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ZORA Robot Based Interventions to Achieve Therapeutic and Educational Goals in Children with Severe Physical Disabilities

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Abstract
This study aimed (1) to examine the contribution of robot ZORA in achieving therapeutic and educational goals in rehabilitation and special education for children with severe physical disabilities, and (2) to discover the roles professionals attribute to robot ZORA when it is used in robot-based play interventions in rehabilitation and special education for children with severe physical disabilities. A multi-centre mixed methods study was conducted among children with severe physical disabilities in two centres for rehabilitation and one school for special education. The participating children played with robot ZORA six times during a period of 6 weeks, in individual or group sessions. Quantitative data were gathered about the contribution of ZORA in reaching individual goals for all of the participating children, using the Individually Prioritized Problem Assessment (IPPA). Playfulness was measured with a visual analogue scale (0–10) and children could indicate whether they liked the sessions using a scale consisting of smileys. Video-stimulated recall interviews were used to collect qualitative data about the different roles of ZORA. In total, 33 children and 12 professionals participated in the study. The results of the IPPA showed a significant contribution of ZORA to the achievement of (children's) individual goals. The data gathered using the IPPA during the ZORA-based interventions showed that the largest contributions of robot ZORA lie in the domains of movement skills and communication skills. Playfulness of the sessions was 7.5 on average and 93% of the sessions were evaluated as 'enjoyable' by the children. Overall, ZORA could positively contribute to the achievement of individual goals for children with severe physical disabilities. According to the participating professionals the most promising roles in which robot ZORA can be used are motivator, rewarder or instructor.

Keywords Robot · Effects · Goals · Roles · Children · Physical disabilities

1 Introduction

Robots are becoming more and more advanced, their presence in society is increasing, and they have great potential to improve our daily lives at home, at work and in play. However, there are still some challenges, such as integrating robots into the human world, fine-tuning and customising robots for particular purposes and increasing their reasoning abilities [1]. There is increased attention for the possible role of robots in health and care and generally there is an expectation that robots will play a role in future healthcare. ZORA is an example of a popular robot, commercially available in the Netherlands since March 2014. The popularity of applying ZORA in health care is increasing, and currently the robot is available on the market in several countries. ZORA has often been used in elderly care. A study in the Netherlands in 15 elderly homes found that clients enjoyed using ZORA and that the robot had positive influences on the behaviour of the residents. For example, ZORA elicited spontaneous participation and, in addition, a resident who normally did not speak, started to do so. Positive influences were also experienced by many of the professionals who worked with ZORA—two-thirds of them had more fun at work—but clear goals for applications of ZORA and the role

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the robot can have were not described. Furthermore, the care professionals working with ZORA indicated several barriers of using robot ZORA, such as limited battery life, long start-up time and the technical complexity of programming the robot to perform certain activities [2]. A Finnish study about the use of ZORA in elderly care yielded comparable results. In this study there were positive, negative and neutral reactions to the use of the robot. Overall, care professionals indicated that ZORA has potential for rehabilitative work and activities [3].

For children with severe physical disabilities, robots may offer new possibilities for play, which may also be used in therapeutic and educational settings. Studies show promising results when it comes to letting children with severe physical disabilities work with robots and technology. The IROMEC robot, a mobile robot which is programmed to play simple games with children such as a turn-taking game or the follow-me game, is one example of such an application [4]. Another example is the PLAYROB robot, which enables children with severe physical disabilities to play with standard toys (LEGO) [5]. In addition to robot systems, other technologies are being used to facilitate play. A computer game-based rehabilitation platform for children with cerebral palsy which is currently being evaluated [6], and a virtual reality system to support upper limb rehabilitation in children with motor impairment [7] are two examples of such technologies.

A pilot study with robot ZORA was carried out in 2016 to explore the potential of ZORA for children with severe physical disabilities. This pilot study aimed to collect data on feasibility, usability, barriers and facilitators for the child and professionals, and to obtain an indication of the effects of ZORA on playfulness and the achievement of goals. The result showed that ZORA could make a positive contribution to achieving these children's therapeutic and educational goals, and that ZORA was experienced as playful. The pilot also indicated specific application areas where professionals expected the best results. This triggered us to further study the possibilities of ZORA, focusing on these specific application areas and with a larger number of children [8].

According to the literature, robots can fulfil different roles in the context of human–robot interaction. These roles are categorised and defined in different ways. For example, in a study by Giuliani and Knoll [9], robots were applied in, amongst others, an instructive role in which the robot gave instructions to the user (adults 17–59 years) to teach them something or get them to do something. Robots can also be given a supportive role, in which they perform tasks (e.g. handing things over to the user) and only instruct the user when needed [9]. Mubin et al. [10] suggested different roles that might be attributed to robots in the context of the learning process of children, depending on the content, the instructor, the type of student and the nature of the learning activity. Robots can also have a passive role. This is the case when they are used as a learning tool or teaching aid, for example when students build, create and program robots themselves to improve their technical skills. Furthermore, robots can have the role of co-learner, peer or companion and care receiver. The role of a robot can also be that of a mentor. In summary, Mubin et al. [10] defined the aforementioned roles of robots into three categories: tools, peers or tutors. Dautenhahn [11] described six different roles of robots in human society: the autonomous robot operating without significant contact with humans, the robotic tool used by human operators, the robot operating in a human-inhabited environment, the robot as a persuasive machine, the robot as a social mediator and the robot as a model social actor. The last three of these roles were identified based on research in the Aurora project focusing on children with autism. In 2005, Dautenhahn et al. already described the potential role of a robot companion in their study. The participants in this study were asked what role a future robot companion in the home should have. The majority of the participants indicated they preferred the robot to be an assistant, a machine or a servant. Fewer people preferred the robot to be a friend or a mate [12]. Overall, it is clear that robots can be used in a variety of roles. Each of these roles may have different effects on people's behaviour.

The aim of our study was twofold and translated into two research questions:

- To what extent can individual goals within the domains of movement, communication and cognitive skills be achieved using robot ZORA?
- In which different roles can robot ZORA be applied in therapeutic or educational sessions for children with severe physical disabilities?

2 Methods

2.1 Study Design

A multi-centre mixed methods study combining quantitative and qualitative methods was executed among children with severe physical disabilities in two centres for rehabilitation and one school for special education between May 2017 and October 2017.

2.2 Robot ZORA

ZORA is a humanoid robot combining unique user-friendly software with the existing hardware robot platform NAO which was originally produced by Softbank Robotics (https://www.ald.softbankrobotics.com). The Belgian company Zora Robotics (https://www.zorarobotics.be) worked with

Softbank Robotics to develop accessible and unique software for the robot to make it useable for the field of care. This combination of robot NAO with the new software is called 'ZORA'. ZORA is 58 cm high and has seven senses for natural interaction: moving, feeling, hearing, speaking, seeing, connecting and processing. ZORA is one of the first humanoid robots that is commercially available and sold as a care robot. ZORA has three sensors on the head, two sensors on the feet and two sensors on the hands. Furthermore, ZORA can recognise speech (preprogrammed answers) and is equipped with a camera, which enables it to scan QR codes or to make pictures and videos. The robot can for example dance and interact with the user via preprogrammed scenarios. Via the ZORA software, users can easily select standard scenarios (for example, dancing, movement exercises, card games). Via the composer software, users can create new scenarios based on the basic functionalities of the robot. Sensors can be programmed to react to the user's touch. Some scenarios can be executed with the tablet control using the Wizard of Oz technique because, with the current software, it is not possible to create all the desired behaviours of ZORA as autonomous scenarios. For example, responding to speech commands of the child (ZORA sit down, stand etc.). Figure 1 shows a picture of ZORA while dancing. Examples of ZORA scenarios used in our study are described in Sect. 2.3.

Fig. 1 Robot ZORA dancing

2.3 Study Population

The study was performed in three facilities for children with severe physical disabilities in the Netherlands: two paediatric rehabilitation centres (which also offer special education facilities) and a school for special education (which also offers rehabilitation). The main researcher of the current study invited the professionals (therapists and special educators) to participate in this study. These professionals were selected by the head of their organisation, trying to select a mix of teachers and therapists from different disciplines. The invited therapists and special educators selected and invited children (via their parents) to participate in this study. The selection of children was done by convenience sampling, because the professionals selected children from their own therapy list or class, keeping in mind the in- and exclusion criteria of this study [13]. Inclusion criteria for children to participate in this study were: children with a severe physical disability (gross motor function classification system ranging from I to V), a developmental age between approximately 2 and 8 years, a chronological age between 2 and 18 years, and a stable cardiopulmonary status. Exclusion criteria were: epilepsy, deafness, blindness and severe aggressive behaviour. To ensure that all 3 studied domains (communication skills, cognitive skills and movement skills) were sufficiently represented in the goals of the participating children, the decision was made to include at least 30 children in the study.

2.4 Intervention and Study Procedure

Before starting this study, a training session with the main researcher and the professionals took place in which the professionals could discover and try out ZORA and the possibilities it offers. During this session, the professionals decided which goals they were going to work on for each of the three domains (movement skills, cognitive skills and communication skills) with each of the participating children and how they would like to apply ZORA. For each child the goals were determined and the specific scenario with ZORA was designed. After this session, the scenarios designed by the professionals were realised with ZORA by the researcher and IT specialists. All newly created approaches/options were checked with the professionals individually before the intervention sessions with the children took place. The intervention sessions were also preceded by an introduction session in the first week of the study, to allow all children to get used to robot ZORA. Over the next 5 weeks intervention sessions with ZORA took place. Each child took part in a total of six sessions. Examples of scenarios related to the individual goals of the children are displayed in Table 1.

Most of the scenarios were tailor-made for the child(ren) and setting, or used in Wizard of Oz-technique (not functioning autonomously, but remotely controlled by an IT expert). Professionals prepared the sessions in advance and decided during the sessions which scenarios they were going to use at which moment (based on their preparation and the response of the child). The duration of a ZORA session was approximately 30 min. The robot was controlled by the researcher using the tablet interface, upon requests for scenarios from the professional. Examples of these goals were 'Child imitates after 6 weeks the arm movements of ZORA', 'Child speaks to ZORA within 6 weeks' and 'Child recognized within 6 weeks the sounds of the farm animals'.

When children were selected based on the in- and exclusion criteria by the participating professionals, their parents received informed consent forms and they had 7 days to decide whether they agreed with participation of their child in the study and videotaping of the sessions. Children were included after signed informed consent. An accredited medical ethics committee approved this study (Medisch Ethische Toetsingscommissie Z NL 31192.096.17).

2.5 Measurements and Data Collection

A mix of quantitative and qualitative methods was used to examine the contribution of ZORA robot-based play intervention to the achievement of goals and to gain insight into the roles for which ZORA is best suited.

2.5.1 Quantitative Outcome Measures

In order to gain (further) insight into whether the ZORA robot can contribute to the achievement of goals in the fields of movement skills, communication skills and cognitive skills, it was necessary to assess the extent to which such goals (more precisely, goals that were set by the therapist/special educator for each individual child before the intervention sessions) were reached in robot-based play interventions with ZORA. The measurement tool used for this assessment was the IPPA. This instrument has been used in different studies evaluating the effect of assistive technology [14–16]. During a baseline interview each professional was asked to determine goals for each of the children and to rate the importance and level of difficulty associated with each goal on a baseline form before the intervention sessions (scale 1–5). After the sixth session, a follow-up interview was conducted in which the professionals were asked to complete the follow-up form (scale 1–5) to evaluate the level of difficulty associated with each goal after the intervention sessions. IPPA scores were calculated by using rated importance as weighting factor and multiplying this rated importance with the level of difficulty of a goal before and after the intervention [16]. The difference between the IPPA before and after scores represents the degree to which the difficulty has diminished.

To gain insight into how children experienced the sessions, playfulness and the children's experience of the sessions were measured. The level of playfulness children experience as interpreted by the respective professionals was measured using a visual analogue playfulness scale (0–10). After every session, professionals were asked: "In your view, how high was the level of playfulness of the child during the play session?". Children's experience of the play sessions was taken into account as well. After every session, the children were asked to indicate their feelings (scaled as like, neutral, or dislike) by pointing out one of three different symbols (smileys). Furthermore, during each session notes were made by the respective professional on circumstances or issues which might have influenced the (outcomes of the) session (such as information on the general health/wellbeing

Table 1 Examples of set goals and ZORA scenarios used in the study

Domains	Example goals	Short description the scenario
Movement skills	Child is able to imitate the movements of ZORA Child spontaneously dances together with ZORA after 6 weeks	Movement exercises, robot explains and carries out exercises (e.g. sitting, standing, lying on your back) Robot dances to famous songs which have been selected in advance together with the professional
Cognitive skills	Child is able to choose the animal card that ZORA asks for Child is able to link the sounds of different animals to the right pictures	ZORA asks to show cards with pictures of different animals and gives a reward by clapping or cheering when answer is correct ZORA makes the sounds of different animals and gives a verbal reward when the answer of the child is correct
Communication skills	Child is able to answer questions using his/her speech generating device Child is able to say goodbye in different ways	ZORA asks different questions and child searches for the answers on their speech generating device. ZORA gives a reward by e.g. clapping ZORA sits and responds to different touches (hands, feet and head). ZORA shakes hands if its hand is touched, ZORA gives a high five if its foot is touched and ZORA waves if its head is touched

of the child or unusual incidents). In addition, two cameras were used to record the sessions, so that the sessions could be reviewed afterwards.

2.5.2 Qualitative Outcome Measures

Video-stimulated recall interviews with the participating professionals were used to gain insight into the different roles the robot fullfils in the sessions. Additionally, during the same interview semi-structured interview questions were asked. Approximately 1 week after the last session these qualitative interviews took place. They lasted 30–45 min. Before the interviews were held, the main researcher viewed the video footage of each session to select relevant fragments to be used during the interviews. Video fragments were selected based on the different scenarios the professionals used during the ZORA sessions. Four fragments of four different scenarios were selected for each child or group of children. Fragments were only taken from the videos of sessions 2, 3, 4 and 5, since session one was an introductory session and session six was the goodbye session. To make sure that the selected video fragments contained a broad spectrum of different roles ZORA can be used in, they were assessed independently by two researchers using the list of aspects of roles of robots presented in Table 2. Once the independent assessments were done, the researchers compared their assessments of the video fragments and they verified if they assigned comparable roles to the fragments. Initial consensus was 80%. The fragments the researchers did not agree on were discussed until consensus was reached about the roles of ZORA in these fragments. Based on this discussion two roles were added to the overview, namely 'the robot teaches the child specific knowledge', and 'the child elicits a response from the robot' (Table 2).

The selected video fragments were used during the video-stimulated recall interviews to stimulate professionals' thinking about ZORA's different roles. The video fragments shown were always taken from the video footage of the intervention sessions the respective professionals participated in themselves. Although the main topic discussed during the interviews was the roles the professionals attributed to ZORA, the interviews also offered room for discussing conditions that are necessary to work with ZORA independently in the future, which target group(s) would likely benefit from working with ZORA, what goals could be achieved with ZORA, the influence of ZORA on the attention of participants, and how using ZORA compared to the regular situation in the participating facilities. The topic of the influence of the robot on the attention of the child was incorporated in the interview guide, since professionals in the pilot study indicated that ZORA can contribute to the improvement of attention span, motivation, concentration and taking initiative [8].

Table 2 Aspects of roles of robots

Source	Aspects
From the literature	Robot gives instructions to the child
	Robot supports the child
	Robot elicits verbal interaction
	Robot attracts and maintains attention
	Robot involves the child in the activity
	Robot supports social behaviour between the children (or between child and adult)
	Robot teaches the child a (social) behaviour
	Robot has a passive role
	Robot shows spontaneous active participation (applause, reward, support)
	Robot helps the child
	Robot elicits imitation
	Robot teaches the child social skills
Additional roles based on coding of video fragments	Robot teaches the child specific knowledge (e.g. recognizing animal sounds)
	The child elicits a response from the robot

2.6 Data Analysis

Descriptive statistics were used to analyse the quantitative data. IPPA scores were calculated according to Wessels et al. [16] by using rated importance as weighting factor and multiplying this rated importance with the level of difficulty of a goal before and after the intervention. The difference between the IPPA before and after scores represents the degree to which the difficulty has diminished. The significance of the difference was calculated with a Wilcoxon signed rank test in SPSS [17]. Furthermore, average IPPA scores were calculated per child and for each of the different domains per child. Subsequently, for these scores per child the average difference between before and after was calculated per domain, to have an overall score of each domain.

Qualitative data were transcribed verbatim and subsequently divided into fragments and labelled. Two researchers independently coded two interviews based on the principles of directed content analysis guided by the topics of the interview guide [18] and then compared their coding (approximately 75% consensus). They reached consensus about their coding by discussing the differences (approximately 25%) and one of the two researchers proceeded coding the other 10 interviews.

3 Results

3.1 Description of the Participants

In total, 33 children (11 girls and 22 boys) participated in our study. All children had a physical disability ranging from very mild to very severe (I–V) on the Gross Motor Function Classification Scale [19]. The chronological age of the children ranged from 3 to 18 years, and their developmental age varied between 2 and 8 years old. The cognitive age of the children could not be defined very specifically, because a child might have a different developmental age in each of the different domains (e.g. emotional, cognitive) of development. The children were selected based on the in- and exclusion criteria and, after selection, divided into group and individual sessions, based on their goals and the professionals' assessment of their suitability for group or individual sessions. An overview of the characteristics of the participating children (and the type of session they participated in) can be found in Table 3. Children B to P all participated in group sessions at institution 1, with group sizes varying from 2 to 7 children. At institution 2, children Q, R, S and Z participated in individual sessions, and children T to Y participated in

Table 3 Description of the participating children

Child (code)[a]	Age (years)	Sex (male/female)	Ability to walk (mobility aid)	GMFCS	Group/individual
B	17	Female	Yes (with crutches)	III	Group
C	14	Male	Yes	II	Group
D	21	Male	No (electric wheelchair)	IV	Group
E	19	Male	No (electric wheelchair)	IV	Group
F	11	Female	Yes	II	Group
G	10	Male	Yes	III	Group
H	8	Male	Yes	II	Group
I	6	Female	Yes	II	Group
J	11	Female	Yes	I	Group
K	12	Male	Yes	II	Group
L	12	Male	Yes	II	Group
M	12	Male	Yes	II	Group
N	12	Male	No (electric wheelchair)	IV	Group
O	13	Male	No (wheelchair)	V	Group
P	9	Female	Yes	II	Group
Q	16	Female	Yes	II	Individual
R	5	Male	No (wheelchair)	IV	Individual
S	7	Male	Yes	I	Individual
T	4	Male	No (electric wheelchair)	IV	Group
V	3	Male	Yes	II	Group
W	3	Male	No (wheelchair)	IV	Group
X	3	Male	Yes (walker)	III	Group
Y	4	Female	Yes (walker)	III	Group
Z	7	Female	Yes	II	Individual
AA	3	Female	No (wheelchair)	IV	Individual
AB	5	Male	Yes	II	Individual
AC	8	Male	Yes	I	Individual
AE	7	Male	No (electric wheelchair)	IV	Group
AF	8	Male	Yes (walker)	III	Group
AG	7	Male	Yes	II	Group
AH	7	Female	Yes	I	Group
AI	7	Female	Yes	III	Group
AJ	7	Male	No (wheelchair)	IV	Group

[a]Children A, U and AD are missing since these children were selected by the professionals, but did not meet the in- and exclusion criteria

group sessions. And at institution 3, 3 children participated in individual sessions (AA, AB and AC), while children AE to AJ participated in group sessions. Each child participated in six sessions.

In addition to the children, 12 professionals took part in this study. They prepared and led the individual and group sessions, and took part in the video-stimulated recall interviews. The professionals represented different expertises and occupations: 3 were physiotherapists, 3 were speech language therapists, 2 were occupational therapists, 1 was a physical education teacher, 2 were special education teachers and 1 was a group leader of a daycare group with pedagogical support. The age of the professionals ranged from 25 to 63 years old and they had between 2.5 and 35 years of working experience with children with physical disabilities.

3.2 Quantitative Outcomes

3.2.1 Individually Prioritized Problem Assessment (IPPA)

The IPPA scores show to what extent robot ZORA was able to contribute to the achievement of the individual goals of the children (measured for each child). Professionals set between 2 and 11 goals per child to be reached during the six sessions. In Fig. 2 the individual IPPA scores of each child are displayed in a graph, showing a decrease in IPPA scores between the start and the end of the ZORA intervention in 26 of the 33 children. This means that there was a decrease in the level of difficulty these children experienced in performing in a way that enabled them to reach their goals. The mean IPPA score before the intervention sessions was 13.5 (SD 4.3), with a minimum of 6.3 and a maximum of 28, and the mean IPPA score after the intervention sessions was 10.3 (SD 4.2), with a minimum of 3.2 and a maximum of 18. A significant difference was found between IPPA before and after the intervention sessions ($p=0.001$; $Z=-3.43$), which indicates a positive contribution of the ZORA-based intervention sessions to the achievement of goals.

The goals that were established by the professionals were categorised into the domains 'movement skills', 'communication skills' and 'cognitive skills'. However, some goals could not be categorised into these three domains. These goals all turned out to be related to attention, motivation and concentration. Therefore, an additional domain was added: attention. In Table 4 the average of the mean differences (corrected for child), standard deviations and ranges of the scores within the four different domains are displayed. These mean differences show a decrease in the difficulty of reaching a certain goal, which indicates a positive contribution to the achievement of goals. The highest mean differences were those for the domains of movement skills and communication skills.

It is possible that either group sessions or individual sessions are more 'successful' at achieving decreases in IPPA

Table 4 IPPA scores categorised for the four domains

Domain	Mean difference	SD	Minimum	Maximum
Movement skills	4.50	5.58	−6	20
Communication skills	3.47	5.56	−5	15
Cognitive skills	1.56	4.72	−8	9
Attention	2.79	2.06	−0.33	6.33

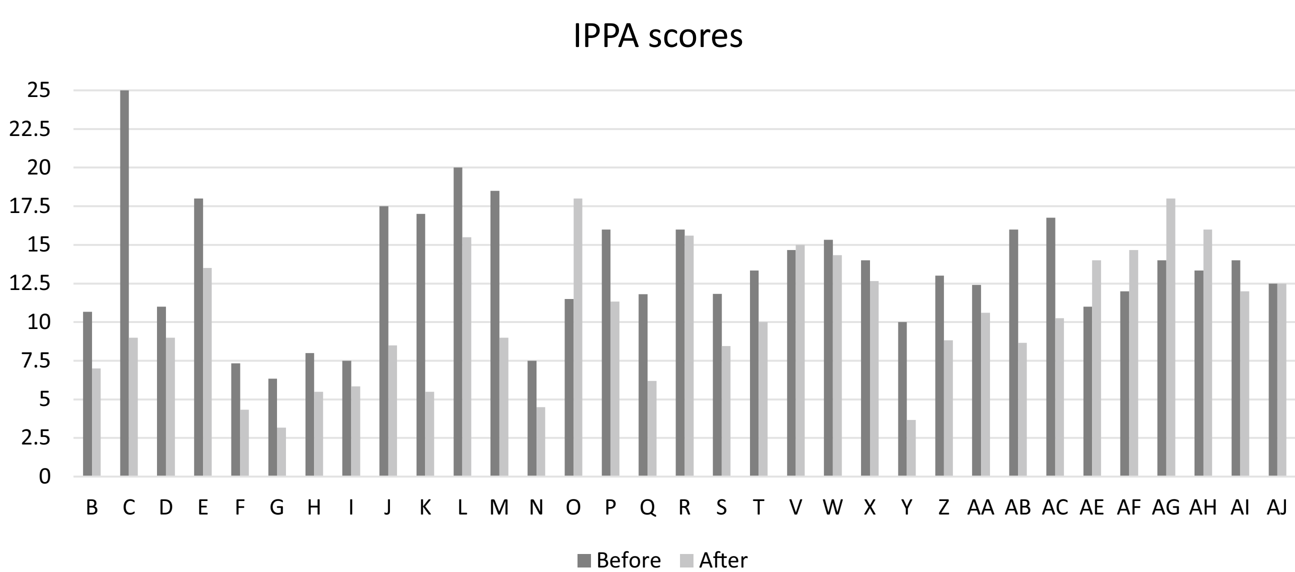

Fig. 2 IPPA scores before and after the ZORA based intervention sessions for each child

scores. When comparing the results of children participating in the group sessions to the results of children participating in the individual sessions, no relevant difference can be observed between the two conditions.

3.2.2 Playfulness and Children's Feelings About the Sessions

Table 5 shows the scores that were given concerning playfulness using the visual analogue playfulness scale (0–10) for the six sessions. The maximum playfulness score that was awarded across all sessions was 9 and the minimum score was 0. The average playfulness score across all sessions was 7.5. According to the professionals, children mostly liked playing with ZORA during the sessions. Based on the fact that children frequently indicated the 'like' smiley after a session, it can be concluded that 93% of children felt positive about the ZORA-based intervention sessions (n = 159).

3.2.3 Unplanned Circumstances/Issues During Sessions

The notes that were made by the professionals in each session about the general wellbeing/health of the children and about unforeseen or unplanned issues/circumstances that might influence the session, were clustered into three themes: participation of the child, functionalities of ZORA, and environmental factors. Some examples of notes on occurrences belonging to the first theme are "participation is very good and increases when ZORA mentioned the name of the child", "after some sessions focus on ZORA increases", "participation increases with ZORA", "child seems to be annoyed and participation decreases with time". Notes on the functionalities of ZORA included "ZORA distracts the child from the actual task in a negative way", "child needs new scenarios/features to stay focused", "child gives varying responses to ZORA, sometimes laughing and very happy; sometimes sad", "session cancelled because ZORA wasn't functioning (properly)". And concerning environmental factors, the professionals mentioned things such as "child was distracted by people close by", "temperature was very high, which influenced the wellbeing of the child in a negative way", "ZORA is speaking too fast".

Table 5 Descriptives of the playfulness scores

Session	N	Minimum	Maximum	Mean	SD
1	28	3	9	7.34	1.38
2	30	0	9	7.02	2.03
3	24	6	8.5	7.71	0.72
4	25	3	9	7.50	1.43
5	31	6	9	7.89	0.94
6	28	5	10	7.66	1.25

3.3 Qualitative Outcomes

The video-stimulated recall interviews led to relevant results on the role of the robot, conditions to work with ZORA independently, target groups that might benefit from working with ZORA, goals ZORA can help achieve, ZORA's influence on attention, and how ZORA interventions compare to regular therapy/education. In the following paragraphs the main findings on each of these topics are described.

3.3.1 The Role of the Robot

The professionals mentioned that ZORA could be used as an instructor, a motivator, a (co-)therapist, a rewarder, a buddy, an intermediate, as a tool during movement exercises, as support, as an example, and in a comforting role. The role for which ZORA was most suitable, which was also the role that was identified as being most effective by all professionals, was the role of motivator. Most of the professionals also mentioned the role of rewarder. Some professionals mentioned the role of instructor (imitation) as most suitable role. Although it technically does not say anything about the role of the robot, it is worth mentioning that most of the participating professionals experienced their own role as difficult at times. They often responded too fast, even though they felt that they should wait for the response of ZORA, which was sometimes delayed. In an effort to deal with this issue, professionals experimented with finding the right balance between supporting the child and waiting for ZORA's response.

3.3.2 Conditions Necessary to Work with ZORA Independently

A number of comments were made concerning what is required to successfully work with ZORA independently in the future. With regard to the space and location in which the intervention sessions take place, professionals indicated that the existing therapy rooms or classrooms were suitable for the sessions with ZORA and that no special rooms were needed. In addition, one of the professionals mentioned that there was a difference between using ZORA on the table and using ZORA on the floor. Using ZORA on the floor felt much more threatening for the youngest children who participated, because these children felt less save without their chair.

Some professionals indicated that at least two therapists or teachers should be present in a session, to allow working with ZORA independently (without IT assistance), so that one person can control ZORA while the other works with the child. Others are convinced that they could work with ZORA independently in the future after some training in using and programming the robot. Furthermore, professionals indicated that more time should be facilitated for training and programming ZORA.

Some professionals suggested that an expert should be available to program the options they suggest into ZORA, as these professionals felt it was not their role to take care of this technical side of working with ZORA. Furthermore, professionals indicated that it is sometimes impossible to respond immediately to the child using ZORA, because there is a delay between giving a command (through, for example, speech) to ZORA and the actual performance by ZORA. One of the occupational therapists participating in our study suggested that ZORA should be able to grab things with its hands, which would make the robot more suitable for occupational therapy related goals. A point that was highlighted by the speech language therapists concerned the intonation of ZORA, which, they indicated, is often unclear or confusing, and should be improved.

3.3.3 Relevant Target Groups for Working with ZORA

Regarding the question whether the use of ZORA is more or less useful with children with a minimum level of specific skills (whether they be movement skills, cognitive skills, communication skills, or attention/motivation skills), the professionals gave some valuable insights. In their view, ZORA can best be used with children who are able to understand simple instructions from ZORA (cognitive skills). The level of motor skills (e.g. wheelchair or no wheelchair user) does not really matter because important aspects like the instructions given to the child can be adapted to the abilities and limitations of the child. Professionals also indicated that children who need to be motivated to move can possibly benefit the most from using ZORA. In addition, it became apparent from the interviews that ZORA can be used for children with autistic characteristics, because of the structure a robot can offer and the option to repeat scenarios in exactly the same way, again and again. Some professionals mentioned that they saw most possibilities for young children between 4 and 8 years old or 2 and 12 years old, depending on their developmental age.

3.3.4 Relevant Goals for Application of ZORA

Professionals suggested that ZORA is most suitable for helping to achieve goals related to gross motor skills and eliciting communication. For example, ZORA can offer support in the instruction and guidance of imitation of e.g. arm movements, lying on the belly, sitting, etc. When it comes to communication ZORA can, amongst others, teach social manners (handshake, saying goodbye etc.) and help children to tell stories.

3.3.5 Influence of ZORA on Attention

The professionals indicated that most of the children were attracted to ZORA during the 6-week session period and that they were able to have and keep their attention on ZORA during the 30 min sessions. Some professionals indicated that the attention children had for ZORA was better than the attention the children had for the professionals when they gave instructions or rewards. Some professionals mentioned that the concentration of the children was outstanding, While others mentioned that the level of attention children paid to ZORA differed depending on the way in which ZORA was used. For example, the dances (songs with movement) ZORA performed, were more attractive to most children and got more attention than verbal instructions.

3.3.6 Comparison with Regular Therapy or Education

When professionals compared ZORA-based intervention sessions with regular therapeutic or educational sessions, they highlighted both positive and beneficial aspects and influences of ZORA-based interventions as well as negative points and recommendations for improvement. It should be taken into account that the intervention does not consist of ZORA alone, but is always a combination of the professional with an individual plan and the robot as a tool.

One of the positive points mentioned was the fact that professionals could let ZORA take over tasks, giving them the opportunity to observe the child instead of giving instructions. This increased opportunity for observation allowed the professionals, amongst others, to assess the performance of the child on a weekly basis. Professionals also highly appreciated that the sessions were very similar, which was the case because ZORA gives exactly the same instruction every time. Furthermore, professionals mentioned that ZORA was attractive, nice and fascinating for the children as compared to the usual everyday routines of the therapists or teachers. As a result of this attractiveness and fascination children were, for example, more willing to listen to ZORA than to their mentors/supervisors in regular sessions, and the level of concentration of the children in sessions with ZORA as compared to their concentration in sessions without ZORA also stood out. As became apparent from the recall interviews, ZORA's interactive dances were experienced by the children as very attractive. Additionally, the professionals said that the size of ZORA was a positive aspect, as it was easier for children to see ZORA as a friend or mate, rather than seeing their teacher or therapist as such, because ZORA is closer in size to that of the child. Furthermore, ZORA offers the possibility to exclude certain stimuli, for example only giving a verbal instruction without an accompanying facial expression, which is much more difficult to do for a professional.

An aspect of ZORA professionals indicated as being both positive and negative, was the strict structure in the pre-programmed scenarios, which cannot be adapted during a session. This characteristic can be seen as positive because some children prefer and like repetitions and predictability (e.g. with autistic characteristics), and as negative since it would be useful if the professionals could adapt scenarios during a session (e.g. when something did not work out as expected or when something was too difficult for the child). In addition, professionals gave negative feedback about the fact that the use of the robot in sessions with very severely disabled children is limited, as there are no options for these children to control ZORA (for instance via switches or table commands). Lastly, one child was very afraid of ZORA and this influenced her muscle tension in a negative way.

4 Discussion

The aim of this study was to examine to what extend individual goals within the domains of movement, communication and cognitive skills can be achieved using robot ZORA and to examine the different roles in which ZORA can be applied in therapeutic and educational sessions for children with severe physical disabilities. The results of this study indicate that ZORA-based intervention sessions contribute to the achievement of goals of children with severe physical disabilities, especially in the domains of movement skills and communication skills. ZORA may also contribute in the domains of cognitive skills and attention. Out of the different roles in which ZORA can be used, professionals indicate that a role as motivator is most promising. Other roles in which ZORA could make valuable contributions to children's success in achieving their goals are the role of rewarder and instructor. Furthermore, children mostly liked playing with ZORA and the professionals appreciated working with ZORA.

When the results of the present study are compared with studies that used ZORA in care for elderly people, ZORA also seemed to have an important contribution in the motivational domain, because ZORA stimulated spontaneous participation [2]. This matches with the results of our study with ZORA contributing to attention and the role of ZORA as a motivator. Apart from ZORA, in rehabilitation and special education more and more innovative technologies are being used and tested. For example the PITS system from the study of Wille et al. [7] appeared to have highly motivated children. This might indicate a positive contribution of innovative technologies to motivation of the children, compared to commonly used interventions.

With respect to the different roles ZORA can fulfil, the insights the professionals in this study described in the recall interviews partly overlap with roles that are described in the literature. The three roles of which the professionals indicated ZORA would be most suited to perform (motivator, rewarder, instructor) were also described by Giuliani and Knoll [9] and Mubin et al. [10]. Other roles mentioned in the literature did not come up in the current study as roles ZORA would be suitable to fulfil. This discrepancy might be explained by the fact that ZORA is a so-called social robot and (in its current state) not an assistive robot delivering physical support. In addition, some roles described in the literature (e.g. the passive robot role which allows children to learn things from robots by for example building or programming them) may not fit the specific target population of this study, and were therefore not identified by the professionals. Furthermore, the roles of assistant, machine, servant and care receiver were not mentioned. These roles are probably more suitable for assistive robots.

When comparing the roles ZORA can be used for to the roles or professional competencies of therapists (occupational therapists, speech language therapists and physiotherapists) and special educators, it becomes clear that the competencies 'giving instructions' and 'motivating' that ZORA performs, are part of the competence profiles of these professionals [20]. And, although the role 'rewarder' is not specifically described as a competence of the professionals, it is of course part of the natural behaviour of professionals working with children. Given the competences of the professionals working with the severely disabled children in this study, it is likely that ZORA might serve as a support or additional tool to fulfil their professional competencies. This idea is further supported by the fact that, when they elaborated on how they would like to use ZORA, professionals seemed to choose roles that are closely related to their own roles, responsibilities and competencies. The range in background and working experience of the professionals participating may have contributed to a broad range of roles, based on the different backgrounds and experiences of the professionals.

Professionals have many tools, toys and materials at their disposal to match with children's therapeutic and educational goals and match their play preferences. This study aimed to examine if robots and ZORA in particular can add to the repertoire of therapeutic or educational materials. This study showed that ZORA can be an attractive, stimulating tool to support play and that ZORA-based interventions can contribute to the achievement of goals in rehabilitation and special education. Robots may offer more variety in play and interventions for the children and professionals and offer them new possibilities regarding control options, communication and interaction which are continuously improving due to ongoing technological advancements. In this explorative phase with ZORA in this context the testing with 33 children provided meaningful insights into contribution of ZORA to reach individual goals in different domains and into different roles of ZORA. Besides on the functionalities of the robots, the success of the robot mainly depends on the way the robot is used in practice. Therefore, the total package of the intervention and the role of the professional should be carefully considered. To limit the chance of creating significant differences in the skill with which ZORA was controlled (which could occur if, for example, technical experts were in charge of ZORA in some sessions and not in charge in other sessions) and thereby possibly skewing the results of this study, the researcher controlled ZORA in all sessions. To be able to realize sustainability in the future it should be arranged that the professionals receive a longer and proper training and instruction to be able to work with ZORA independently and ideally program ZORA themselves. Recommendations for future use also include improvements of technical performance of the robot.

In total, three organisations, 12 professionals and 33 children participated in this study, which makes it a relatively large study in this field of research. As with any study, both large and small, some limitations have to be acknowledged. When interpreting the results of this study, it is important to keep in mind that regular therapy and educational activities continued during the period of the ZORA study. These activities might have influenced the results. For example, in general physical activity lessons they may also have been working on improvement of gross motor skills. During the group sessions, peers also may have influenced the children, particularly during the group sessions. In addition, the use of convenience sampling via the professionals means that, despite the inclusion criteria, preferences of the professionals could have influenced the results. They may have selected children for whom they thought ZORA could be most beneficial or children of which they expected that they would really like ZORA. In the registration forms of the sessions some additional aspects were filled in which, according to the professionals, may have influenced the ZORA sessions as well. For example, the study was conducted in summer and the temperature was very high during some of the weeks (also inside the buildings), which may have influenced the alertness and the physical condition of the children.

For future studies, it is recommended to supply robot ZORA to rehabilitation centres and/or schools for special education for a longer time (e.g. 6 months instead of 6 weeks), allowing both children and professionals to work and get properly acquainted with the robot and all of its technical functionalities. Combined with proper instructions and training sessions in advance, and ICT support during future studies if necessary, it should be possible to allow professionals to work with ZORA independently. Research may support practical use and sustainable implementation of robots, by gathering and providing data during a longer research period, for example data about the actual frequency of use, the goals they work on with the children, the problems they encounter, and solutions for these problems. It would be worthwhile to involve managers or policy makers of institutions that work with ZORA in this process, since they play an important role in creating conditions for sustainable implementation of innovations.

4.1 Conclusion

Based on the results of this study it can be concluded that the ZORA-based intervention sessions contribute to the achievement of goals of children with severe physical disabilities, especially in the domains of movement skills and communication skills. Furthermore, ZORA may contribute to the domains of cognitive skills and attention. The role of ZORA as a motivator is the most promising one based on the professionals opinion. Other roles in which ZORA could make valuable contributions to children's success in achieving their goals are the role of rewarder and instructor. This study showed that robot ZORA can be an effective tool to be used in rehabilitation and special education. ZORA in particular, and robots in general, may offer the next generation of play for children with severe physical disabilities.

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