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Human-Robot Interaction for Children with Cerebral Palsy: Reflection and Suggestion for Interactive Scenario Design

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Abstract

This paper explains how a humanoid robot NAO can be used as an assistive technology in specific therapy for children with cerebral palsy (CP). The role of the robot is to motivate the children as to keep them engaged in therapy. To achieve this, the robot must have appropriate appearance to be able to establish affective engagement between child and robot. In addition, the robot should exhibit the right therapeutic approach of managing children with CP. How the humanoid robot NAO acts as a tool to assist in improving the outcome of conventional therapy especially by imitation learning will also be explained. Four interactive scenarios in human-robot interaction (HRI) were designed based on the measurement items in Gross Motor Functional Measure (GMFM). The scenarios will then be constructed based on suitability that will be executed by the robot. As a result from the discussions between clinicians, therapists and engineers, four interactive scenarios consists of introductory rapport, sit to stand, body balancing and ball kicking activity have been formulated. The study has been performed in collaboration between the Faculty of Medicine and the Faculty of Mechanical Engineering at the Medical Specialist Centre, Discipline of Rehabilitation Medicine, Faculty of Medicine, UiTM Sungai Buloh, Selangor, Malaysia.

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Keywords: *Human-robot interaction, humanoid robot ; cerebral palsy; rehabilitation*

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1. Introduction

Cerebral Palsy (CP) is an umbrella term that encompasses a group of non-progressive and non-contagious motor conditions that causes physical disability, chiefly in the various areas of body movement[1] which is the most common physical disabilities in children[2]. Over the last decade, an unchanged of the prevalence of CP in the world population has been noted. Generally, worldwide statistics showed that approximately 2-4 in every 1000 children has CP[3, 4].

Robotic assistive technology nowadays has been widely used in rehabilitation[5]. It is an approach that must be able to demonstrate requested exercises, have an appearance that is attractive to children, and should be able to communicate (verbal and non-verbal) with patients and therapists[6]. One of the expected benefits of the robot is to assist the therapist to conduct specific

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therapeutic exercises. It can also establish affective engagement between the child, therapist and robot[7]. Rehabilitative therapy for children with CP has started to see some advantages due the increasing of the feasibility and applicability of the robotic solution to physical problems[5]. Because of attention span of a child is shorter than that of an adult, difficulties maybe faced by therapist in getting the child to comply with required exercise. A way to manage this is to combine therapy with play. Many researchers have focused on child rehabilitation with play to engage the children in performing action that aid their rehabilitation process. At the moment, intervention therapy involves Social Assistive Robotics (SAR) is still a few. SAR is one of the robotic technologies that assists its' user mainly through social interaction[8]. For example, previous study from G.Keren[9] introduced Kindergarten Assistive Robotics (KAR) as a learning development tool for typically developing children in preschool education. Motivation and communication of the children has increased during the interactions. Apart from that, robotic toys have been shown to aid in early intervention for children with developmental delays and to engage children in imitation based play[10]. A study from M. Fridin from Ariel University Center in Israel had used a humanoid robot called "Robotics Agent Coacher" to help children with CP to improve their motor function and daily living skills. It has resulted in positive interactions between the child and the robot[11]. Studies conducted using SAR has shown positive impacts in many aspects especially in increasing the children's social interaction. Thus, this study aimed to observe the therapeutic exercises in children with CP with involvement of the therapist.

In this study, two children with CP were exposed to the humanoid robot NAO once a week for eight weeks. Approval by UiTM Medical Ethics Committee was granted for the purpose of this research project. The study has been conducted in collaboration with Medical Specialist Centre, Discipline of Rehabilitation Medicine, Faculty of Medicine, UiTM Sungai Buloh and Faculty of Mechanical Engineering, UiTM, Shah Alam, Malaysia.

1.1. Humanoid robot NAO

a b

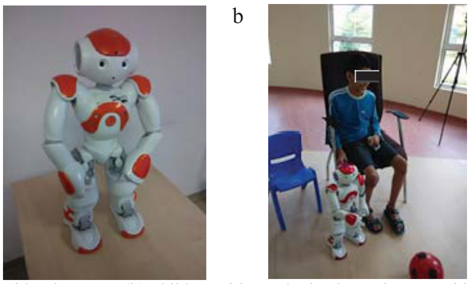


Fig. 1. (a) Humanoid Robot NAO (b) Children with Cerebral Palsy and Humanoid robot NAO

Figures above show a humanoid robot called NAO that is produced by the French company Aldebaran-Robotics. It comes with its height of 0.57 meter and weighing 4.5 kg. The main advantages of NAO are the light weight and affordable cost compared to other available robots of same performance[12]. As most children prefer robots, a humanoid robot NAO has the potential to be used as a tool in rehabilitation therapy for children with CP. Furthermore, the size of the humanoid robot NAO is like a 2 years old toddler draws the attention of the chils. In this study, humanoid robot NAO will execute interactive scenarios focusing on repetitive motion training with an aim to improve truncal balance, coordination and lower limb gross function of children with CP. The robot needs to produce repetitive actions and maintain its stability. With the potential to increase children's motivation, this robot will be able to help the children to be more active and motivated during the interactive sessions.

2. Conventional Therapy vs Robot-assisted Therapy for Children with CP

Conventional treatment includes physical, occupational and speech therapies, medical procedures, surgeries, and medications. Nevertheless, treatment plans are variable because each condition of the child with CP is different. The treatments are tailored to a child's physical, developmental, mental, and emotional needs. Physical exercise is one of the conventional therapies to improve motor skills. It is used to manage spasticity and to improve the pattern of motor function. However, conventional physical therapy conducted by therapists may have its limitations in term of repetitive movement. The robot can assist the therapists in producing high number of repetitive movement with more precision.A humanoid robot is very attractive to the child who can interact with it depending on how the robot has been programmed. The human-like shape and simple design can capture the interest and attention of the children interacting with the robot. Previous study shows that children have good respond towards the robot[6]. Some children showed the increment of duration in attention, smiles more frequent and spontaneous, vocalizations and verbalization while using robots[9]. It is important to stress that the use of robot in rehabilitation is not to replace the function of the therapist. Physical therapy aimed at imitation learning will be more effective compared to conventional therapy by using the humanoid robot which is physically shaped like a human being that can produce controlled and repeatable movements.

2.1. Development of HRI Interactive scenario

The interactive scenarios were programmed based on the inputs from the clinical experts and several items in the Gross Motor Functional Measure (GMFM) which are suitable and appropriate for imitation learning of children with CP. GMFM is a validated assessment to evaluate gross motor function for children with CP. It should fulfill the aim of the study while taking into consideration the technical limitation of the robot itself including software and hardware. All the interactive scenarios were programmed using Choregraphe software, a programming tool that allows programmers to create and compile the behavior of the robot. The robot can be programmed in autonomous mode or manual control. In the manual control, the behaviors and responses of the robot will be controlled by an experimenter who is located at the experimenter station which is unseen by the participant during the session. This set-up has advantages where experimenter can make a decision in real time during the session.

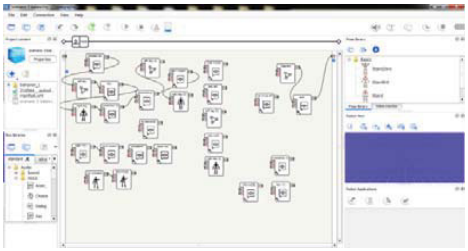
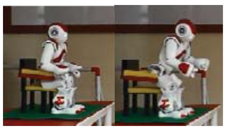
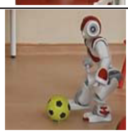


Fig. 2. Overview of Choregraphe software

As most interactive scenarios need a specific movement, a programmer needs to move the limbs and body parts of the robot by using a box of *"Timeline"* in the *Choregraphe*. The recording mode technique in "*Timeline"* is started with connecting the *Choregraphe* to the real robot NAO. Then, box of *"Timeline"* is transferred to input function and the timeline editor is opened. The recording mode is then activated before the recording process is started. Next, the joints actuator is selected and the desired movement of robot NAO is recorded. This technique needs to be repeated for every movement. A simulation test was conducted after all the scenarios have been completely programmed. It was done by utilizing the humanoid robot NAO in a well setup room with cameras. This simulation is important to ensure that all the scenarios are functioning well and follows the study protocol. During the session, both controller and therapist will be familiar with the flow of the study.

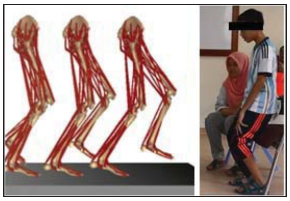
Table1 1: Development of interactive scenario

Picture	Description
	*Interactive scenario 1: Introductory rapport* In interactive scenario 1, there is two-way communication between the child and the robot which is aimed to create rapport between the child and the robot. In Choregraphe, dialog box "Say","Animated Say" and "Choice" are used while programming this scenario.
	*Interactive scenario 2: sit to stand* The aim of this scenario is to improve lower extremity function, truncal balance and coordination by doing stand-up and sit-down activity. In order to sit, the axis of the hip is slowly flexed to a sitting position. To maintain the stability of the motion, the upper body is bent forward to move its Center of Mass (CoM). Meanwhile, the knees of the robot are at a level slightly higher than the hips to achieve stability while sitting. In Choregraphe, all these movements require the programmer to use "Timeline" box.
	*Interactive scenario 3: Balance* The aims are to achieve therapeutic standing, left and right single leg stand. Similar with scenario 2, the programmer used "Timeline" box in the Choregraphe. During single leg stand, the robot needs to transfer its CoM to support another leg. The robot also spreads both hand and move the knee slightly higher than the hip to achieve stability of the motion.
	*Interactive scenario 4: Ball kicking* This scenario is aimed to improve the child's lower extremity function. There are three phases that the robot shifts its' CoM to support its' leg, which includes 1) the robot raises the kicking foot off the ground 2)the robot kicks the ball and 3)the robot puts the kicking foot on the ground. Similar with scenario 2, the programmer used "Timeline" box in the Choregraphe.

2.2 Why walking is not selected as a HRI Interactive scenario

Gait is a person's manner of walking. One of the characteristic of children with CP is gait abnormalities[13]. It means children with CP has abnormal walking pattern compared to typical human. Three main criteria of gait disorders for children with CP include tip toe-walking gait, crouched gait and scissors gait[14]. Crouch gait is one of the most frequent gait disorders in patients with CP[15]. Therefore, interventions that aim to improve physical mobility by addressing gait abnormalities of walking are important treatment to maintain or improve independent functioning. Definition of walking of robot is a movement with desired speed in frontward, sideward and even rotating directions[16]. Biped walk is define as a simple walking using two legs which is a complex, non-linear and dynamic process for humanoids but natural for human[17]. In order to maintain the stability of the robot such as NAO despite the change in walking patterns and ground surfaces variation the adopted controller needs to be robust.

a



b

Fig. 3 (a) Typical crouched gait pattern for children with CP [15]; (b) walking pattern of NAO

Figure above shows the similarity gait pattern between children with CP and robot NAO. From discussion with clinicians and therapists, both humanoid robot NAO and children with CP exhibit crouched gait pattern primarily to achieve stability and balance. As this study focuses on imitation learning, it is not a good idea for walking activity to be selected as one of the interactive scenarios.

3. Experimental study

The samples of children with CP in this study are obtained from the Medical Specialist Centre, Discipline of Rehabilitation Medicine, UiTM, Sungai Buloh, Malaysia. Children who will partake in the intervention program need to comply with these inclusion criteria; children diagnosed with CP (GMFCS level I –IV). The age ranges of the sample are between 5-14 years old. The child shall have no hearing and vision deficit, and able to follow simple command in English. Information will be given to the parents or caregivers before the consent to participate is obtained.

Fig. 4. Human-robot interaction with children with cerebral palsy

In this research, safety is an important issue since the study is using live human subjects. From figure 4, the distance between the child and the robot is 1.5m. This precaution distance is taken in order to avoid any accidents and to make sure that the robot will not hurt the child if the robot fails to function well.

3.1. Mechanical limitation during the Human-Robot Interaction (HRI)

Table 1. list of mechanical limitation during HRI

Items	Description
Error in pronunciations	The child did not understand on what the robot said
Error in hearing response	The child answered the question correctly but NAO did not detect the answer
Error in internet connection	It will interrupt the flow of the experiment
Mechanical error • Motor overheat • Fall • Smoothness of motor movement	Noise from motor movement will interrupt the clarity of the dialog
Battery flat	

Table 1 shows the mechanical error during the experiment. These mechanical errors did have an effect on general engagement of the children specifically during time of error. However, the child quickly reengaged with the humanoid robot NAO once the error has been rectified.

3.2. Human-robot interaction during interactive scenario

Both children underwent the exposure of eight weeks with the humanoid robot NAO showed positive responses in imitation learning. All completed the four interactive scenarios and were able to engage in the therapy led by the humanoid robot NAO. During the interactive scenario, the child exhibit joint attention with the therapist by participation in conducting the session. This included assisting in the experimental set up between scenarios. Both children followed the instructions given by the humanoid robot NAO in all scenarios and compliant to turn taking in scenario 4. All these skills are crucial in translating to adaptive social interaction in daily life.

4. Conclusion

The use of robots in the rehabilitation therapy for children with CP promising an exciting and promising direction in the field of HRI. The robot is aimed to improve the treatment's efficiency by initiating joint attention between child and therapist. Four interactive scenarios have been formulated with concern to the suitable measurement items in the GMFM that is suitable to be applied by humanoid robot NAO. The capacity of humanoid robot NAO in executing certain movement limits its' potential in some aspect of physical imitation learning. With the presence of humanoid robot NAO, the effect and impact of the therapy will be increased and more effective since the robotic elements have a potential attraction to the children's interest. Overall, expertise agreed on the appropriateness of the interactive scenario contents to be implemented for children with CP.

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