MASTER

Shall we play?

an exploratory research into motivational exercises with the ZORA robot for children with a physical disability

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SHALL WE PLAY?

An exploratory research into motivational exercises with the ZORA robot for children with a physical disability

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In partial fulfilment of the requirements for the degree of

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Abstract

The ability to play is important for every child's development, especially for enhancing motoric, social and cognitive skills. One of the concerns is that children with severe physical disabilities are often unable to play like their peers due to physical and cognitive limitations. Educators and therapists, like physiotherapists and speech therapists, use guided and structured interventions to stimulate children to play. More and more toys are being developed that specifically aim to support children in their play. Especially the upcoming field of robotics offers new possibilities. By using a robot as an educative tool, physically disabled children might be able to enhance their skills in a fun and motivating way. The aim of the study was to explore the usefulness for the ZORA robot to increase motivation during therapy sessions with physically disabled children. In previous studies the participants played with the ZORA robot in general and their responses were documented during a complete session or several sessions. The question arises whether the type of exercise influences the extent of a child's motivated to play. Leading to the following research question: Which category of exercises with the ZORA robot is most motivating for children with physical disabilities?

The effectiveness of four different exercise categories (Movement, Dance, Cognitive Skills and Robot Control) on improving the motivation to play was quantified experimentally during a field experiment. For every category, Motivation was evaluated as the average of Attention, Enjoyment and Participation. Each child played with the ZORA robot in six consecutive therapy sessions, either in a group or during individual sessions.

It was hypothesized the category Dance would show a higher level of Motivation in comparison to the Movement category because of the known positive influence of music on motivation (H1). Unexpectantly, our study showed a higher Participation level in the Movement category instead of the Dance category. It was expected that children would show a higher motivation for the Robot Control category because it gives them the freedom of making their own choices, rather than being told what to do (H2). The data confirmed this hypothesis, but mostly during individual sessions rather than group sessions. Lastly, one of the concerns was the long-term effectiveness of the robot because of the so called novelty-effect (H3), however the data did not show any significant differences between sessions over time. In addition to the hypotheses described above, other results have been found. Data analysis showed that the Movement and Dance categories are most motivating in a group, while Cognitive Skills and Robot Control are better suited for individual sessions. Gender and child specific preferences should be taken into account when defining what type of exercises to use, not everyone likes the same music and games.

The main question "Which category of exercises with the ZORA robot is most motivating for children with physical disabilities?" could be answered, but this does not have one simple answer. Specific exercises are useful for different settings and goals. Overall, this study showed that the type of exercises children play, influenced the motivation of the children. This means that use of the ZORA robot can greatly aid in the therapy for physically disabled children, though additional research may benefit the achieving of a broader range of predefined goals by the therapists.

Contents

1. Introduction

The ability to play is important for every child's development, especially for enhancing motoric, social and cognitive skills. Extensive research into the effects of play on children's development has been done (Dautenhahn, 2001; Besio, 2008). One of the concerns is that children with severe physical disabilities are often unable to play like their peers due to physical and cognitive limitations (Kolehmainen et al., 2011). Educators and therapists, like physiotherapists and speech therapists, use guided and structured interventions to stimulate children to play. These interventions are used to increase their cognitive, motoric and social skills.

What is Play?

Every child has the right to play according to the Convention on the Rights of the Child (1989). Playing is the natural way for children to learn skills in a casual way.

Everybody directly understands what is meant when a child says: "I like to play with my dolls" or "I played outside with my friend yesterday". Providing a definition of play is more difficult. Gavery (1990) describes play as follows:

"Most students of play would accept the following inventory:

1) *Play is pleasurable, enjoyable. Even when not actually accompanied by signs of mirth, it is still positively valued by the player.*
2) *Play has no extrinsic goals. Its motivations are intrinsic and serve no other objectives. In fact, it is more an enjoyment of means than an effort devoted to some particular end. In utilitarian terms, it is inherently unproductive.*
3) *Play is spontaneous and voluntary. It is not obligatory but is freely chosen by the player.*
4) *Play involves some active engagement on the part of the player."*

In other words, play is a voluntary activity and requires an active engagement of the child, without predetermined goals that have to be achieved.

Play for children with disabilities

For children with a physical disability it is often more difficult to participate in play in comparison with other children (Howard, 1996; Williams & Matesi, 1988). The ability to play is sometimes restricted in such a manner that these children prefer to watch other children play instead of actively engaging to play along.

Specialized therapists educate this group of children, mostly in specialised education institutes or during rehabilitation sessions. These therapists often use play during sessions. Unlike the normal games that children play, they use play to achieve predefined goals. This does not match the definition of play according to Gavery (1990). For this reason COST action LUDI (https://www.ludi-network.eu) has made a distinction between Play for Play's Sake and Play-Like Activities (Besio, et al, 2016). Play for Play's Sake follows the definition according to Gavery (1990). Play-Like activities have the same characteristics as Gavery's definition, with a few exceptions. Play-like activities are used in therapeutic sessions and during special education. As a result, there is an extrinsic motivation and predetermined goals.

Motivation

The motivation to engage in play and other childhood activities is central to the well-being and healthy development of young children. Within the International Classification of Functioning, Disability and Health (ICF), motivation is defined as a mental function that produces the incentive to act. It can be considered as an individual characteristic, which influences activity and participation outcomes, therefor also impacting body structures and functions (World Health Organisation, 2001). During play-like activities, an extrinsic motivational factor is provided by the therapist. However, better learning outcomes are achieved when children are intrinsically motivated through personal enjoyment, interest or pleasure (Lai, 2011).

Assessing motivation has several challenges, especially in children, mainly because motivation is not directly observable (Turner, 1995; Lai, 2011). Miller et al. (2014) conducted a systematic review regarding the measurement of motivation for children with a physical disability or motor delay. They noted that although there are many papers involving motivation in clinical studies, measurement of motivation is seldom performed. Motivation is frequently assessed using either self-report measures or rating scales completed by teachers or parents (Broussard & Garrison, 2004; Deci et al., 1999; Gottfried, 1990; Miller & Meece, 1997). According to Lai (2011), self-report measures of motivation often lead to generalized responses instead of responses related to the specific task at hand. Using self-report measures with children may be even less useful, since children have the tendency to report optimistic values.

One of the reviewed measures for motivation by Miller (2014) is the Paediatric Volitional Questionnaire (PVQ). PVQ is a 15 item play-based assessment of a child's motivational strengths and weaknesses and is based on the Model of Human Occupation (Kielhofner, 2002). In the Model of Human Occupation (Kielhofner, 2002) the motivation for occupation is explained by the construct of volition. Volition is described as thoughts and feelings about doing something and includes values, interests and personal causes. How motivated a person is, will be a combination of the volition of a person and the characteristics of the environment. Thus, volition conceptualizes motivation as a dynamic process involving person-environment interaction. Andersen (2005) used the PVQ in a study and stated that a child's motivation for activities like play and self-care is a function of both a child's volitional characteristics and environmental circumstances in which the child is doing something.

Since motivation is not directly assessable, the PVQ uses several indicators, for example "Stays Engaged", "Expresses mastery pleasure" and "Tries to solve problems". All of the items are scored by observers and ranges from 1 (Passive, child does not show behaviour) to 4 (Spontaneous, child shows behaviour without support, structure or stimulation). The PVQ is developed to use within a free-play situation, where children have the freedom to choose what they want to do and how to interact with the environment. During studies which uses structured play and play-like activities, instead of free-play situations, only a few items are useful to measure. These items are: "Stays engaged", "Expresses pleasure" and "Practice skills". Another way to measure motivation, is analysing micro-behaviours in children. Dautenhahn (2001) and Marti (2005) both describe a model where engagement is measured during therapy sessions with autistic children during interactions with a robot. The micro-behaviours resemble the same values as used in the PVQ. Examples of measured micro-behaviours are "Attention", "Emotional reactions" and "Posture control". Instead of rating the behaviours on a scale, the number of times a child shows the micro-behaviour is counted.

Tools and Toys

More and more toys are being developed that specifically aim to support children in their play. Especially the upcoming field of robotics offers new possibilities in the development of toys and new ways to play. 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.

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).

IROMEC

In November 2006, an international study called "Interactive RObotic social MEdiators as Companions" was launched to develop a robot aimed to improve play for children with physical disabilities (http://www.iromec.org). This resulted in the development of the IROMEC robot (Figure 1). The IROMEC robot is a mobile robot platform with two screens: a small screen displaying the face and a larger touchscreen on the back of the robot. Several different games and controls can be displayed on this touchscreen and is the main type of in- and output for the IROMEC robot. In addition, it has a number of infrared sensors to measure distances and three wireless buttons for the children to control the robot from a distance. The IROMEC robot has four predefined game scenarios. An overview of these scenarios can be found in appendix I List of IROMEC robot scenario's.

Several studies have been executed with the IROMEC robot (Klein et al., 2012; Heuvel et al., 2016a). The IROMEC showed promising results regarding stimulating play and reaching predefined goals set by the therapists during these studies. Although the results were promising, the IROMEC robot was not suitable for long-term use and the researchers and therapists faced some major drawbacks. The main drawback of the IROMEC is the availability. The IROMEC robot was developed for research purposes only and the development and maintenance stopped after the project ended. Production, maintenance and updates for the IROMEC robot have stopped since 2010. At this moment in time, there is only one working IROMEC robot left in the world.

Figure 1: IROMEC Robot

In addition to the fact that the IROMEC robot is no longer available, other shortcomings of the IROMEC robot have emerged during the study. One of the biggest problems reported by the therapists, was the fact that only the four pre-programmed games could be played and that no adjustments were possible. The appearance of the robot was not very appealing, he has been described several times as a moving printer and was very heavy to transport between locations. Furthermore, because the touchscreen was located on the back of the robot, some children were not able to control the robot without assistance. For example if a child was seated in a wheelchair or only able to crawl on the floor, it could not reach far enough to touch or even see the screen.

The ZORA robot

In order to continue the research, existing and commercially available platforms to stimulate children to play were investigated (Heuvel, 2016b). One of the investigated possibilities was the ZORA robot (https://www.zorarobotics.be).

At its core, the ZORA robot is actually a NAO robot produced by the company SoftBank (https: //www.ald.softbankrobotics.com). NAO is a humanoid robot of 57 cm high, with similar movement possibilities as a human being and has the ability to speak in multiple languages (Figure 2). In addition, the NAO has various sensors and cameras to be able to observe the surroundings. The Belgium company ZORA Robotics adapted the software from the NAO in cooperation with Softbanks and called the combination of this hard- and software the ZORA robot. The software has been adapted specifically for the healthcare sector and ensures that the ZORA robot can be controlled remotely from a tablet or laptop. The software environment is user-friendly, so that it can be operated by care providers (such as therapists and nurses).

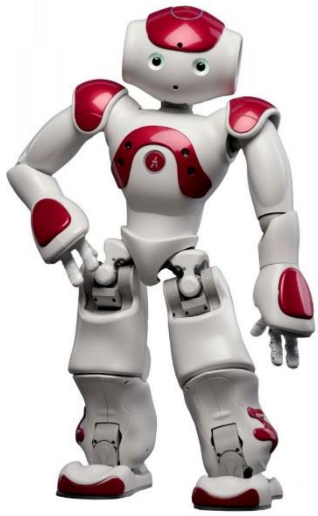

Figure 2: The ZORA Robot

The software contains a large number of different games and songs that are included with the ZORA robot and the collection is regularly updated and expanded by ZORA Robotics. In addition, adjustments can be made on the existing games. This includes for example adjusting the number of rounds to be played for a quiz game. For a more advanced user, the NAO Choregraphe software offers the possibility to create entirely new games and dances, which can be uploaded to the ZORA robot. This flexible setup and a good maintenance service makes the ZORA robot a good alternative for the IROMEC robot.

In the past years, the use of the ZORA robot has increased in the rehabilitation and care sector. Studies carried out with the ZORA robot or the original NAO in elderly care aimed to support and motivate elderly individuals to perform movement exercises (Görer et al., 2016). In an intervention program for children with autism spectrum disorder, NAO was used to stimulate communication (Shamsuddin 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 these scientific studies with ZORA or NAO in different healthcare sectors, attention towards the ZORA robot 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-like activities in therapy and special education. The current possibilities of the robot seem to be meaningful to explore its potential further in this area.

Present Study

This study is conducted at the research group Assistive Technology in Healthcare of Zuyd university of applied science and is linked with Social Robotics in Care (RAAK-PRO, grant number 4-10), especially with the PhD project "The next generation of Play" by Heuvel. Previous research and findings from the PhD project are used as a base for this study.

By using a robot as an educative tool, physically disabled children might be able to enhance their skills in a fun and motivating way. In previous studies the participants played with the ZORA robot in general and their responses were documented during a complete session or several sessions. When playing with the ZORA robot, it is noticeable that the participants are not responding the same way when playing different games or exercises. The question arises if the type of exercises is causing children to be less or more motivated to play. According to Anderson (2005), motivation is not only a personal trait, but also depends on the environment and the activities at that moment. With this study, research was done to assess whether the motivation of physically disabled children depends on the type of exercises that are played. Leading to the following research question: **Which category of exercises with the ZORA robot is most motivating for children with physical disabilities?**

During earlier studies with IROMEC, Heuvel (2017) conducted research into goals therapist set for the children and how the IROMEC robot could aid to accomplish these goals. The goals were based on the International Classification of Functioning, Disability and Health for Children and Youth (ICF-CY) domains, which are commonly used in special education. The domains were split into several areas, for example Movement functions, Learning an applying knowledge and Communication. After switching to the ZORA robot, the list of goals set earlier were re-examined with the researchers and the therapists to define goals which could be accomplished with the ZORA robot.
The exercise possibilities of the ZORA robot can be divided into difference groups. On one hand, ZORA offers physical exercises that can enhance motor skills in children. On the other hand, exercises are available to train cognitive abilities and communication. For physical activities, ZORA provides movement exercises and dance exercises, therefore this distinction is also used as different categories (Movement and Dance). Within the mental exercises, a division is less obvious. Two categories are selected to enhance cognitive skills, each using different ICF-CY domains. While the Cognitive Skill category contains exercises which lead to enhancing communication and concentration, the Robot Control category focuses on self-care and taking initiative by letting the child(ren) control their own and the robots actions.

1. Movement
   Exercises in which the children imitated the actions and poses of the ZORA robot without music. The ZORA robot either showed the pose and the children had to mimic it, or the ZORA robot gave instructions and performed the exercise along with the children.
2. Dance
   The children imitated the robot's movement guided by music. In some cases the exercise was accompanied with clear movement instructions, for example with the song "Head, shoulders, knees and toes". Another type of dance exercises aimed to activate children to dance along freely, for example with "Gangnam style".

3. Cognitive Skills
   Exercises focussed on improving cognitive skills by responding correctly to the questions the ZORA robot asked. Examples of these exercises were QR quizzes, where children needed to reply by showing the correct card (recognized by the ZORA robot through a QR code), or exercises where the children needed to touch ZORA on the indicated body part (e.g. “Touch my foot”).
4. Robot Control
   This category contained action-reaction type of exercises. The children were in control of the actions the ZORA robot performed by, for example, shouting “sit” and “step” or choose an action the robot performed by touching one of the robots sensors.

A full list of exercises for each category can be found in appendix II List of ZORA exercises.

The effectiveness of the different exercise categories on improving the motivation to play was quantified experimentally during a field experiment. For every category, Motivation was evaluated as a combination of Attention, Enjoyment and Participation.

Hypotheses

(H1) Exercises in the Dance category combined movement with music. Accompanying movements with music is known to have a positive influence on motivation. Gold (2004) examined the overall efficacy of music therapy for children and youth with psychopathology. The use of music had a positive effect on the participants and recommended for clinical use. Boldt (1996) investigated the influence of music on the willingness to participate during therapy sessions with bone marrow transplant patients. The study showed an increase in endurance during music sessions, participants were more motivated to go the extra mile and participated better. Therefore we expected the Dance category to show higher levels of enjoyment and participation in comparison with the Movement category.

(H2) In comparison with able bodied children, children with disabilities are more often not given the chance to choose what they want to do (Elliott, 2016). Research done by Lai (2011) gave students in a classroom more autonomy over their own learning by allowing them to make choice regarding assessment activities. The freedom to choose increased to motivation to complete tasks. Similarly, Turner (1995) noted that when teachers allow students to make decisions about their own work, students are more likely to be interested in the work. Students who are given choices tend to exhibit more persistence, goal setting, and other self-regulated learning behaviours. With the Robot Control exercises, the children were in control of the ZORA robot, which gave them the freedom to make their own choices. Therefore we expected children to participate better with Robot Control exercises than other exercise categories.

(H3) It is known that people’s enjoyment of games and toys wears off with time (novelty effect). Therefore we expected that the motivation for the ZORA robot would decrease over time.

To test the hypotheses described above, a field experiment was conducted between October 2016 and December 2016. The experiment consisted of several sessions, in which the therapist instructed children to perform various exercises with the ZORA robot.

2. Method

Design

The main goal of this study was to determine whether the ZORA robot was able to contribute to a child's motivation to play.

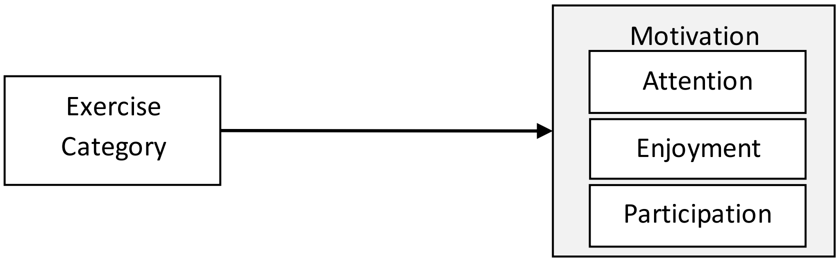

Figure 3: Overview of DV and IV

In this study a field experiment was conducted to determine the effect for different exercise categories (Movement, Dance, Cognitive Skills and Robot Control) on Motivation. Motivation is not directly observable (Turner 1995; Lai, 2011; Miller, 2014) and is therefore measured with underlying variables. For every category, Motivation was evaluated as a combination of Attention, Enjoyment and Participation (Figure 3). The variables were developed based on research by Marti (2005) and the Paediatric Volitional Questionnaire (PVQ; Kielhofner, 2002). Marti (2005) describes micro-behaviours with which can be measured how a child responds to a robot in two areas: physical-functional and engagement area. The micro-behaviours for the engagement area are comparable in this current study. In this area, there are different ways to determine engagement by looking at the reaction of the child, for example gazing at the robot and smiling / laughing. Deci (1999) also used behavioural indicators of motivation. For example, they used free-choice persistence, which is typically a measure of the amount of time spent on an activity. The PVQ is developed to use during free-play activities and measures volition with 15 different items, based on ratings from observers. Since this study used play-like activities instead of free-play, not every behaviour was shown. Combining the micro-behaviours from Marti (2005) with the items in the PVQ, the variables Attention and Enjoyment are selected for this study, other behaviours (like crying and tries to solve problems) were not expected and therefore not used.

From interviews and focus group sessions with therapists and educators, performed by Heuvel (2016a), participation during the exercises was considered as an important factor to improve the skills of the children and reaching the therapy goals. This matches Gavery's definition of play (1990), which states an active engagement of the child is one of the conditions for play. Therefore the variable Participation has been added as a third variable, so measure whether the children are motivated enough to actively participate instead of just observing.

Attention was measured based on the number of seconds that a child focuses on the robot. As soon as a child walks away or looks at something else, the timer was stopped. This resulted in a number of seconds of attention per child per exercise and was rescaled to a value between 0 and 1 (seconds attention / total number of seconds). Both Participation and Enjoyment of an exercise were subjective values between 1 (very bad) and 5 (excellent). Enjoyment was indirectly assessed by judging facial expressions and body language (enjoyment vs boredom), the eagerness to participate and the enthusiasm while performing the exercises. Participation was the willingness to participate in an exercise. If a child only participated after the therapists encouragement, the score was decreased.

For all parameters, scores were rescaled to ensure comparability between the scales. To this end, Enjoyment and Participation values were divided by 5 to obtain a 0-1 scale. In our current study, we defined Motivation as being composed of equal parts of Attention, Enjoyment and Participation. The variable of Motivation is therefore the average the scores obtained for Attention, Enjoyment and Participation.

Participants

The experiment was conducted in a school for special education. Children were selected based on the following inclusion criteria: disabilities due to cerebral palsy or acquired brain injury, cognitive age between approximately 2 and 8 years, chronological age between 2 and 20 years and a stable cardiopulmonary status. Applied exclusion criteria were: epilepsy, deafness, blindness and severe aggressive behaviour. Selected children were approached through the therapist or special educators at the selected institution and were only enrolled in the study after the parents given their consent.

10 children in total were included in the study, of which six girls. While the chronological age ranged from 11 to 18 years, their cognitive ages ranged between 2 and 8 years. The physical disability of the children was mild (Gross Motor Function Classification level II (Palisano et al., 2007)) and all children were able to walk. The children were already in therapy before the start of the study, either in group sessions or individually. To reduce the interference with their treatment, the groups were not rearranged for this study. The characteristics of the children and their grouping is included in Table 1. Due to illness or other reasons, some children missed one or two sessions. Only children who attended at least four sessions were included in the study. Child F did not attend because of long term illness.

Table 1: Characteristics of the children

Child	Chronological age (months)	Sex	Group
A	139	Female	Individual
B	150	Male	Individual
C	186	Male	Group
D	164	Male	Group
E	211	Male	Group
G	222	Female	Group
H	207	Female	Group
I	176	Female	Group
J	185	Female	Group
K	198	Female	Group

Experimental Setup

Two group sessions of four children each and two individual sessions were held at a special education facility for children with multiple disabilities. A deliberate choice was made to carry out a field experiment, instead of an experiment in a controlled environment. The children did not have to go to an unfamiliar research environment, but were able to stay in their own school with their own therapists and in their own daily rhythm. The only new element for them was the ZORA robot.

The group sessions were located in an empty room with only mats for the children to stand upon. The individual sessions were held in a room with a desk and some empty space. Each session was filmed from two different angles, with written consent from the parents. Prior to the sessions, the accompanying therapists and researches discussed the different possibilities with the ZORA robot.

Figure 4: Experiment room for a) individual sessions and b) group sessions

Procedure

Every child participated in a minimum of four and a maximum of six sessions. These sessions took place six consecutive weeks, at the same day and time in the week. Each session lasted about 30 minutes, with the first five minutes being spent on entering and welcoming the robot. After each session, the children went back to their own classroom.

During the sessions, the therapists indicated which exercises should be started at that moment. The researcher(s) then started the requested exercise, this was not done by the therapists. The exercises were mostly executed autonomously by the ZORA robot. A number of exercises (including “Step, stop, stand” and “Imitate positions”) were performed using the Wizard of Oz technique, where the researchers changed the robots position. In some cases, the children themselves made a request for a particular exercise or song (for example “Gangnam Style”), which was usually granted.

For each session was noted which exercises have been played and to which category these exercises belonged. During video analysis, every exercise was timed to see how many seconds it lasted in total. Most exercises were variable in length and therefore varied each time. The start of an exercise was marked by the robot getting up. The end of an exercise was marked as the moment the ZORA robot sat down in its resting position (crouched). All data was extracted afterwards based on the videos and not during the sessions themselves. Due to the flexible setup of the sessions, a different amount of data is available for each category.

3. Results

To investigate which category of exercises (Movement, Dance, Cognitive Skills or Robot Control) with the ZORA robot is most motivating for children with physical disabilities, we first assessed the global variable of Motivation between the categories. Because the Motivation variable is a combination of the parameters Attention, Enjoyment and Participation, these parameters were thereafter analysed individually to obtain a more detailed understanding and the opportunity to gain insight to improve therapeutic sessions with the ZORA robot.

Descriptive Statistics

317 valid entries are reported and used for the analysis, without missing values. Each entry contains the following data: Name of the exercise; the child that participated; gender; group or individual session; number of the session; category of the exercise and scores for Motivation, Attention, Enjoyment and Participation (Table 2). A complete overview of the descriptive statistics per variable can be found in appendix III Frequency Statistics.

Table 2: Overview of data

Data	Specifics
Exercise	30 different exercises
Kid	A – K (excluded F)
Gender	Male (n=4; entries=123)/ Female (n=6; entries=194)
Group	Individual (n=2; entries=55)/ Group (n=8; entries=262)
Session	1 – 6
Category	Movement (entries=61) / Dance (entries =147) / Cognitive Skills (entries =50) / Robot Control (entries =59)
Motivation	Lower bound = 0.14 – Upper bound = 0.95
Attention	Lower bound = 0.01 – Upper bound = 1.00
Enjoyment	Lower bound = 0.20 – Upper bound = 1.00
Participation	Lower bound = 0.20 – Upper bound = 1.00

Analysis of Motivation

In our current study, we define Motivation as being composed of equal parts of Attention, Enjoyment and Participation. To this end, the variable of Motivation is the average scores obtained for Attention, Enjoyment and Participation.

To analyse whether the three variables measure the same construct, Cronbach's Alpha was assessed, which was 0.37. The variable Attention showed a very low Item-Total correlation (0.013) and also had a low inter-item correlation with Enjoyment (0.010) and Participation (0.012). Therefore the variable Attention was deleted before calculating Motivation. After discarding the Attention variable, Cronbach's Alpha was raised to 0.60. This value was considered acceptable for this study, though lower than desired. The low value was possibly due to the small number of variables remaining to calculate Motivation. For the remainder of the analysis, only the variables Enjoyment and Participation were used to calculate Motivation.

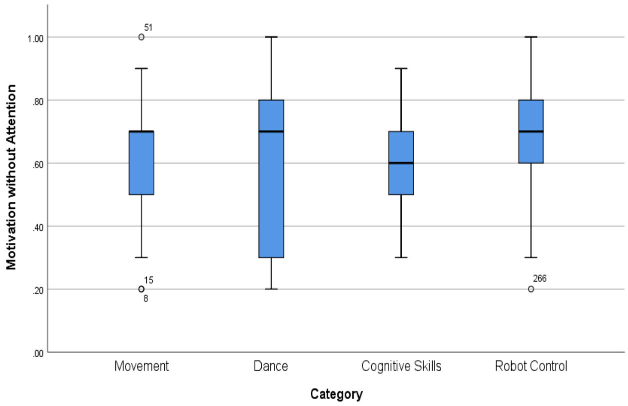

Figure 5: Boxplot Motivation per category

Overall comparison of Motivation scores between the categories using an ANOVA, resulted in a significant difference (ANOVA, F(3,313)=2.882, p=0.036, R^2=0.027). Significant effects were found between Robot Control and Cognitive Skills (Post hoc Games-Howell, p=0.008) and between Robot Control and Dance (Post hoc Games-Howell, p=0.027). Both the Cognitive Skills (M=0.5780, SD=0.12824) and Dance (M=0.5857, SD=0.25589) categories are scoring less motivating than Robot Control (M=0.6729, SD=0.17304). Figure 5 shows a higher variance for Movement and Dance as compared to Cognitive Skills and Robot Control. The variance suggests a difference in factors influencing the Motivation scores. Therefore, separate analyses were carried out in order to identify these influencing factors.

Influencing factors for Motivation

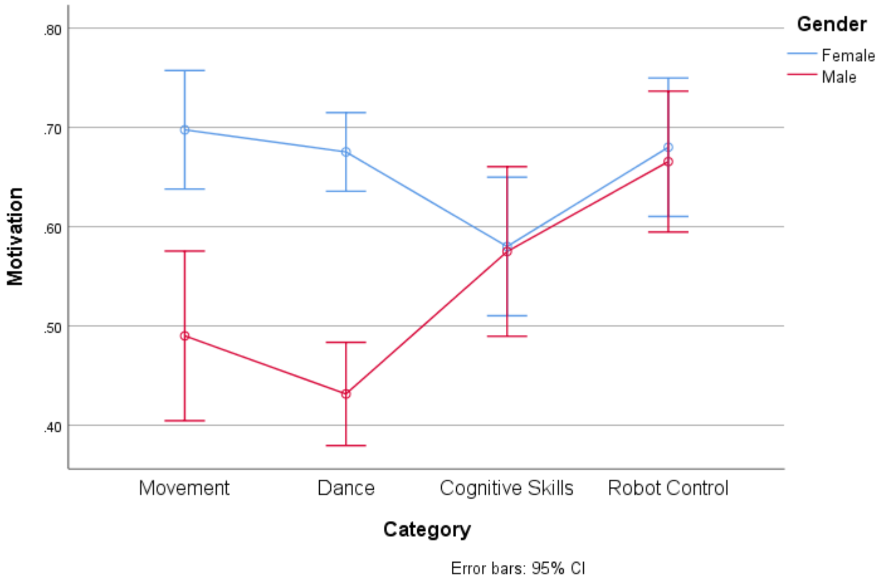

Figure 6: Gender differences for Motivation per category

Figure 6 suggests a difference based on gender. An ANOVA (F(3,309)=7.664, p<0.001, R^2=0.205) showed an interaction effect between category and gender, therefore, the gender effect is tested separately for each category.

Table 3: Mean and standard deviation per category per gender

Gender	Movement		Dance		Cognitive Skills		Robot Control	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Female	0.6976	0.15246	0.6753	0.21951	0.5800	0.12429	0.6800	0.02218
Male	0.4900	0.18610	0.4315	0.24171	0.5750	0.13717	0.6655	0.04010

For the categories Movement (Student's T-test, $t(61)=4.329$, $p<0.001$) and Dance (Student's T-test, $t(147)=6.095$, $p<0.001$), females are displaying higher Motivation scores than males in both categories (Table 3). On the other hand, the categories Cognitive Skills (Student's T-test, $t(50)=0.134$, $p=0.984$) and Robot Control (Student's T-test, $t(59)=0.316$, $p=0.753$) were not significantly influenced by differences in gender.

The influence of group composition on Motivation is analysed using an ANOVA. An interaction effect is found between categories and group composition ($F(7,309)=6.911$, $p<0.001$, $R^2=0.119$), therefore, the effect of group composition is tested separately for each category. The Movement (Student's T-test, $t(61)=-1.299$, $p=0.399$), Cognitive Skills (Student's T-test, $t(50)=-1.791$, $p=0.080$) and Robot Control (Student's T-test, $t(59)=1.832$, $p=0.072$) categories are not influenced by group composition. The Dance (Student's T-test, $t(147)=-5.974$, $p<0.001$, $d=1.1557$) category did show a significant effect of group composition, where the Motivation score was higher in a group (M=0.6242, SD=0.25162) compared to individual sessions (M=0.3783, SD=0.16502).

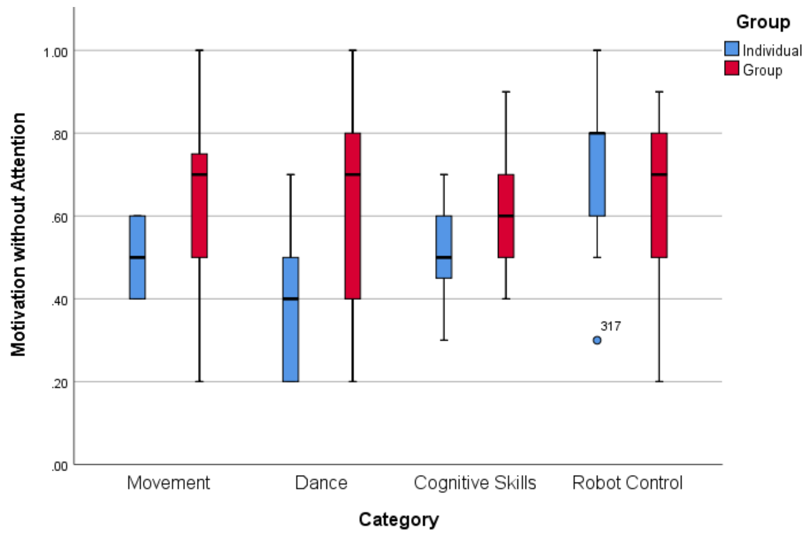

Figure 7: Boxplot of Motivation by group per category

Furthermore, we assessed whether the variance between categories could be due to motivation changes over time. However, no significant differences for Motivation scores were found between sessions (ANOVA, $F(5,293)=0.365$, $p=0.872$, $R^2=0.068$).

Analysis of individual variables Attention, Enjoyment and Participation

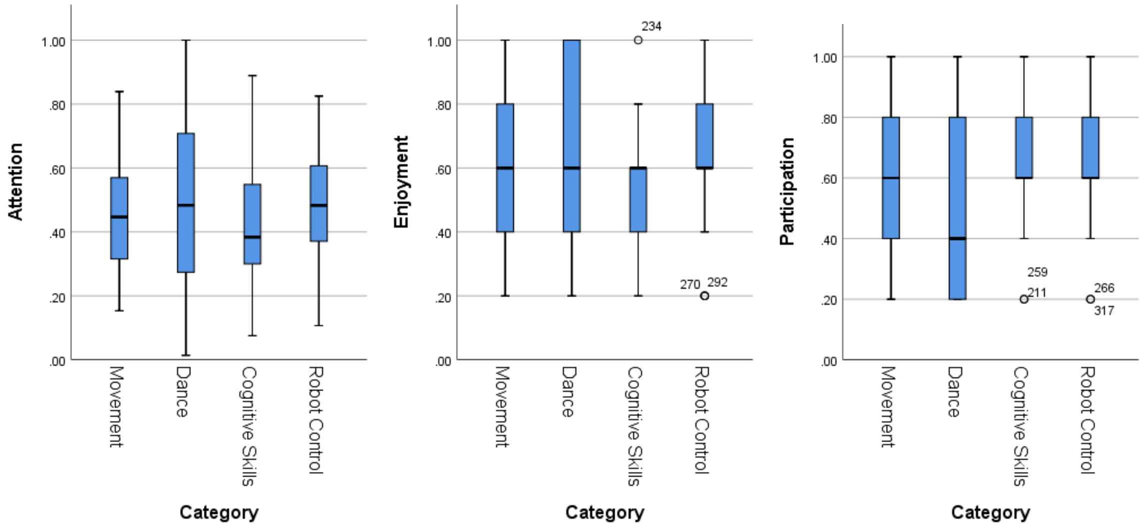

Figure 8: Boxplots per category for a) Attention, b) Enjoyment and c) Participation

Analysis to determine influencing factors continues with more detailed analysis of the individual parameters Attention, Enjoyment and Participation in order to unravel the best application of different exercises with the ZORA robot during therapeutic sessions. Overall comparison for each variable shows a significant difference between categories for the variables Enjoyment (ANOVA, $F(3,316)=3.355$, $p=0.019$) and Participation (ANOVA, $F(3,316)=7.811$, $p<0.001$). Attention scores did not differ between the categories (ANOVA, $F(3,316)=1.416$, $p=0.238$).

Post hoc comparisons for Enjoyment showed a significant difference between Dance and Cognitive Skills ($p=0.027$) and between Cognitive Skills and Robot Control ($p=0.037$). For Participation there was a significant difference between Movement and Dance ($p=0.004$) and between Dance and Robot Control ($p<0.001$).

Attention

The variable Attention was assessed for influencing factors. Like the overall analysis, Attention scores for the categories were not significantly influenced by differences in gender (ANOVA, $F(7,309)=0.033$, $p=0.856$), group composition (ANOVA, $F(7,309)=0.516$, $p=0.473$) or between the sessions over time (ANOVA, $F(23,293)=0.815$, $p=0.540$). In combination with a low item-total correlation, measuring the attention in this manner was not suitable for determining motivation.

Enjoyment

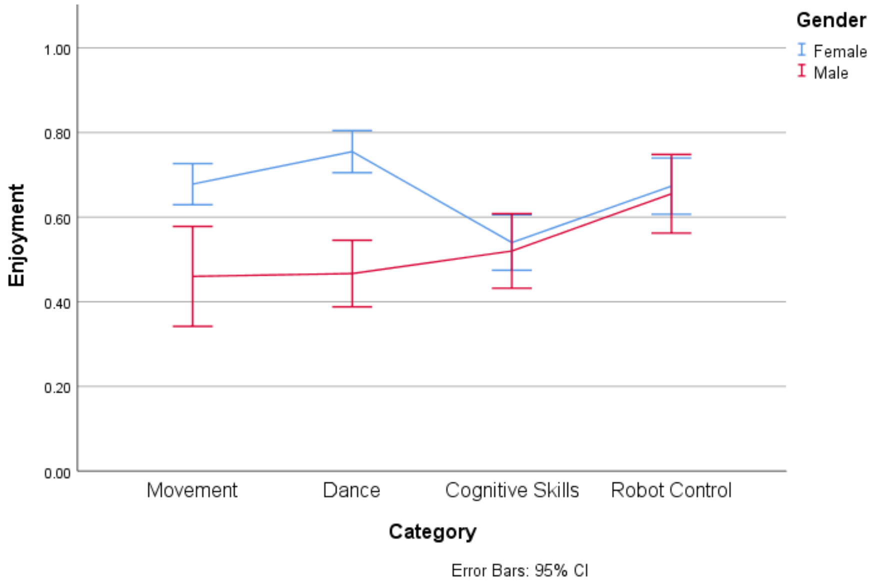

Figure 9: Gender differences for Enjoyment per category

An ANOVA ($F(3,313)=20.167$, $p<0.001$) showed an interaction effect between category and gender, therefore the gender effect is tested separately for each category. Figure 9 and Student's T-tests confirmed a large difference based on gender for the Movement ($t(61)=3.557$, $p=0.001$) and Dance ($t(147)=6.193$, $p<0.001$) categories, in which females seemed to enjoy the exercises more than males (Table 4). Both the Cognitive Skills ($t(50)=0.378$, $p=0.707$) and Robot Control ($t(59)=0.325$, $p=0.746$) categories did not show this difference.

Table 4: Mean and standard deviation per category per gender

Gender	Movement		Dance		Cognitive Skills		Robot Control	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Female	0.6780	0.15413	0.7548	0.24161	0.5400	0.17538	0.6733	0.17798
Male	0.4600	0.25215	0.4667	0.28813	0.5200	0.18806	0.6552	0.24434

The influence of group composition was tested separately due to an interaction effect with category (ANOVA, $F(3,309)=3.058$, $p=0.29$). In the separate comparisons, an effect was found for the categories Dance ($t(147)=4.522$, $p=0.001$) and Cognitive Skills ($t(50)=-2.617$, $p=0.015$). In both categories, the exercises were more enjoyed in a group (Table 5).

Table 5: Mean and standard deviation per category per group composition

Group composition	Movement		Dance		Cognitive Skills		Robot Control	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Individual	0.7000	0.14142	0.4783	0.23151	0.4364	0.12060	0.6947	0.19285
Group	0.6034	0.21812	0.6806	0.29403	0.5590	0.18456	0.6500	0.22072

Enjoyment scores did not change significantly over time (ANOVA, $F(23,293)=0.978$, $p=0.784$).

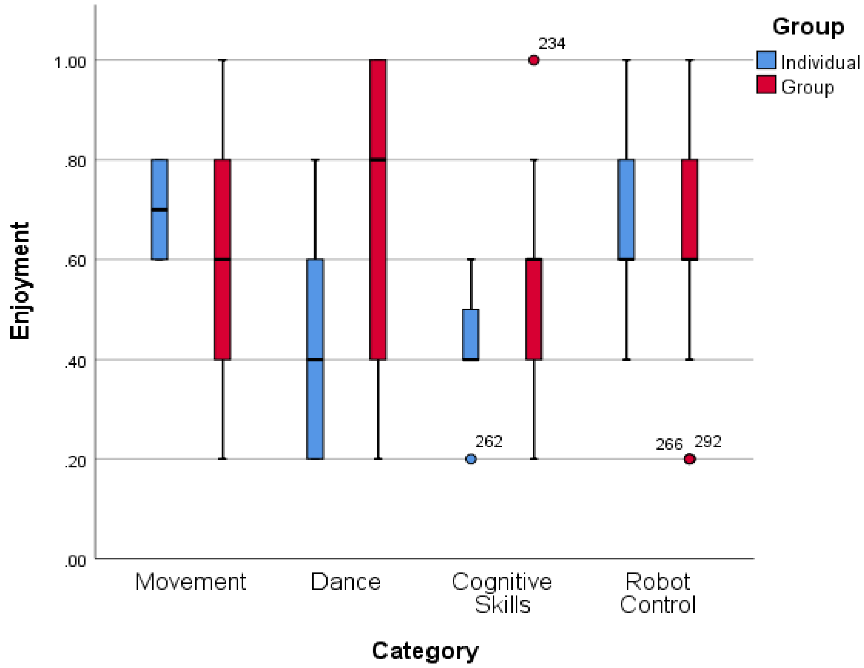

Figure 10: Boxplot of Enjoyment by group per category

Participation

Analysis of influencing factors for Participation scores resulted in highly similar findings to influencing factors for Motivation scores (Figure 11). Like other variables, an interaction effect for gender was found (ANOVA, $F(7,309)=3.925$, $p=0.009$). Only Participation scores of the categories Movement ($t(61)=3.132$, $p=0.003$) and Dance ($t(147)=4.522$, $p<0.001$) were significantly influenced based on gender, with females displaying higher Participation scores than males (Table 6).

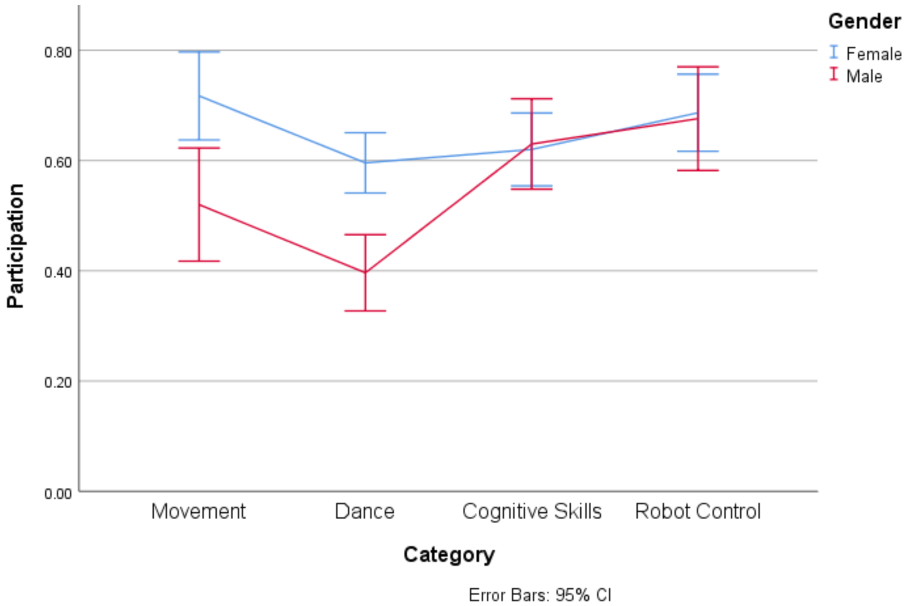

Figure 11: Gender differences for Participation per category

Table 6: Mean and standard deviation per category per gender

Gender	Movement		Dance		Cognitive Skills		Robot Control	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Female	0.7171	0.25289	0.5957	0.26536	0.6200	0.17695	0.6867	0.18705
Male	0.5200	0.21909	0.3963	0.25325	0.6300	0.17502	0.6759	0.24735

Also group composition influenced Participation scores with an interaction effect (ANOVA 3,309)=9.116, p<0.001). Simple tests for group composition for each category showed a significant difference for Dance (t(147)=4.522, p<0.001) and Robot Control (t(59)=2.120, p=0.042). In the Dance category, the children participated better during group sessions (M=0.5677, SD=0.27395) in comparison with individual sessions (M=0.2783, SD=0.13128). For the Robot Control category, the children participated better during individual sessions (M=0.7684, SD=0.22374) than during group sessions (M=0.6400, SD=0.20356). Furthermore, the individual sessions did not significantly differ over time for any of the categories (ANOVA, F(23,293)=0.361, p=0.875).

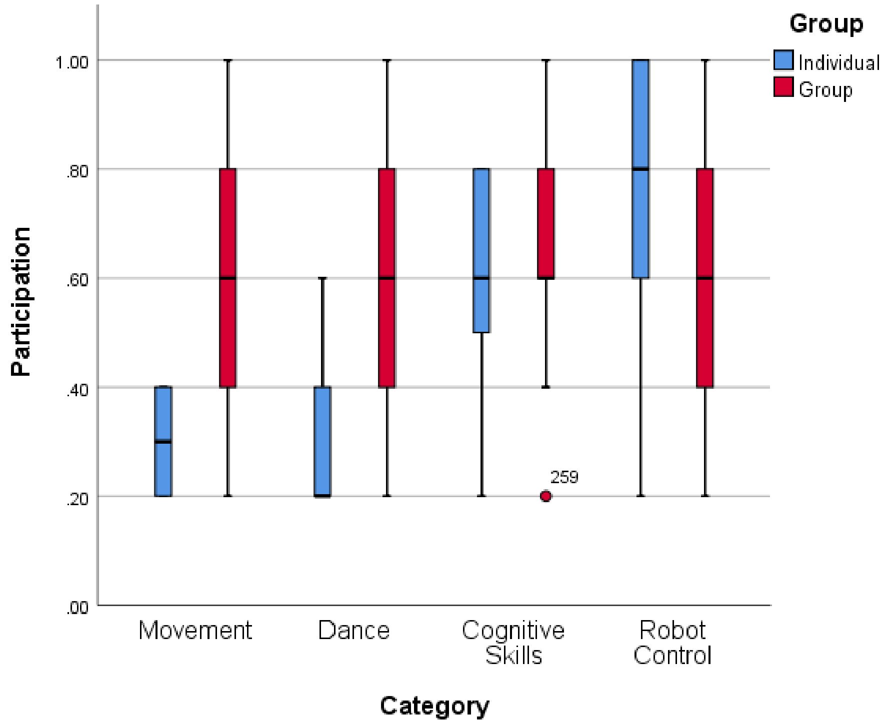

Figure 12: Boxplot of Participation by group per category

4. Discussion

The aim of the study was to explore the usefulness for the ZORA robot to increase motivation during therapy sessions with physically disabled children. In order to determine the level of Motivation of the children, Attention, Enjoyment and Participation were measured in four exercise categories (Movement, Dance, Cognitive Skills and Robot Control).

A deliberate choice was made to carry out a field experiment, instead of an experiment in a controlled environment. Previous studies (Tieman, 2004; Razak, 2010) show children perform better in their familiar environment and a field experiment is more suitable for understanding children's experience and interaction with technology. In the present study, the children did not have to go to an unfamiliar research environment, but were able to stay in their own school with their own therapists and in their own daily rhythm. The only new element for them was the ZORA robot. The field experiment was also preferred by the therapists. They were able to see the robot within the school and are now able to use the ZORA robot during the therapy sessions, after some training on how to operate the robot.

Six consecutive therapy sessions were held with the ZORA robot, either in a group (four children per group, two groups) or individual sessions (two children). The children performed different exercises, selected by the therapist during the sessions. Sessions were recorded and analysed afterwards. Attention was measured by timing the seconds the child looked at the robot, Enjoyment and Participation were defined as a 5-point Likert-scale (1: Very poor, 5: Excellent). Initially, Motivation was defined as the average of the three former variables. However, Cronbach's Alpha indicated that Attention was not measuring the same construct. Therefore, this variable was discarded for the calculation of Motivation and was analysed only as an independent variable.

It was hypothesized the category Dance would show a higher level of Motivation in comparison to the Movement category (H1). Previous studies showed that people were more motivated and participated better when accompanied by music (Boldt, 1996; Gold, 2004). Although previous studies showed positive effects of music on motivation, in this study the overall score for Motivation and the separate variables Attention and Enjoyment did not show significant differences between the Movement and Dance categories. There was however a significant difference found in Participation (Post hoc comparison Games-Howell, $p=0.008$) between Movement and Dance. Unexpectantly, our study showed a higher Participation level in de Movement category ($M=0.6525$, $SD=0.25794$) instead of the Dance category ($M=0.5224$, $SD=0.27741$). This might be explained by difference in the exercises that were played. In the Movement category, the children are guided in their movement, because the robot told and/or showed them what move to perform. In the Dance category, the children are inspired to move along with the robot, but no clear movement instructions were given. The level of Attention towards the robot was higher in de Dance category. This was partially due to some children not participating themselves, but only looking at how the robot was dancing. This is in agreement with findings according to Howard (1996), who states that children with a physical disability more often watch other children play instead of actively engage in play themselves. Another explanation might be that the children were having difficulties with imagining movements by themselves. This may have been a pitfall for the disabled children within our study, because coming up with own moves, may be hampered by their cognitive limitations (Kolehmainen, 2011) and goes against their passive nature (Behnke, 1984).

A possible solution to avoid this problem is using music that uses specific dance moves. This could be existing music the children already know, like the macarena or "head, shoulders, knees and toes", but it might also be possible to create dances with a clear and easy to learn choreography. The song "head, shoulders, knees and toes" was already included and played a few times. It was noticeable that the children needed some practice before they were able to actually dance along with the robot. This is also compliant with Gallager (1984), who showed active rehearsal is of great importance to young children, but the quality of rehearsal is important. The children should be guided in learning the moves, before they are able to follow the ZORA robot on their own. The ZORA robot could have the possibilities to teach the dance moves step by step until each child can dance along, but these training exercises are not available yet and will take time and effort to create. Even after these exercises are created, it might be necessary for the therapists to help and guide the children in this learning process. So next to using known music and dances, practice and repetition also seems to enhance the capability for the children to participate better.

For both Movement and Dance, gender played an important role. This is compliant with other research. Biddle (1985) for example describes clear gender differences for physical activities. Girls have a higher preference for non-competitive dance-related exercises. Boys on the other hand, show a higher motivation when they are able to engage in a (friendly) competition. The data in our study indeed showed girls were more motivated, seemed to enjoy Dance exercises more and participated better compared to boys. Boys might respond better to more sportive / "boot camp"-like exercises, where they are able to compete with other children. Furthermore, the Dance category is better suited for group sessions compared to individual sessions, suggesting that the children might also be motivated by each other and not only by the robot. This might be due to the more social aspect of the dance exercises.

It was expected children would show a higher motivation for the Robot Control category because it gives them the freedom of making their own choices, rather than being told what to do (Elliott, 2016) (H2). Lai (2011) and Turner (1995) described a positive effect on motivation to complete tasks when students are allowed to make their own decisions about the activities. The same effect is also reflected by the data in this study. The overall Motivation was highest for the Robot Control category, indicating that the children benefit from being able to make their own decisions. In the current study, the therapists made the decision which exercises were played and when. In follow-up research, the freedom for the children to make their own choices, could also be extended by letting the children decide which exercise they want to do. The Robot Control category is especially effective for individual sessions, when a child is able to control the robot on its own, without taking into account the wishes and preferences of other children. The waiting time in between actions for the children in group sessions seemed to cause a drop in participation during group sessions. Only one child at a time is able to interact with the ZORA robot, while other children had to wait until it was their turn to give the robot a command. The waiting time is not present during individual sessions.

A new toy is always exciting, but the fun could be over after playing with it for a while. Before the start of the study, one of the concerns was the long-term effectiveness of the robot because of the so called novelty-effect (H3). Looking at the Motivation over time, there was no significant difference found between sessions. In the first sessions, when everything was new, we indeed saw the children being excited and motivated to play. However, also some hesitation in some of the children was observed because they did not know what to expect from the robot and what was expected from them. After a few sessions, the children still participated with the same level of motivation.

We noticed the children became more active during the exercises in later sessions. Although no significant difference was found in the data, most of the children appeared more motivated during the last sessions. In these sessions, the exercises were not new anymore, but because the exercises were familiar for the children and they knew what was expected from them, it was more fun. The children even started to request some of the songs and exercises they really liked. One of the children did show signs of boredom during the last sessions. This might be because the exercises became too familiar and did not challenge this child anymore. Research by Abuhamdeh (2011) showed a strong relation between challenge and enjoyment, indicating that the exercises should be challenging enough for participants to stay motivated, without making the exercises too difficult to complete. With individual sessions, the therapist should consider the level of difficulty for per child in order to keep them challenged and motivated.

Overall the exercises were well received by the children and therapists. Linked to this research, interviews with the therapists were held after the last session, assessing the usefulness of the ZORA robot for different disciplines (Heuvel, 2017). The speech therapist was enthusiastic about the robot, but the speech and pronunciation goals could not be achieved using the exercises played with the ZORA robot. Although the ZORA robot is able to speak and recognize several languages, speech and pronunciation is not the main option of the ZORA robot. The physiotherapists on the other hand, did see useful applications for the ZORA robot during therapy sessions and were positively surprised by the children's activities. They saw several different opportunities how to use the ZORA robot they did not deemed possible at the start of the experiment. If the ZORA robot will be used regularly during sessions, the number of exercises and songs should be expanded and have more variety. Some of the songs should be adapted for different target groups and different levels of difficulty. For example, the current version of "head, shoulders, knees and toes" is very slow and was not very appealing to the children participating in this study, but was well received during sessions with younger children at another school (Heuvel, 2016b). Also additional themes could be added to the exercises, fitting for the seasons of the year or festivities like "carnaval" and Christmas.

Some difficulties were encountered during the execution of the experiment. The variables are difficult to measure objectively. For example, not every child shows enjoyment with a smile or enthusiastic gestures, but a person can tell he/she is enjoying the exercise. The use of multiple observers is advised in order to get a more objective rating. In this study, only a limited amount of data was checked for inter-rater reliability, but it was considered sufficient to continue the complete set by the main researcher. Most difficulties were experienced with the measurement of Attention. Data processing was a highly time-consuming activity which is not suitable for a large number of participants. Because the Attention variable did not show any significant differences and did not measure the same construct as the other variables, it is not a discriminating factor when measured in this particular way. Attention is therefore not advised to be used as an indicator for Motivation in future studies. In hindsight, this study could have benefitted from the addition of more items to measure motivation to get a better understanding of the underlying factors that cause a category to be more or less motivating than others. The PVQ (Kielhofner, 2002) is a starting point for measuring motivation. In order to make a good use of all the items in this questionnaire, the setup should be adapted to include the ability for children to show more problem-solving skills and the freedom to try new things.

In summary we are able to answer the main question: "Which category of exercises with the ZORA robot is most motivating for children with physical disabilities?", but this does not have one simple answer. As stated before, different exercises are useful for different settings and goals. The Movement and Dance category are most motivating in a group, while Cognitive Skills and Robot Control are better suited for individual sessions. Also gender and child specific preferences should be taken into account, because not everyone likes the same music and games. Overall, this study showed that the type of exercises children play, influenced the motivation of the children. This means that use of the ZORA robot can greatly aid in the therapy for physically disabled children, though additional research may benefit the achieving of a broader range of predefined goals by the therapists.

One thing that needs to be emphasized, is that the ZORA robot will not replace an actual therapist. The therapist will still play an important role in guiding the children during sessions with the ZORA robot and setting the goals for each child. But we think the ZORA robot is an effective tool to motivate children with a physical disability to participate in therapy sessions.

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Appendices

I. List of IROMEC robot scenario's

Scenario	Explanation
Turn taking	Collaborative turn taking activity. The robot has a start/stop activation mechanism that can be controlled by the user. The first player turns the robot to face the second player and presses the touch screen. This causes the robot to move to the second player and stops at a predefined distance from the player. The second player turns the robot around to face the first player and presses the touch screen in a similar way. This action / reaction can be played until the activity is stopped.
Turn taking for sensory reward	This scenario is the same as the scenario described above. The only difference being the input to control the robot. Instead of pressing the touch screen, each player has one of the buttons provided with the IROMEC robot to send the robot to the other player.
Make it move	The three buttons provided with the IROMEC robot are used to make the robot move. The green button to move the robot forward, the red button to turn right and the yellow button to turn left.
Follow me	The IROMEC robot starts to move around the room, searching for a child. As soon as it finds the child, it follows him/her with a predefined distance. If the child stops, the robot stops as well. As soon as another player is closer to the IROMEC robot, the robot will start following this player.
Get in contact	Therapist can select the robot's behaviour: Tactile mode: The IROMEC robot does not move. The main purpose is the ability for children to explore the robots surface. Fear: The robot moves back with a scared face as soon as a child moves too close to the robot. Communicative mode: In this mode, the IROMEC robot tries to approach the child with a happy face.

II. List of ZORA exercises

Exercise	Category	Explanation
Moving with ZORA	Movement	The ZORA robot performs several different movements in a series. The children perform the movement together with the ZORA robot. The number of times each movement is performed varies between 1 and 10 and has to be told to ZORA before starting.
Imitating Positions	Movement	Zora move into a specific pose, for example lying down or raising the arms. The children have to mimic each pose. As soon as every child performs the movement, Zora moves into another position. This exercise was done using the Wizard of Oz technique, meaning the robot moved into a new pose at the command of the researchers.
K3 – Mama se	Dance	Pop song in Dutch language.
K3 - 10000 luchtballonnen	Dance	Pop song in Dutch language.
Nielson – Sexy als ik dans	Dance	Pop song in Dutch language.
Los del Rio – Macarena	Dance	Pop song with known movements.
PSY – Gangnam style	Dance	Pop song.
Head, Shoulders, Knee and Toes	Dance	Children's song with known movements.
"Klappen in de handjes"	Dance	Children's song with known movements.
"Hallo, hier ben ik weer"	Dance	Song created by the school.
Frozen – Let it go	Dance	Pop song (performed in Dutch language)
Caravan Palace	Dance	Song created by ZORA company
QR Quiz ST	Cognitive Skills	Quiz using Quick Response Cards; Theme: Words starting with "ST"
QR Quiz SP	Cognitive Skills	Quiz using Quick Response Cards; Theme: Words starting with "SP"
QR Quiz Animals	Cognitive Skills	Quiz using Quick Response Cards; Theme: Animals
QR Quiz Autumn	Cognitive Skills	Quiz using Quick Response Cards; Theme: Autumn
QR Quiz Sinterklaas	Cognitive Skills	Quiz using Quick Response Cards; Theme: Sinterklaas (Dutch holiday)
Press my sensors	Cognitive Skills	The ZORA robot asks to press a sensor (e.g.: "Touch my feet") and the child has to press the correct sensor within the time.
"He sits"	Cognitive Skills	The ZORA robot performs an action like sitting down, walking, lying down, etc. The child has to tell which action it is performing in the correct way.

Exercise	Category	Explanation
“Stap, stop, sta” (Step, stop, stand)	Robot Control	The child can tell the robot what to do by saying “Stap” (step/walk), “Stop” or “Sta” (stand still). This is a Wizard of Oz type of exercise, where the researchers made the robot perform the action when the child said the words correctly.
“Nu wil ik hier zitten” (I want to sit here)	Robot Control	“I want to sit here”. The ZORA robot walks around an stops and crouches somewhere in the room. The child can either decide he/she wants to sit where the robot is sitting. By telling the robot he/she wants to sit there, the robot stands up, walks around a bit and crouches down again.
“Klappen in de handjes” stop en go	Robot Control	The ZORA robot starts the song “clapping in the hands”. When the robot stops singing, the child can press its sensor to activate ZORA again.
“Nu mag jij weer” (Now you may move again)	Robot Control	The ZORA robot performs a move, while the child has to stand still. After the move, the ZORA robot tells the child he/she may move until he/she does not want to anymore and says: “Nu mag jij weer” (Now you may move again).
Dag zeggen	Robot Control	Each of the sensors makes the ZORA robot say goodbye in a different way. For example by waving or blowing a kiss.

III. Frequency Statistics

Child	Frequency	Percent
A	23	7.3
B	32	10.1
C	31	9.8
D	34	10.7
E	26	8.2
G	32	10.1
H	31	9.8
I	36	11.4
J	36	11.4
K	36	11.4
Total	317	100.0

Category	Frequency	Percent
Movement	61	19.2
Dance	147	46.4
Cognitive skills	50	15.8
Robot control	59	18.6
Total	317	100.0

Gender	Frequency	Percent
Female	194	61.2
Male	123	38.8
Total	317	100.0

Group	Frequency	Percent
Individual	55	17.4
Group	262	82.6
Total	317	100.0

Session	Frequency	Percent
1	50	15.8
2	45	14.2
3	52	16.4
4	46	14.5
5	63	19.9
6	61	19.2
Total	317	100.0