school teacher, and participated as part of a normal class. In all cases, parental consent was provided. Also, in the introduction of the workshop, all children were told that they did not need to participate in the workshop activities, that they were allowed to stop the activities whenever they wanted, and that they could refuse being recorded and/or sharing their products with us. In the theatre activity, before each play, children were asked if they wanted to participate. The mediator of this activity made sure that every child got the chance to participate, but it was not mandatory. Ethical approval was obtained from the ethics board of our university.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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