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Using social robot PLEO to enhance the well-being of hospitalised children

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Abstract

Hospitalisation is stressful for children. Play material is often offered for distraction and comfort. We explored how contact with social robot PLEO could positively affect a child's well-being. To this end, we performed a multiple case study on the paediatric ward of two hospitals. Child life specialists offered PLEO as a therapeutic activity to children in a personalised way for a well-being related purpose in three to five play like activity sessions during hospital visits/stay. Robot–child interaction was observed; care professionals, children and parents were interviewed. Applying direct content analysis revealed six categories of interest: interaction with PLEO, role of the adults, preferences for PLEO, PLEO as buddy, attainment of predetermined goal(s) and deployment of PLEO. Four girls and five boys, aged 4–13, had PLEO offered as a relief from stress or boredom or for physical stimulation. All but one started interacting with PLEO and showed behaviours like hugging, caring or technical exploration, promoting relaxation, activation and/or making contact. Interaction with PLEO contributed to achieving the well-being related purpose for six of them. PLEO was perceived as attractive to elicit play. Although data are limited, promising results emerge that the well-being of hospitalised children might be fostered by a personalised PLEO offer.

Keywords

Anxiety, child, distraction, hospitalized/psychosocial factors, play and play things, robotics

Introduction

Hospitalisation can be a very disturbing experience for children with a negative impact on their well-being (Carnevale and Gaudreault, 2013; Coyne, 2006; Jepsen et al., 2019; Nabors and Liddle, 2017). The children are ill, out of their familiar environment and often subjected to medical

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procedures that may be unpleasant, painful and can raise fear. A child life specialist (CLS) can help child and family to cope with these stresses. This care professional who is not part of the medical staff, focuses on the optimal development and well-being of a child, while promoting coping skills (Committee on Hospital Care and Child Life Council, 2014). Part of their work is to offer play activities for distraction and relaxation.

A fairly new technology, a social robot or socially assistive robot (SAR) could perhaps provide such support as well. A SAR is designed to interact with humans in a social way and usually comes in the shape of a pet or human (Fong et al., 2003). Due to their ability to engage people through social and emotional dimensions, SARs are identified as particularly suitable for deployment in healthcare contexts to help people achieve personal goals for instance by motivating, coaching or enabling communication (Breazeal, 2011; Dahl and Boulos, 2013). Research on therapeutic SAR-applications in children started in mental healthcare, where interventions were developed for children with autism spectrum disorder to improve their skills in communication and social behaviour (Pennisi et al., 2016; Scasselati et al., 2012). In more recent years, these robots have also been tried for other purposes in other healthcare domains, for instance to increase mobility and cognitive functioning in children with cerebral palsy (Malik et al., 2016; Miguel Cruz et al., 2017), improve self-management skills in children with diabetes (Blanson Henkemans et al., 2017), strengthen psychosocial counselling for children with cancer (Alemi et al., 2016) or make it less terrifying to get an injection (Beran et al., 2013; Jibb et al., 2018). The little research that has been done into the well-being of children during hospital stay (Moerman et al., 2019; Robinson et al., 2019; Trost et al., 2019) shows that a SAR/pet robot might provide distraction or engagement, thereby reducing pain, anxiety or stress (Logan et al., 2019; Okita, 2013). Based on these outcomes it is assumed that social (pet) robots can positively affect the well-being of children who are hospitalised.

We chose baby dinosaur pet robot PLEO^{TM} (developer Innvo Labs) to perform the intervention. A pet robot is modelled after animals and can make animal-like movements and sounds. These robots have the advantage over real animals that they are clean, do not bite or scratch, can be controlled by programming and can meet the hygiene standards. The robot has been deployed for several years in the children's hospital San Joan de Deú in Barcelona, Spain, where volunteers offer PLEO to children who are hospitalised in order to distract them. Reports on the experiences with the robot are very positive, yet anecdotal. This means that the potential of PLEO is promising, but needs factual underpinning.

Aim

To explore how the offering of pet robot PLEO to a hospitalised child can contribute to the well-being of this child when offered for a well-being related purpose. The following research questions were addressed: (1) how does a child interact with robot dino PLEO, (2) what is the involvement of the parent(s) or other adults in the child–robot interaction and how does this affect the interaction, (3) how does the child–robot interaction develop over a series of contacts and (4) how does interaction with the robot affect the (psychological) well-being of the child.

Methods

We designed an applied research project in co-creation with members of the pedagogical team in the paediatric ward of two hospitals, mainly CLSs, to develop and test a therapeutic intervention with robot PLEO. A CLS trained in the Netherlands has completed a bachelor's programme in the field of

child development and pedagogical issues with additional on-the-job training in guiding sick children and using methods developed especially for this niche to, among other things, process experiences of illness through offering play activities (e.g. Van Wageningen, 2004).

We proposed a framework for intervention: a pursuable well-being related goal for the child, planning of three to five sessions with child and robot to study a possible development and preparation of an individual plan of action. In children, well-being is generally understood to refer to negative states such as stress, anxiety or depressed mood related to illness and its consequences or positive states related to autonomy, enjoyment or emotional regulation during hospitalisation (Barlow and Ellard, 2006; Carter, 2012). We operationalised a well-being purpose as a goal to be defined by the CLS for a specific child aiming at providing comfort or reducing anxiety or stress.

In defining the action plan, the CLS chose the objective to be pursued, specifying when and where the robot would be offered, in consultation with the child and parent(s), according to the child's personal needs and suitable for their own daily work routines. We assumed that PLEO robot would be attractive to children in different stages of development in different ways, depending on a child's developmental characteristics, personality and interests (Berk, 2018) and the functionalities of the robot (see Supplementary Materials 1 for PLEO's functionalities and repertoire for interaction). We also assumed that the CLS had the expertise to make an optimal match between the characteristics of the child and the functionalities of the robot. We supported the CLS in drawing up the plan by interviewing them about their considerations in this respect (pre-intervention interview).

By choosing a multiple case design (Yin, 2014), we allowed the CLS to model the robot intervention for each child in a personal way, thus creating an individualised data collection. The intervention was shaped as a play like activity, meaning serving a therapeutic goal and of playful character (Besio, 2017).

The CLS guided the PLEO-sessions. At the start of each session, the child received a pet bag containing PLEO and a child-friendly guide on how to handle PLEO. The child was able to consult the guide at any time during the session as desired.

In this qualitative study, we collected data through observations and interviews with those directly involved: child, parent and CLS. We pursued triangulation by applying different data collection methods and using different actors as a source of information. After completing data collection and analysis we organised a concluding focus group meeting with representatives of both pedagogical teams to discuss research results on recognisability from their own experiences, in particular the effects of the intervention on a child's well-being and the role the children assigned to PLEO, allowing professionals to substantiate the results as part of the research method to reinforce the value of the results.

Recruitment

Children between 4 and 13 years old were eligible for participation. A strict lower age limit was applied, based on the age at which a child is assumed able to reflect on contact with a robot (Berk, 2018), while the upper limit was loosely determined by the age at which children seem to lose interest in the robot. Another defining criterion was an anticipated duration of hospitalisation of at least four days or a series of at least four weekly visits to an outpatient facility to allow the child to have three to five sessions with the robot on different days/visits. The first day/visit was reserved to approach an eligible child's family and allow them to decide on the child's participation: they received a flyer with a general introduction to the study, followed by a contact moment during which

the CLS introduced PLEO to child and parents, informed them of the purpose and conduct of the study (including in writing) and asked for written permission (informed consent).

Role of the CLS

CLSs played a central role in the design and implementation of the intervention. They were responsible for identifying children who could benefit from contact with PLEO, informed the families about the study and sought permission to participate. They drafted the content of the action plan and supervised the robot sessions. To facilitate them in this role, we informed them during a special meeting on how to implement the study protocol from their position and gave instructions on how to perform their tasks and also left this information in writing (CLS protocol). We gave them training to become familiar with the robot and a manual on how to use PLEO.

Role of research team

The authors designed the study and wrote the CLS protocol. They were supported by a research team in data collection and analysis. Together they represented various backgrounds (medical, allied healthcare, social studies and industrial design).

We received approval from the local ethics committee of the Academic Medical Centre/University of Amsterdam for the study (letter 10 February 2016, reference W16_048 # 16,064).

Data collection

Figure 1 shows the sequence of actions with associated data collection for a case (Supplementary Materials 2).

Child–robot observations were directed to the child's reaction to PLEO and interaction with PLEO, whether other toys were present and interaction with other adults (for instance parent, CLS) and other children. The focus was on what was appealing to the child and how it responded to the robot's functionalities.

Observation duration was set to 10 min (to be extended if the play went on), sufficient to record the nature of the child–robot interaction and, in case a child was not or only briefly interested in PLEO, to see if the child would (re)start interacting after a while. A team of eight independent researchers, who had received special training for this purpose, performed the observations.

Immediately after the last session, a researcher interviewed child and parent(s) separately and briefly about their appreciation of the robot and its role in achieving the well-being related goal(s). The child was questioned about their experiences and asked to rate the extent to which PLEO had helped to achieve their goal(s) on a 5-point scale with smileys.

The CLS was interviewed using Think-Aloud Protocol Analysis (Ericsson and Simon, 1993) twice, prior to the intervention on the child's eligibility for the study and about their clinical reasoning regarding the contents of the action plan (pre-intervention interview) and after the conclusion of the intervention, about their clinical reasoning regarding the course of the intervention and the chosen well-being promoting goal (post-intervention interview). After the first interview the CLS used a form to draw a personalised action plan.

Observation form, form for plan of action and interview guides were all semi-structured. We developed an interview guide for each type of interview. All interviews with the CLS and the concluding focus group meeting were audiotaped and typed verbatim. Observations and interviews

with child and parent(s) were noted on a special form. Supplementary Materials 3 shows more details on the instruments for data collection.

Data analysis

Child–robot contacts were analysed by two researchers, combining textual information from observations and post-intervention interviews with child, parent and CLS. The analysis was performed on a case-by-case basis, starting with observations of a child's behaviour towards the robot, followed by its development in the series of sessions with directed content analysis, a method whereby predefined codes are further refined during the coding process (Hsieh and Shannon, 2005). Application to our data led to the categories: 'child involvement', 'child–robot dynamic interaction' and 'interaction with others' (see Supplementary Materials 4 for coding tree). Subsequently, interview information was included and the focus broadened to analyse appreciation for PLEO and the robot's role in achieving the well-being related goal(s). Outcomes of this two-step analysis were integrated over all cases and described using the six topics that emerged as framework: interaction with PLEO, role of adults, preferences for PLEO, PLEO as buddy, attainment of predetermined goal(s) and deployment of PLEO. These results were presented and discussed with pedagogical team members in the concluding focus group, mainly to check against their experiences and enrich the observational outcomes. The focus group outcomes were analysed along the six topics and then fully integrated in the description of the results.

Results

The study was conducted at two Dutch hospitals (an academic and a regional) where a team of CLSs works in the paediatric department. The field studies lasted 12 and 14 weeks, respectively.

Six experienced CLSs participated in the study. 10 families agreed to participate. Five boys and four girls had three to five sessions with the robot. A 10th child was discharged from hospital after the first session and dropped out. The observers worked in a variable schedule based on availability. The interviews with the CLSs (pre- and post-intervention) were conducted by a team of three researchers, one of whom did the majority. For no case were all data collected by the same person.

Pet robot PLEO was offered for a variety of well-being related purposes ranging from distraction from boredom to activation. Observations took place in various places in the ward where the child played with PLEO, such as the play room, child's bed space, treatment room or waiting space/dialysis department. Table 1 shows some specifics of child, action plan and data sources per case.

The time period in which the series of observations on a particular child took place was determined by the treatment protocol and varied from 5 days to 5 weeks. Observations lasted between 5 and 30 min. The CLS was present during most observations and if not, a parent was present. In most cases the parent(s) were present when their child was observed.

For one participant PLEO was not appealing. He only looked briefly at PLEO in the first session and responded reluctantly when PLEO was shown to him at session two and three. We therefore stopped presenting PLEO after three offerings. According to the CLS, the child was ill and not in good physical and mental condition. Since he did not really participate in the intervention, we limit the reporting on the first four topics to the remaining eight children. The reporting on 'attainment of goals' and 'deployment of PLEO' again refers to experiences with nine participants.

Table 1. Characteristics of child, plan of action and data sources per case.

Case	Child			Plan of action		Data sources		
No	Sex	Age (year; month)	Reason for hospital admission	Well-being related goal	Role for PLEO	Number of observations	CLS[a]	Parent interviewed
1	Boy	4; 4	Oncology treatment	Stress reduction before & during medical procedure (enjoyment during wait time)	Distractor	5	A	Mother and father
2	Boy	5; 9	Oncology treatment	Relief from boredom during stay Activation	Distractor Activator	3	B	Mother
3	Girl	6; 8	Renal dialysis (outpatient clinic)	Relief from boredom during visit Make return to hospital easier	Distractor Motivator	4	C	Mother
4	Boy	5; 9	Oncology treatment	Relief from boredom during stay/visit Make return to hospital easier	Distractor Motivator	5	A	Mother
5	Boy	7; 7	Oncology treatment (partly at outpatient clinic)	Relief from uneasiness, boredom, stress reduction (Entertaining activity during stay)	Distractor	4	A	Mother
6	Girl	7; 8	Oncology treatment	Relaxation during stay	Distractor	4	D	Mother
7	Boy	5; 1	Asthma treatment	Relief from uneasiness during stay & during nebulisation	Distractor	4	E	Mother
8	Girl	7; 2	Pyelonephritis	Relief from uneasiness during stay Trigger for interaction	Distractor Enabler	3	F	Father
9	Girl	13; 0	Perforated appendix	Distraction from apathy	Distractor	4	F	Mother

[a]CLS: child life specialist. Six specialists took part in the study, each indicated by a letter of the alphabet.

Interaction with PLEO

All eight participants were attracted by PLEO and showed play behaviour, like caressing, hugging, feeding and trying to teach PLEO tricks (like walking and dancing). Five out of eight were relatively well, having some better and some worse moments. The other three were physically or otherwise restricted because of their illness or the treatment they received. Intensity and nature of the contact with PLEO varied among the children. Some played in a functional way by discovering the capabilities of PLEO and giving the robot food. Others were more into caring for PLEO, wondering how to interpret the robot's behaviour. All eight noticed every movement and sound PLEO made and responded spontaneously.

> 'I like PLEO as he moves a lot and he walks backwards' (interview child case 9).

Most participants tried to get PLEO's attention, to make it move or repeat sounds. The interactions with PLEO gave all eight participants a lot of joy and elicited their curiosity. Negative reactions also occurred. One participant got frustrated when PLEO went to sleep when he, in fact, wanted the robot to be active. Another child was irritated when PLEO could not learn a specific activity the child had in mind.

> 'I think that PLEO was not challenging enough for ..[the child]. He said several times during the play "he can't do anything". I think there was not enough challenge and PLEO was too slow. We looked every week at what PLEO had learned, but actually there weren't that many changes' (interview with CLS, case 4).

The children told in the post-intervention interviews what they in particular liked about PLEO were the strange sounds and the movements the robot made and that they could feed leaves to the robot and teach it to perform actions. They also said that it could be frustrating not be able to manage to teach PLEO or have PLEO perform an activity.

The CLSs mentioned in the post-intervention interviews and concluding focus group interview that they observed in the children basically two types of behaviour towards the robot that could make them feel less stressful: robot-focused behaviour (exploring the robot's features and capabilities) and interaction-focused behaviour (playing together, as in for instance hugging and caressing, being distracted). Approaching the robot as a buddy (see below for a further explanation) can be considered a special form of interaction-focused behaviour.

Role of adults

An adult (CLS, parent) initiating the interaction with PLEO was important for four children for whom it was not clear how to use PLEO. For two other children, an adult sought interaction with PLEO, whereupon the child started to imitate the adult, thus initiating contact with the robot by themselves.

> 'She [her daughter] didn't know what to do with PLEO, so I tried some things. I thought PLEO was responding to my actions, but this wasn't the case. PLEO does things by itself. I had to show her [her daughter] this and stimulate the play' (interview mother case 6).

Some parents commented how PLEO's appearance or features were in line with the interest of their child, for instance in dinosaurs, animals and technical toys.

CLSs reported that the presence of PLEO sometimes served as an enabler to start a conversation between a child and their parent or siblings about playing with PLEO or about daily life topics and the hospital situation. For some participants, PLEO also became a mediator in the interaction with the physician or nurse who performed the treatment. CLSs said to be surprized by the impact PLEO had on enabling such contacts.

Preference for PLEO

Although PLEO was offered in a targeted manner, in half of the observations, other toys were also available in the room or were brought in by the child. Five children showed their preference for another toy at some of their planned PLEO-play moments.

PLEO was favourite for four participants in all encounters. The robot remained interesting for them during the whole series of sessions, as shown by ongoing interaction and play. Children who wanted to play with another toy asked for a tablet to play games. Interaction with PLEO was characterised in one child by a more passive approach: she mainly observed PLEO.

> 'Child sits very still, offers PLEO food, mainly observes PLEO, scratches lower lip, talks to father about PLEO. She doesn't lift up PLEO. She shows other toys to PLEO. Starts to caress PLEO again' (observation case 9).

> 'PLEO spent the night in my room'. He pointed at the smiley with the biggest smile when he was asked about his opinion of PLEO (interview child case 7).

PLEO as buddy

Observation data showed that some participants were emotionally attached to PLEO, even approaching PLEO as a buddy, whereas others played with the robot in a functional way: stimulating PLEO moving and making sounds. Two young participants treated PLEO as their buddy, as the CLSs described it during their post-intervention interview or focus group. One boy, four years old, talked to PLEO as if it was a real animal. He dragged PLEO into his activities and showed PLEO his situation. The boy also introduced PLEO to others, explaining what he could teach the robot. The other participant was a five-year-old boy who approached PLEO as his puppy dog that he missed so much in hospital. He shared activities with PLEO, like watching TV and lending PLEO his teddy bear and told his mother that PLEO helped him to overcome his homesickness. The CLSs involved confirmed these observations in their post-intervention interview: these two participants showed an emotional bond with PLEO, while other children only liked to discover PLEO's features, playing with it.

> 'Child talks more and more to PLEO. Tells him he is not allowed to bite. He caresses PLEO, hugs him. He wants PLEO to stay in bed with him. He presses the off button, hugs PLEO and puts him under the blanket. He keeps caressing PLEO' (observation case 7).

Attainment of predetermined goals

For all nine participants, the personal action plan contained a well-being related goal for which PLEO had to act as a distractor. Eight of the nine children were found to be distracted by PLEO. Whether the distraction also led to the achievement of this predetermined goal differed from child to child (see Table 2).

According to parents and CLSs, the goals were (substantially) achieved for six (including two who showed a reduced need for stress reduction as the sessions progressed and a third who recovered strongly from a serious illness), only in part for one and not at all for two children. The fact that a goal was not always (substantially) attained sometimes had to do with a diminished need within the child to be distracted and sometimes with the too small entertaining quality of the robot, meaning that interacting with the robot could be too complicated or not attractive enough. For the four participants for whom PLEO was also used for another purpose, the distracting quality of PLEO determined whether the second goal (making it easier to return to the hospital, to generate interaction or to activate) was achieved or not.

> 'She was very interested and is much more relaxed. Yesterday, when I deployed PLEO for the first time, it was the first time she made eye contact, smiled at me and communicated in her own way with me' (interview CLS case 8).

Deployment of PLEO

CLSs acted extremely careful in deciding how and when to offer the robot to the child. They closely monitored how the child–robot interaction progressed, and were prepared to adjust the robot intervention whenever needed to better accommodate the child's need for support. They also took care of organisational aspects, such as the conditions that a robot must meet to be useable in a children's ward or charging the PLEO battery.

In summary, we found that nature and intensity of interaction with PLEO varied among the children. A child's attention could be more focused on a technical exploration of the robot's features or more on an (emotionally charged) encounter with an animated object or sometimes on the communication with others through the robot. Sometimes, an adult was needed to initiate or maintain a child's interaction with the robot. The children showed varying degrees of intensity in interacting with the robot within a session and over a series of sessions. Over the course of the sessions, a child could fully favour the robot or express a declining interest or a shift in attention to a replacement toy or activity. For six out of nine children, their well-being was supported in a way that was defined prior to the intervention with the robot.

Discussion

This study about the well-being promoting potential of pet robot PLEO as part of a play like activity is an example of an intervention that fits in with the existing integrated care approach at the paediatric ward. Data collection was based on systematic gathering of a series of observations of sick children in contact with PLEO and the experiences of those involved. Data were collected at two locations, a regional hospital with a paediatric ward and a children's hospital with specialised care within an academic hospital. CLS offered the robot to each child in a minimal driven play situation, following the child's initiatives and attuned to their needs and abilities, keeping the

Table 2. Attainment of the predetermined well-being related goals and the contribution of PLEO to this per case, based on various data sources. Cases arranged according to the achievement of goals.[a]

Case no.	Well-being related goal	Attained	Contribution PLEO[a]	Comment
3	Relief from boredom during visit	Yes	Positive	Child liked playing with PLEO, which gave her joy and comfort
	Make return to hospital easier	Yes	Positive	Child asked several times for PLEO at home and in the hospital and reported that it was nice that PLEO was present
7	Relief from uneasiness during stay & during nebulisation	Yes	Positive	Child showed interest and affection towards PLEO. Became more relaxed, showed active posture and became increasingly communicative PLEO became buddy
8	Relief from uneasiness during stay Trigger for interaction	Yes Yes	Positive Positive	PLEO drew interest and gave pleasure. Child became more active, engaged in interactive play and started nonverbal communication with CLS
9	Distraction from apathy	Yes (goal might have become less relevant)	Positive, size uncertain	Child enjoyed PLEO and interacted more. The recovery from being seriously ill could also have had a positive impact on the child's initial apathetic state
1	Stress reduction before & during medical procedure (enjoyment during wait time)	Yes, marginally (need in child reduced)	Positive	PLEO helped child to distract and divert focus. Child did not need much distraction, because he had already developed own coping strategy to deal with the stresses PLEO became buddy
6	Relaxation during stay	Yes, marginally (need in child reduced)	Virtually absent	PLEO elicited pleasure. Child did not understand how PLEO worked and needed help with interacting with PLEO Child already had distractions from other toys and did not need much extra distraction
5	Relief from uneasiness, boredom and stress reduction (entertaining activity during stay)	At most partially	Marginally positive	PLEO drew attention in the beginning, was less entertaining for the child later on

(continued)

Table 2. (continued)

Case no.	Well-being related goal	Attained	Contribution PLEO[a]	Comment
4	Relief from boredom during stay/visit	No	Absent	PLEO was not enough a challenge, could not do and learn enough for the child
	Make return to hospital easier	No	Absent	PLEO had no role in making it easy to return to the hospital PLEO acted as a facilitator in conversation between child and CLS
2	Relief from boredom during stay	No	Possibly negative	Child did not want to interact with PLEO
	Activation	No		Child might have experienced the offer of PLEO as burdening, because he had to explicitly say 'no' to PLEO (express refusal)

[a]Determination of the attainment of goals and contribution of PLEO to this is based on collected information from various sources. The conclusion on the attainment of goals and PLEO's contribution is based on the discussion by the CLSs at the concluding focus group meeting.

therapeutic goal in mind. The guiding role of the professional trained in the use of the robot and knowledgeable of the child in their context was of utmost importance. None of the (few) studies that published on the use of a SAR in a medical setting to support a child's well-being (Logan et al., 2019; Moerman et al., 2019; Robinson et al., 2019; Trost et al., 2019) reported on such minimally driven play like situations like we did.

The current small study shows that interacting with PLEO under guidance of a pedagogical care professional has the potential to support children's well-being, by having them to take part in an activity they like and which supports relationships with others. CLSs were positive about the intervention because it was well applicable and beneficial for the children, although they strongly recommended to improve the robot's functionality (more active and expanded behaviour).

We offered PLEO to a child a number of times in succession to study the prolonged attractiveness of the robot, considering a novelty effect that may occur. Because we demonstrated long-term attractiveness in different children and even a kind of attachment in some, we assume that interaction with PLEO can connect to an existing need in a child and that the effect of the robot is based on more than its newness (novelty effect).

Limitations

We were only able to include 10 children in the study, nine of whom successfully completed the intervention, although we had a three-month period at each location to collect data. Our decision to have participants play with the robot multiple times in a row affected the number of children we could recruit, as children were found to be discharged as soon as the medical situation allowed, continuing treatment on an outpatient basis. The resulting small sample limits the generalisability and transferability of the results.

Because only limited data on child–robots effects were available at the moment we planned the study, we decided to do an explorative evaluation of child–robot interaction although we knew that PLEO could lure a child into play through its functionalities allowing programmed sounds and movements. So we did not consider using existing tools to evaluate play and playfulness (Ray-Kaeser et al., 2018) and kept the way to observe child and robot in this minimally driven play situation quite general. Children's development and cognitive, sensorimotor, socio-emotional elements of play were not further elaborated. It is conceivable that we therefore missed important specifics of the interaction.

In addition, we needed a relatively large team of eight observers, due to the spread in PLEO sessions over the day, as planned by the CLSs according to their work routines and hospital treatment times. Such a large team could have yielded less reliable data, despite the fact that they were all trained.

PLEO's value in health care settings

The children identified various features of the robot as attractive and approached the robot as if they met a toy, a friend and sometimes a mediator for interacting with other people. This illustrates the robot's capability to accommodate different orientations in play behaviour, making it attractive to a wide range of children at different stages of development with specific interests and needs. It is not yet clear which elements contribute to the quality of the interaction with PLEO and to the long-term effects.

PLEO's limited technological possibilities that prevent the robot from recording and interpreting a child's reactions and translating them into an appropriate response can sometimes be detrimental when the child starts feeling misunderstood and frustrated. So far, all existing SARs have this inability. They operate semi-autonomously. To overcome this disadvantage, experiments with SARs have been set up with an on-site operator, invisible to the child and controlling the robot, so that the robot can give a response tailored to the child's reaction. This gives the child the suggestion that it is the robot itself that responds to them (e.g. Logan et al., 2019). In our study, parent and CLS fulfilled such a mediating and tailoring role.

Future research

First of all, research should be repeated among sick children on well-being related effects of a therapeutic offer of a SAR in a minimal driven play situation, extended with a focus on how the cognitive, sensorimotor and socio-emotional requirements of the activity contribute to the nature and quality of the effect. A second step would be investigating which elements stimulate the start and continuation of the interaction with a SAR. This might be done in a comparative design with other types of toys, robots or play situations. Another focus of research can be in-depth study of the supporting role of the adult.

Conclusion

A group of nine hospitalized children, receiving three to five therapeutic sessions with PLEO according to a personalised plan and guided by a skilled professional to improve client-tailored well-being related goals, showed experiences of distraction and less boredom, less discomfort, less anxiety and stress, more active and playful behaviour and more communication with parents, siblings or healthcare professionals. For six of them, the predetermined goal(s) were achieved.

PLEO can be appealing to a child when offered in a minimal driven play situation because of its capability to accommodate different behaviour in children. Due to the semi-autonomous operation, the robot produces spontaneous sounds and movements that elicit the child to respond. This made the CLSs perceive PLEO robot as a potential tool for interventions at the paediatric ward. Although PLEO has limited functionality, its semi-autonomous behaviour is a strength which might stimulate children in disadvantageous situations to play.

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Supplemental material

Supplemental material for this article is available online.

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