Robot ZORA in rehabilitation and special education for children with severe physical disabilities: a pilot study

Renée J.F. van den Heuvel[a,b], Monique A.S. Lexis[a] and Luc P. de Witte[b,c]

The aim of this study was to explore the potential of ZORA robot-based interventions in rehabilitation and special education for children with severe physical disabilities. A two-centre explorative pilot study was carried out over a 2.5-month period involving children with severe physical disabilities with a developmental age ranging from 2 to 8 years. Children participated in six sessions with the ZORA robot in individual or in group sessions. Qualitative and quantitative methods were used to collect data on aspects of feasibility, usability, barriers and facilitators for the child as well as for the therapist and to obtain an indication of the effects on playfulness and the achievement of goals. In total, 17 children and seven professionals participated in the study. The results of this study show a positive contribution of ZORA in achieving therapy and educational goals. Moreover, sessions with ZORA were indicated as playful. Three main domains were indicated to be the most promising for the application of ZORA: movement skills, communication skills and cognitive skills. Furthermore, ZORA can contribute towards eliciting motivation, concentration, taking initiative and improving attention span of the children. On the basis of the results of the study, it can be concluded that ZORA has potential in therapy and education for children with severe physical disabilities. More research is needed to gain insight into how ZORA can be applied best in rehabilitation and special education. ***International Journal of Rehabilitation Research*** **00:000–000**

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[a]Department of Health, Research Centre for Assistive Technology in Care, Zuyd University of Applied Sciences, Heerlen, [b]CAPHRI School for Public Health and Primary Care, Department of Health Services Research, Maastricht University, Maastricht, The Netherlands and [c]School of Health and Related Research, Centre for Assistive Technology and Connected Healthcare, University of Sheffield, Sheffield, UK

Correspondence to Renée J.F. van den Heuvel, MSc, Research Centre for Assistive Technology in Care, Zuyd University of Applied Sciences, Henri Dunantstraat 2, 6419 PB Heerlen, The Netherlands
Tel: + 31 880 272 120; e-mail: renee.vandenheuvel@zuyd.nl

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Introduction

Play is essential in children's development and contributes towards cognitive, physical, social and emotional development (Besio, 2008; Spaargaren, 2011). A large variety of tools and technologies to support play in children with disabilities are being developed. Developments in the field of robotics create new opportunities for this target group. Besides supporting play for play's sake, new technologies may also contribute towards the achievement of therapeutic and educational goals, making use of play-like activities.

During the past decade, the field of robotics has been an upcoming field of research and development, characterized by a rapid increase in the application of robot-technology among a large variety of populations. Several studies have been carried out using robots for children with disabilities. Especially for children with physical disabilities in rehabilitation and special education, meaningful application possibilities for robots have been reported. The LEGO Mindstorms and the PlayROB system, for example, are both robots that can stimulate engagement in play (Kronreif *et al.*, 2005; Schulmeister *et al.*, 2011; Van den Heuvel *et al.*, 2016b). The LEGO Mindstorms has been found an excellent tool to facilitate play and learning activities for children with physical disabilities and the PlayROB system successfully improved the opportunity to play with LEGO for physically disabled children (Kronreif *et al.*, 2005; Schulmeister *et al.*, 2011). However, the results of these studies were all based on relatively small studies with low numbers of participants (one to six children). Within a European research project (*https://www.iromec.org*), the IROMEC robot was developed. An explorative pilot study with the IROMEC robot among children with severe physical disabilities showed a promising positive effect on achievement of individual therapy or educational goals. In addition to achievement of therapeutic or educational goals, playing and having play fun were indicated by the professionals involved (therapists and teachers) to be of equal importance. The children enjoyed playing with IROMEC and the professionals indicated that robots may be attractive for this target group. Professionals reported meaningful application possibilities for IROMEC for this target group; however, the robot appeared to have limited adaptability, expandability and technical stability (Van den Heuvel *et al.*, 2016a). The IROMEC robot was developed for research purposes and is not a commercially available product. This also accounts for the LEGO robots and PlayROB, which are not commercially available as used in these studies. Accessibility of these robots for daily care practice is therefore still very limited. Other commercially available robots, such as the social robotic toy animals PARO and Pleo, are often used in care (Fernaeus *et al.*, 2010); however, they have different aims and technical possibilities. In contrast, ZORA is a commercially available care robot encompassing several characteristics suitable to support play and rehabilitation or special education goals. When comparing ZORA with the aforementioned robots/robotic systems, ZORA seems to have some major benefits, such as an attractive appearance, better technical stability and ease of control and transport.

ZORA is a humanoid robot actually produced as the NAO robot by Softbank Robotics (*https://www.ald.softbankrobotics.com*). The Belgium company Zora Robotics (*https://www.zorarobotics.be*) developed together with the producer accessible and unique software for the robot to enable application in the field of care and they called this combination of robot and software ZORA. ZORA is a 58 cm high humanoid robot with seven senses for natural interaction: moving, feeling, hearing and speaking, seeing, connecting and thinking. ZORA is one of the first humanoid robots that is commercially available and sold as a care robot. Preprogrammed scenarios can be used to let the robot dance or interact with the user. Sensors can be programmed to react on the user's touch and 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 behaviours of ZORA as autonomous scenarios. With its attractive appearance and variation of interaction and communication possibilities, this robot is promising. Figure 1 shows a picture of ZORA.

ZORA is a commercially available robot that is increasingly being used in the care sector. As described before, NAO is the same robot; the difference is the simplified software developed for ZORA, focused on application in the rehabilitation and care sector. Studies carried out with NAO in elderly care aimed to support and motivate elderly individuals to perform movement exercises (Görer *et al.*, 2016). In an intervention programme for children with autism spectrum disorder, NAO was used to stimulate communication (Ismail *et al.*, 2012), and in children with cerebral palsy, NAO was used to improve treatment efficiency (Malik *et al.*, 2015). Stimulated by the positive results of scientific studies with ZORA or NAO in different healthcare sectors, attention towards ZORA in healthcare is increasing rapidly and questions have been raised on what its possibilities could be for children with severe physical disabilities in supporting play activities in therapy and special education. The current possibilities of the robot seem to be meaningful to explore its potential further in this area.

Fig. 1

The ZORA robot.

This study aimed to explore the potential of ZORA robot-based interventions in rehabilitation and special education for children with severe physical disabilities. Aspects of usability, feasibility, barriers and facilitators for the child as well as the therapist/special educator and an indication of the effects on playfulness were studied. Furthermore, the choice for the types of therapeutic and educational goals by the educators and therapists of different professions (e.g. physical therapists, occupational therapists, speech therapists) and the achievement of these goals were determined.

Participants and methods

Study design

A two-centre explorative pilot study was carried out from October 2016 to December 2016 involving children with severe physical disabilities with a developmental age between ~ 2 and 8 years.

Study participants

The study was carried out in two institutions in the Netherlands: a school for special education (institution 1) and a paediatric rehabilitation centre (institution 2). Parents were invited for participation of their child through the therapist or special educator and they were free to refuse participation. Children were included in the study if they had severe physical disabilities, for example as a consequence of cerebral palsy or acquired brain injury, if they had a developmental age between ~ 2 and 8 years and a chronological age between 2 and 20 years. Furthermore, the cardiopulmonary status of the children had to be stable. Children were excluded when they suffered from epilepsy, deafness, blindness or when they showed severe aggressive behaviour. It was intended to include ~ 12–16 children. Professionals, including teachers, group leaders or therapists, were invited through the coordinator of each centre.

Intervention

The intervention with ZORA started with a first session to introduce the robot to the child or children and to become familiar with the robot. After this session, five intervention sessions with ZORA were scheduled. The available scenarios can be divided into four different categories: movement exercises, dance exercises, robot control and cognitive exercises. When scenarios were executed according to the Wizard of Oz technique, they still fitted into these four categories. Table 1 describes the ZORA scenarios and examples of games. During the sessions, the professionals were in charge of deciding which scenarios they were going to use depending on the preferences of the child at that specific moment and on the basis of their own experience. A session lasted ~ 30 min, with at least 20 min effective therapy time. Goals established before the sessions were for example: 'The child is able to imitate all the movements of the robot within 6 sessions', 'The child has a longer attention span using ZORA' and 'The child is able to use the grammatical construction He + verb'. Each child participated in six individual sessions or in six group sessions. The robot was controlled by the researcher with a tablet interface.

Study procedure

After selection of the children, their parents received full information and they were given at least 7 days to decide whether they agreed to their child's participation in the study and whether they agreed to the videotaping of the sessions. After a signed informed consent was obtained, children were included in the study. The week before the study started, a training session for the professionals was organized in which the different scenarios were demonstrated and a role play between the professionals was done to become familiar with the robot. Two sessions per child per week were organized over a period of 3 weeks. Because of the regular planning of group therapy, the group sessions were scheduled once a week over a period of 6 weeks. The study was approved by an accredited medical ethics committee (Medisch Ethische Toetsingscommissie Zuyderland NL58646.096.16).

Measurements and data collection

A mixed-methods approach was used, combining qualitative and quantitative methods to collect data on aspects of feasibility, usability, barriers and facilitators for the child as well as the therapist and an indication of the effects on playfulness and the achievement of goals.

Quantitative outcome measures

In addition to 'play' being an important aim in therapy and education, the professionals indicated that play is often being used as a means to achieve other goals. To assess the effect of the robot in achieving these goals, an instrument to assess the effectiveness of assistive technology was used: the Individually Prioritized Problem Assessment (IPPA) (Wessels *et al.*, 2002). With IPPA, it is possible to assess to what extent the goals established by the professional before the series of ZORA sessions were reached. 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 (scales 1–5). A checklist with the goal overview from our former study was used to help the professional to think about possible goals (van den Heuvel *et al.*, in press). After the sixth session, a follow-up interview was conducted in which the participants were asked to complete the follow-up form (scales 1–5) to evaluate the level of difficulty associated with each goal.

A previous study on robots for children with severe physical disabilities showed that play is an important aim related to interventions with robots (van den Heuvel *et al.*, in press). Play as goal in itself came up as one of the main domains in the goal overview (van den Heuvel *et al.*, in press). For this reason, the outcome measure

Table 1 Description of ZORA scenarios

Categories	Example scenarios	Description of scenarios
Movement exercises	Leg exercises (on a chair) Movement exercises	Movement exercises, robot explains and carries out exercises
Dance exercises	Head, shoulders, knees and toes Hansje, pansje, kevertje (Dutch song) Smakelijk eten (Dutch song)	Movement exercises carried out by the robot and supported by songs
Robot control	Press my sensors Stop, stand, step	Child can control the behaviour of the robot through vocal commands or pressing sensors
Cognitive exercises	QR quiz QA quiz	Card games: robot asks to show a specific card (e.g. animal), child has to show the right card and show it to ZORA. ZORA gives positive feedback or asks to try it again in case of wrong answer. Question and answer games with cognitive tasks that the child has to complete

QA, question and answer; QR, quick response code (QR code) on the cards.

playfulness was chosen. A 10-point visual analogue scale was used to assess playfulness from the professional's point of view. They were asked: 'How high was the level of playfulness for the child during the play session in your eyes?'. A score of zero means no playfulness and a score of 10 means as high as possible playfulness (Freyd, 1923). The aim of this score was to be able to evaluate playfulness over time for the group of participants.

The success of the ZORA-based interventions mainly depends on the children's viewpoint about the ZORA sessions. However, for children with severe physical disabilities, this was challenging. The children were asked to indicate their feelings (like, neutral, dislike) by pointing out smileys after every session. The playfulness scale and indication of smileys have been used successfully before in former studies with the IROMEC robot (Bernd *et al.*, 2010; van den Heuvel *et al.*, 2016a).

Qualitative outcomes

Qualitative interviews were performed with the professionals on aspects of usability, feasibility, barriers and facilitators in the use of ZORA. Usability can be defined as 'The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use' (Frøkjær *et al.*, 2000). Feasibility refers to the state of being possible, in the case of this study being able to work with ZORA in the future. Items included in the interviews are as follows: what was your experience working with ZORA? What do you think about the usability of the robot? What makes it easy or hard to use? Which factors influenced the use of the robot in a positive or a negative way (e.g. physical and social environment)? How could the robot be applied best in the future? Furthermore, the professionals were able to reflect their own impression of the possible effects of the robot during this interview. A more detailed description of the main topics of the interview guide is presented in Table 2.

Procedure

Quantitative data were collected at the start, during and after the ZORA sessions. All sessions were video recorded using two cameras at two positions to enable review the sessions afterwards. The IPPA forms and the playfulness scale were completed by the professionals after each session. The researcher registered the smileys that the children indicated by pointing their finger representing their feeling of playing with ZORA. The qualitative interviews lasted ~30 min and were conducted individually 1 week after the last session with ZORA with all professionals involved.

Data analysis

To establish the mean, range and SD for the playfulness scale, descriptive statistics were used. The total IPPA score was calculated by using the rated importance of the first interview as the weighting factor and multiplying the importance with the level of difficulty before and after the intervention (Wessels *et al.*, 2002). The difference between the score before and after the intervention represents the degree to which the difficulty has diminished. A nonparametric statistical test (Wilcoxon signed-rank test) was used to compare the two means ($\alpha = 0.05$). Descriptive statistics were used to show children's viewpoint on the ZORA intervention by counting the number of happy, neutral or sad smileys.

Interviews were transcribed verbatim. Relevant information from the interviews was divided into fragments and labelled afterwards, according to themes and subthemes from the interview guide, on the basis of the principles of content analysis (Table 2) (Hsieh and Shannon, 2005).

Table 2 Overview of the topics and subtopics

Main topics	Subtopics
Usability and feasibility aspects	General experience of working with ZORA Time investment working with ZORA Satisfaction with usability of ZORA (easy to use, errors) Safety of the robot for the children Ability to use robot independently Influence of the social and physical environment
Effects of ZORA	Domains where the robot is most valuable Comparison with regular therapy Improvement in the children using ZORA

Results

A total of 17 children participated in this study (10 boys and seven girls). Some children missed one or more sessions because of illness or absence. The characteristics of the participants are described in Table 3. All children were physically disabled and the severity ranged from Gross Motor Function Classification level II (mild) to IV (severe) (Palisano *et al.*, 2007). The chronological age of the children ranged from 31 months to 18 years and the cognitive age ranged from 24 months to 4 years. Most of the children also had cognitive impairments. Because of the complexity of the conditions, the cognitive age cannot be defined specifically. Children A, B, N, S and T participated in individual sessions with ZORA, and also three groups of each four children participated in the study (group 1 includes participants C, D, E and G, group 2 includes participants H–K and group 3 consists of participants O–R) (Table 3). Children participated in group or individual sessions on the basis of scheduled existing group and individual sessions.

Seven professionals participated in the ZORA sessions and in the qualitative interviews afterwards: two physiotherapists, two speech language therapists, one occupational therapist, one therapeutic group leader and one

Table 3 Characteristics of the participating children

Child	Chronological age (months)	Sex	Ability to walk	GMFCS level
A	139	Female	Yes	II
B	150	Male	Yes	II
C	186	Male	Yes	II
D	164	Male	Yes	II
E	211	Male	Yes	II
G	222	Female	Yes	II
H	207	Female	Yes	II
I	176	Female	Yes	II
J	185	Female	Yes	II
K	198	Female	Yes	II
N	39	Male	Yes	II
O	45	Male	Yes	II
P	48	Male	Yes	II
Q	43	Male	Yes	III
R	36	Male	No (wheelchair)	IV
S	41	Female	No (able to crawl)	IV
T	31	Male	Yes	III

GMFCS, Gross Motor Function Classification System.

physical education teacher. The diversity of professionals shows that there is interest in working with and application of ZORA from different therapy and educational disciplines. The age of the professionals ranged between 26 and 63 years. The number of years of working experience with children with physical disabilities ranged from 4 to 33 years.

Quantitative outcomes

All goals selected by the professionals could be related to three main domains, that is movement skills, cognitive skills or communication skills. Figure 2 shows the IPPA scores. The mean score of IPPA before the sessions was 11.8, with a minimum of 6 and a maximum of 15 (SD: 3.0), and the mean score after the sessions was 8.8, with a minimum of 3 and a maximum of 15.3 (SD: 3.5). This significant difference ($P = 0.002$) between the IPPA before and after scores indicates the contribution of ZORA towards achievement of the goals.

The results of the playfulness scale are shown in Table 4. Across all sessions, the maximum playfulness score was 10 and the minimum score was 4. Generally, the playfulness score is almost stable during the six sessions, and overall quite high, which means that the children showed playful behaviour during the sessions and liked playing with ZORA according to the professionals.

With respect to children's ($N = 17$) impression about the sessions, for children N–T ($n = 7$), it was impossible to indicate the smiley representing their feelings because they were too young to understand. Professionals asked the children whether they liked the session and interpreted the communication of the children. According to the professionals, children N–T all liked playing with ZORA. From the total of 60 sessions in which indication of smileys could be performed (children A–K), 58 sessions were liked, one value was missing because of absence of the child and one score was doubtful; the child indicated the dislike as well as the like smiley. Both for individual and for group sessions, there were children who did not achieve their individual goals, which makes it impossible to conclude anything about the preference for group or individual sessions with ZORA.

Qualitative outcomes

Usability and feasibility aspects

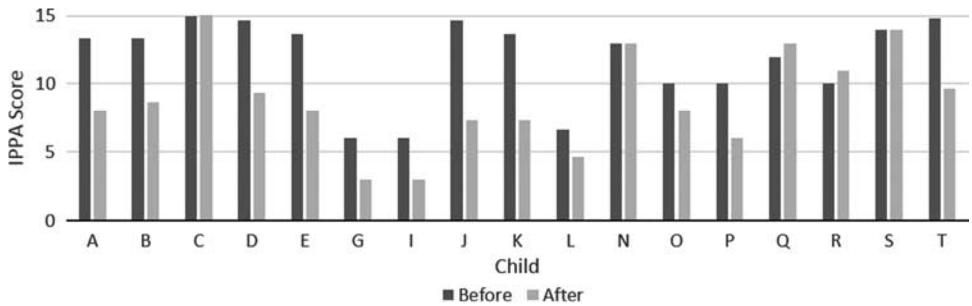
Professionals indicated that they like working with ZORA. The time they had to spend to work with ZORA was comparable with the preparation of regular therapeutic or educational session. Extra time was only related to participation in this research (training session, setting goals and evaluation). Professionals were not able to talk about the usability of the robot control and software because the researchers took care of this. The usability of the robot together with the child was reasonable and everything functioned as expected. Two barriers were indicated: scanning the cards with the cognitive card games was difficult and pressing different sensors is confusing (e.g. robot asks for pressing foot, but actually only toes react). Professionals considered the robot safe to use and they were convinced that they would be able to control the robot themselves in the future.

Usual classrooms or therapy rooms were most of the times of perfect size for a ZORA session, except the physiotherapy sessions; for these sessions, a larger gym (for training of gross motor skills) was preferred. The professionals believed that the presence of cameras and researchers during the ZORA sessions did not influence the sessions.

Effects of ZORA

Professionals do see possibilities for the application of ZORA in their treatments and education. According to them, ZORA has great potential to improve motivation, concentration, taking initiative and attention span. Three main domains were indicated in which ZORA may be beneficial: (re)learning of movement skills, cognitive skills and communication/social interaction skills. These domains were identical to the domains found in the quantitative part of this study. On the basis of the professionals' assessment, all children liked the ZORA sessions and had a playful experience. Progress in the achievement of goals has been observed, but a period of 3–6 weeks was, for some children (especially those with lower cognitive levels), too short to be able to reach the goals. ZORA elicited curiosity and emotional responses in almost all children. Over time, children began to feel safe and comfortable with the robot, but sometimes, the enthusiasm to play and exercise with the robot diminished. Both in individual and in group sessions, ZORA may be able to contribute towards achievement of goals. Some professionals ($n = 2$) mentioned that in group sessions, ZORA may elicit more interaction and may fit best.

Fig. 2



Individually Prioritized Problem Assessment (IPPA) scores before and after the ZORA sessions.

Table 4 **Results on the 10-point playfulness scale**

	Mean	SD	Minimum	Maximum
Session 1 (*n* = 15)	7.6	0.61	6	8
Session 2 (*n* = 16)	6.8	1.52	4	10
Session 3 (*n* = 17)	7	0.97	5	8
Session 4 (*n* = 15)	7	1.27	4	9
Session 5 (*n* = 16)	7.3	1.20	5	10
Session 6 (*n* = 16)	7	1.50	5	9.5

ZORA should be used, combined and varied with other toys, materials, instruments or interventions to stay attractive over time.

Discussion and conclusion

The aim of this study was to explore the potential of a ZORA-based intervention for children with severe physical disabilities in rehabilitation and special education. The quantitative results of this study showed a positive contribution of ZORA towards achieving therapeutic and educational goals as measured with the IPPA. All of the established goals were in the domains stimulation of movement skills, communication skills and cognitive skills. On the basis of the goals established in the IPPA baseline form, we can conclude that in the field of rehabilitation and special education, play is being used to achieve therapeutic and educational goals (play-like activities), and not play for play's sake. Endeavouring for play for play's sake, on the basis of the ideas of the LUDI network, is an interesting concept (Besio *et al.*, 2017). LUDI comes from the Latin word ludi, which refers to play or games. The aim of this European leading network on the topic of play it is to increase attention to and awareness of the importance of play for play's sake, especially for children with disabilities. On the basis of the current arrangement of rehabilitation and special education in the Netherlands and the reporting duties in a goal-oriented way, it seems inconvenient to work with play for play's sake in this area. On a closer look at the playfulness score based on the professionals view, there is no clear increase or decrease of playfulness. This may indicate that sessions with ZORA were playful and did not become boring or less playful over time during the six sessions. The children indicated that they liked the sessions with ZORA almost all the time.

In the interviews, professionals also indicated that the three domains movement skills, communication skills and cognitive skills were the most promising for the application of ZORA interventions. They suggested that, overall, ZORA can contribute towards eliciting motivation, concentration, taking initiative and improving the attention span of the children. The qualitative results also showed positive results on the application of ZORA, and suggestions for further development and improvement of ZORA-based interventions were provided. Professionals prefer to alternate between ZORA and other materials because they expect that interest in ZORA will diminish over time. Usability of scanning the cards or using the sensors was sometimes hard or confusing, which should be improved in the future.

The number of participants in this study was sufficient to gain an idea of usability and feasibility aspects and to gather worthwhile insights on the application of ZORA. Compared with an earlier study with the IROMEC robot (Van den Heuvel *et al.*, 2016a), the sessions with ZORA were also highly dependent on the use of the robot by the professional and the professionals' creativity. This led to a high diversity in the robot sessions. Because this study was carried out in two organizations comparable with other rehabilitation and special education in the Netherlands, comparable results may have been found in other organizations in the Netherlands.

For future research, it is recommended to further focus on studying the application of ZORA in more detail. The present study was explorative and aimed to gather a first impression of the potential of ZORA, but for successful implementation of robots and ZORA in particular in daily practice, it is essential to gain more insight into for example: how should professionals apply ZORA, for which specific goals, for which children in particular, which different roles can ZORA play and also which conditions are necessary to be able to work with ZORA (independently)? Other relevant questions for further research are as follows: will ZORA be interesting over time or will children get used to it and will interest diminish?

Conclusion

It can be concluded that ZORA-based interventions have potential in rehabilitation and special education for children with severe physical disabilities (developmental age: 2–8 years). The most promising domains are the stimulation of movement and motor skills, communication skills and cognitive skills. More research is needed to gain insight into how ZORA can be best applied in rehabilitation and special education.

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Conflicts of interest

There are no conflicts of interest.

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