GoBot Throw: A Toy-Inspired Ball-Launching Robot For Child-Robot Interaction

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Abstract. The childhood obesity epidemic persists as physical activity levels for children continue to fall below health organization recommendations. Assistive robots, which can offer repeatable and engaging behaviors for encouraging movement, may serve as one solution for raising the physical activity levels of young children. To this effect, we designed GoBot Throw, a ball-launching robot for motivating physical activity during child-robot interaction. We conducted an initial pilot session with GoBot Throw and one child with typical development and found that the child demonstrated more vigorous physical activity while the robot was active, compared to during a baseline period. The products of this work can help to inform researchers in the child-robot interaction sphere.

1 Introduction

Fewer and fewer children globally are meeting the recommended amounts of daily physical activity, which is a key factor in the rise of the childhood obesity epidemic [4]. This problem is a topic of broad concern; for example, national programs such as the Let's Move campaign have focused on increasing physical activity in children to prevent the development of obesity [7]. Although encouraging early motor play is a challenging problem, the attainment of childhood physical activity comes with multiple benefits. Beyond mitigating the risk of obesity, increased physical activity in children has been linked to improvements in cognition and decreased risk for cardiovascular diseases in later life [2,5]. Within the realm of robotics, assistive robots offer a new and adaptable solution for encouraging physical activity in young children. For example, our own beginning investigations have studied the abilities of a TurtleBot2 with custom hardware to motivate motor play [6], and other teams have used the commercial NAO and Dash robots [3] to encourage physical activity. In our ongoing work in this research area, *our primary research goal is to use assistive robots to motivate child motion.* Within this short paper, we present the design and early testing of GoBot Throw, a custom ball-launching robot for motivating physical activity in child-robot interaction.

Fig. 1: *Left:* GoBot Bubbles, our custom robot with bubble, light, and sound stimulus hardware. *Center:* GoBot Throw, with ball-launching hardware. *Right:* Partial view of overhead play space with robot, participant, and toys.

2 GoBot Design

As described more completely in our past work [6], we designed GoBot Bubbles, as shown in Fig. 1, to provide developmentally appropriate stimuli (i.e., bubbles, lights, and sounds) for motivating child physical activity during free play. Initial exploratory studies with GoBot Bubbles showed potential for encouraging movement, but also the need for a variety of stimuli to maintain children interest over longitudinal play sessions [6].

GoBot Throw, as shown in Fig. 1, was designed in collaboration with the Oregon State Social Mobility Lab, who has previously used a similar ball-launching mechanism for the playful instrumentation of early powered mobility aids. The core mechanical system of GoBot Throw is analogous to a pitching machine, with a ball-feeding mechanism and a fast-spinning wheel for launching the ball. The funnel atop the robot allows for users to reload balls. To prevent child contact with internal mechanisms, an actuated gate covers the ball exit window. A Raspberry Pi Pico controls the ball-feeding servo motor, ball-launching DC motor, and ball exit-covering servo motor. This Pi Pico is connected to a Raspberry Pi 4 running ROS Noetic for teleoperation and autonomous function modes.

3 Methods

We conducted a pilot session with GoBot Throw and one child participant to begin to evaluate the effectiveness of the robot for encouraging movement. To allow for comparison between typical child behavior and activity with the robot, the session was split into two phases (baseline and treatment), as further detailed below. The presented protocol was approved by our university ethics board.

Participant: The pilot participant was 1.5 years old, male, and had typical development. The child had interacted with GoBot Bubbles before, but had never interacted with GoBot Throw prior to the pilot session.

Measures: Overhead video data of the full session was collected from a GoPro Hero Black 10 camera which recorded at 25 Hz. Child inertial data was recorded by three GT9X Link Actigraph accelerometers (worn on the wrist, ankle, and hip) at a 100 Hz sampling rate. A post-session survey included Likert-type and free-response questions about parent perceptions of the child's interest in the robot. Questions included parent ratings of child engagement with the robot on a scale of 1 (Strongly Disagree) to 7 (Strongly Agree). Free-response questions asked parents to explain their perceptions of the robot during the session as well as how their child interacted with the robot.

Procedure: At the start of the session, the Actigraph accelerometers were placed on the right wrist, right ankle, and hip of the participant. Fig. 1 shows an overhead view of the play space, which included developmentally appropriate toys, the robot, and the participant. During the ten-minute baseline phase, the robot was present in the play space but was inactive. During the ten-minute treatment phase, GoBot Throw was teleoperated by a research team member. This researcher used the robot to intermittently launch balls into the play space, waiting for the child to grab a ball before launching the next one. At the end of the session, the parent completed the closing survey.

Analysis: In this preliminary work, we focus mainly on analyzing the wrist, ankle, and hip accelerometer data, in addition to using video recordings and descriptive text from the parent survey to help explain observed phenomena. We used the ActiLife v6.13.4 software to transfer recorded accelerometer data from the Actigraph sensors to a computer for processing. We calculated the mean acceleration magnitude for wrist, ankle, and hip accelerometer data, respectively, using the Euclidean Norm Minus One (ENMO) approach [1]. This process consisted of calculating the average acceleration magnitude across the three axes for every 0.5-second interval and subtracting 1g from the resulting averages to account for gravity. Results are reported in milli-g's (mg).

4 Preliminary Results and Discussion

Based on the analysis method mentioned above, we calculated the average magnitude of the accelerometer ENMO values for every 0.5-second interval across both the baseline and treatment phases. For each ten-minute phase, a total of 1,200 ENMO values for each accelerometer were computed. Resulting wrist, ankle, and hip average and standard deviations appear in Table 1. Higher magnitudes of acceleration correspond with more intense levels of physical activity, so we report the mean ENMO value for each accelerometer crossed with phase, noting that each average was higher in the treatment phase than the baseline phase. Standard deviations of ENMO values were also larger during the treatment phase, which may have been due to more vigorous physical activity such as running.

Table 1: Mean and standard deviation of wrist, ankle, and hip accelerometer ENMO values during baseline and treatment phases. Results are reported in milli-g's (mg).

	Wrist	Ankle	Hip
Baseline	18.9 ± 73.6	82.6 ± 137.4	38.1 ± 37.3
Treatment	35.0 ± 124.0	122.6 ± 205.2	54.7 ± 69.0

Qualitative data from the study video and survey supports the inertial recording results. From the overhead video, we observed that the participant actively ran after launched balls and brought the balls back to his parent for reloading. Parent survey data indicated that the child was "afraid of vacuum-like noises, so he was initially afraid of the robot until he warmed up to it." However, "he did enjoy chasing the balls after he warmed up to the noise though, so this was more fun for him than the bubbles robot."

In summary, GoBot Throw is a novel combination of a mobile robot base and a programmable ball-launching mechanism. A pilot session with one child showed encouraging results for GoBot Throw's encouragement of vigorous physical activity and reduction of sedentary behavior. A current limitation of the work is the small sample size and brief interaction with the robot; in next steps, we will assess the robot's performance with more child users over a longer study and consider ways to model child responses to the robot.

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