Pilot Observations of an Autonomous Red Light, Green Light Robot for Interactions with Children with Disabilities

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ABSTRACT

In the United States, approximately 7% of infants are born with a developmental disability that will impact their motor and social skill development. Assistive robotics are one method for promoting physical activity for children with disabilities, as they are motivating, repeatable, and adaptable. We implemented the popular children's game 'Red Light, Green Light' (RLGL) with an assistive robot mediator to assess whether robots can motivate children to play the game and engage in physical activity. We conducted two pilot RLGL sessions in each of two groups of children with disabilities. We saw that children actively played the game multiple times and wanted to continue playing with the robot. This paper can help inform future studies on robot-mediated physical activity promotion and play.

CCS CONCEPTS

• **Social and professional topics** → **Children**; **People with disabilities**; • **Computer systems organization** → **Robotics**; • **Human-centered computing** → **Human computer interaction (HCI)**.

KEYWORDS

assistive robots, children's games, movement promotion

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1 INTRODUCTION

Children with disabilities are not getting as much exercise as their peers with typical development [2]. Assistive robots may be part of the answer; robots have already shown early promise for supporting development from social skill practice [8] to exercise in a general population [5]. Accordingly, when forming the presented work, we became curious if a robot that facilitates physical-activity-based children's games could successfully promote movement and play.

Past work provides a helpful example of how child-robot interaction can help encourage child movement without direct physical assistance from the robot. For example, our past study with GoBot, a custom mobile robot with light, bubble, and sound interaction modalities, showed how long-term child-robot interaction can promote general physical activity [5]. In another of our efforts, Shelbytron, an assistive robot with a dog-like appearance, helped encourage independent movement and engagement by a child with motor disabilities via lights, jokes, encouraging phrases, and music [3]. Likewise, another team used the NAO and Dash robots to promote motor practice of children with Down syndrome [4]. Our presented efforts add to the growing research area of robot-mediated playful motor encouragement.

In early exploratory brainstorming, we identified the popular children's game 'Red Light, Green Light' (RLGL) as a potential means for designing new ways for assistive robots to encourage physical activity. We were not the first team to consider robot-mediated RLGL; for example, one past effort used a laser range finder to automatically determine the location of adult RLGL players [7]. Other researchers simulated multiple robots playing RLGL with one another, considering how this interaction could proceed safely [1]. We extend past robotics-based RLGL work with robot mediation for child players in the real world.

The *goal* of our presented pilot investigation was to assess child physical activity and direction-following during a game of robot-mediated RLGL. To this end, we observed the robot's gameplay interactions with children during two test sessions with each of two age groups (four sessions total) of the Oregon State Individualized Movement and Physical Activity for Children Today (IMPACT) program, which works to offer adapted physical activity support to children with disabilities. We used field notes to reason about how robots like ours might encourage children with disabilities to play and interact with peers and the surrounding environment. The *contributions* of this work are the investigation of a new play paradigm for assistive robotics and sharing of anecdotes on the possible impacts of such an activity.

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2 METHODS

We conducted four pilot robot-mediated RLGL sessions. In this section, we first describe the assistive robot and the design of the RLGL game before elaborating on our pilot investigation methods.

2.1 Assistive Robotic System

We used GoBot, as shown in Fig. 1, to mediate the pilot session games. The robot was built with a TurtleBot2 base running ROS Noetic [6] on a Raspberry Pi 4. GoBot can be teleoperated using a PlayStation 4 controller. We used a button on the controller to activate and deactivate the (otherwise autonomous) RLGL game. The game design leveraged the pre-existing robot hardware, which is capable of delivering rewards of lights, bubbles, and sounds. Additionally, the front of the robot had googly eyes that we used to indicate which way the robot was 'looking.' Specifically for the RLGL game, we added a new button module, as shown in the left panel of Fig. 1, which children could press to win the game.

2.2 Gameplay Behavior Design

On the software level, we added an autonomous RLGL game mode to GoBot's pre-existing functions. The game involved three states: *green light*, *red light*, and *game win*. Typically, the green light and red light states alternated until the robot's button was pressed, which activated the game win state. For the second round of pilot sessions, we probed an exploratory new state progression in which the red light state would happen twice in a row 20% of the time.

Green Light: During the green light state, the robot turned away from the participants (i.e., the googly eyes looked away), flashed the green lights, and said "green light" out loud. The green light state indicated to the children that they should move towards the robot. Initially, we designed the robot to stay in this state for a random amount of time in the range of 3-7 seconds but after our first pilot session, we reduced the timer to a random duration from 2-4 seconds. The left side of Fig. 1 shows the green light state.

Red Light: While in the red light state, the robot turned to face the participants, flashed the red lights, and said "red light." The children needed to stop moving during the red light state, and (by the typical rules of the game) any children still moving returned to the starting line. Similar to the green light state, we started with a random duration in the range of 3-7 seconds for the initial red light state, but reduced the timer to a random length from 2-3 seconds for the second pilot session. The right panel of Fig. 1 shows the robot in the red light state.

Game Win: Once a child pressed the button, the win state was activated. The robot showed the green lights, blew bubbles, and played a cheering sound to indicate the victory. In the spirit of inclusive encouragement, multiple players could win the game in sequence, upon each one reaching and pressing the button.

2.3 Participants

We recruited participants by receiving permission to join in two pre-existing on-site sessions of the Oregon State IMPACT program, which focuses on providing developmentally appropriate physical activity experiences to children with disabilities such as Autism Spectrum Disorder (ASD) or Down Syndrome. With permission from the program, we worked with two different age groups of children for the investigation: *tots* and *kids*. Each group included children with a range of different disabilities. The tots group included children 2-5 years old, while the kids group included children 5-10 years old. During the first pilot sessions, the tots groups had six children while the kids group had seven. For the second sessions, we had seven children in both groups. None of the children had prior experience with our robot.

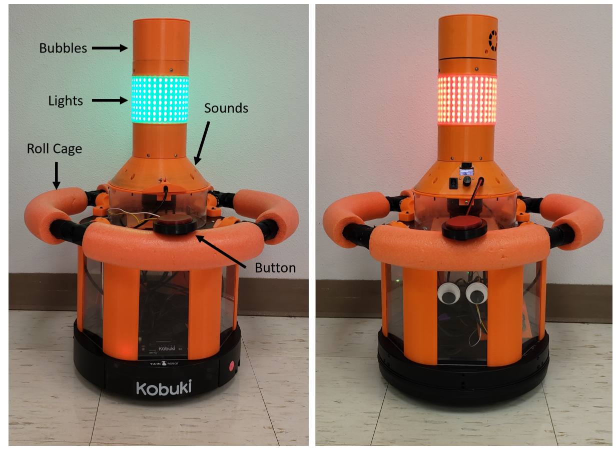

Figure 1: Different RLGL robot states. *Left:* Green light. *Right:* Red light.

2.4 Procedure

We conducted two pilot sessions with each group, via mediation by the assistive robot, two researchers, and the program facilitators. At the beginning of each session, the program facilitators would lead the group with 10 minutes of stretching. We then marked a starting line for the children to stand on and placed the robot 30 feet (9 meters) away. One of the researchers activated and monitored the game while the second researcher took field notes. The program facilitators played the game themselves while encouraging the children to move and follow the rules of the game. Additionally, facilitators who noticed a child moving during the red light state would tell them to return to the starting line. During each session, we played the game five times and then removed the robot while the local program continued.

2.5 Measurement

A researcher recorded field notes on paper during both sessions. The researchers revisited the notes after each session, for further reflection and elaboration.

3 PRELIMINARY RESULTS AND DISCUSSION

Tots Group: In the first pilot sessions, we observed that the tots group struggled with following the instructions of the game independently, but were able to start and stop during each game state with help from the program facilitators. We saw that the children actively ran toward the robot during each green light state and would reach the button within one or two green light cycles. At the end of a round of the game, we noted that the children would continually press the button and play with the bubbles until the facilitators prompted that it was time to play the game again. Toward the end of the first pilot session, it appeared that the children began to understand how the game worked.

As the tots were quick to reach the button in the first pilot session, we reduced the time range for how long the robot stayed in each state. In the second session with the tots group, we observed initial excitement at the robot returning and noted initial uncertainty about the game rules. Perhaps because the children had some experience from the first session, they were still able to reach the button within one or two iterations of the green light state during the first round of the game. To help extend the gameplay, the program facilitators asked the children to walk as fast as they could without running for the remaining iterations of the game. It appeared that the children enjoyed this variation of the game and were eager to continue playing.

Kids Group: We saw similar levels of enjoyment and interaction with the kids group. The children in this group were quickly able to understand how the game worked, and as with the tots group, the kids group were able to reach the button within one or two green light cycles. The children enjoyed pressing the button and playing with the bubbles before starting a new round of the game. At the end of the first pilot session, the children were reluctant to let the robot go, indicating to the program facilitators that they wished to keep playing.

In the second session, we again adjusted the state time ranges. When we brought the robot back for the second kids session, we saw that the children were visually excited and one even exclaimed 'the robot is back!' For the first three rounds, the children walked toward the robot, and the program facilitators decided to add additional variations for rounds four (crab walk) and five (army crawl) to encourage different types of physical activity. The final two rounds took longer than the previous rounds, but the children enjoyed the variations and were again reluctant to let the robot leave. The new repeated red light state occurred once during this session and caught a few of the children by surprise. After that event, we noticed that the children were more cautious and waited to ensure that the robot was in the green light state before moving.

Discussion: Overall, both groups of children showed high levels of excitement and engagement with the RLGL game and the assistive robot. We were initially unsure if both groups of children would understand how the game worked, but it appeared that the tots groups learned the instructions after playing a few rounds and the kids group grasped the game immediately. We did see that the robot changed states too slowly if children were running, even in the second session after we reduced the state durations. However, the program facilitators were able to encourage different types of movement to enable new types of interaction and smooth over this potential pacing concern. We recommend having a wider range of pace options.

The robot's button appeared to encourage interaction and provided an incentive for the children to move quickly. Both groups enjoyed pressing the button at the end of the game to spur robot rewards. Our results demonstrate that assistive robots with game modes such as RLGL could potentially encourage children with disabilities to engage in physical activity. One limitation of this work is the potential novelty of the robot. The children had not interacted with the robot before our pilot investigation, so more sessions would be needed to understand enduring engagement over time. Overall, we showed that incorporating children's games such as RLGL onto an assistive robot may be one novel way to encourage children to move.

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