Lights, Camera, Action! Evaluating Robot Reward Behaviors in Free Play with Children

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ABSTRACT

Most children in the United States do not meet recommended physical activity guidelines. Robot-mediated interventions are one promising and novel approach for encouraging physical activity in young children. We designed a custom robot with age-appropriate rewards (i.e., lights, bubbles, and sounds) and studied child responses to the robot behaviors over repeated play sessions. Results varied by individual reward, but each reward demonstrated the ability to motivate child movement towards the robot in all sessions. Bubbles were the most popular reward, and lights and robot motion seemed to be the next most promising. The products of this work can support the efforts of human-robot interaction and child development experts who study child mobility interventions.

KEYWORDS

Infant-Robot Interaction, Robot Rewards, Early Motion Intervention

1 INTRODUCTION

Although the U.S. Department of Health and Human Services has outlined the importance of physical activity for all children [5], the majority of children are not meeting the recommended amount of physical activity [4]. The toy industry offers some solutions such as walker toys, systems with contingent rewards (e.g., lights and sounds resulting from the press of a button), and even motorized toys; however, these toys are typically not adaptive and do not customize well to individual child needs and interests [2]. We propose robot-mediated interventions as a more intelligent and personalized approach to support physical activity for young children.

Past research has shown that robots can be more motivational than other non-embodied forms of technology [1]. Initial works applying assistive mobile robots in child motor interventions indeed show that NAO and Dash robots can promote motion exploration in young children [6] and NAO robots can teach and reinforce kicking motions [3]. In our work, we use a custom assistive robot for similar motion encouragement purposes. Our robot is more maneuverable than the NAO, more visible than the Dash, and capable of different types of reward behaviors than either platform.

Our central goal in this paper is to understand child responses to our robot's reward behaviors. We use overhead video from child-robot play sessions to analyze these responses. The results will inform future robot behavior strategies and reward design.

2 METHODS

In collaboration with the Oregon State University Social Mobility Lab, we conducted three IRB-approved exploratory play sessions involving a group of children and a custom robot from our lab.

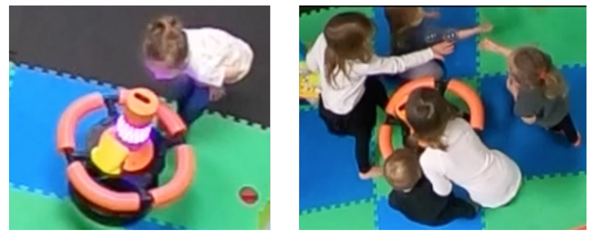

Figure 1: Robot interactions with children. *Left:* Robot using lights. *Right:* Robot using bubbles.

System Design: Our custom assistive robot comprises a TurtleBot2 base and a reward module capable of supplying light, bubble, and sound rewards, as shown in Fig. 1. The rewards were designed in coordination with the Social Mobility Lab to provide a variety of developmentally appropriate stimuli.

Participants: The playgroup included six children (one male, five female) with typical development. Children were 1.6 to 6.7 years old (M = 3.6 and SD = 1.9).

Procedure: The play space consisted of developmentally appropriate toys for children to play with during each session. During play sessions, the robot was teleoperated by a research assistant. The operator tried to engage with each child in the playgroup using motion and each robot reward (i.e., lights, bubbles, and sounds) at least once per session.

Measurement: Activity was captured through overhead video.

Analysis: We used the ELAN annotation tool [7] to code robot actions from video of each play session. Our codebook included: (1) robot actions involving individual rewards (i.e., lights, bubbles, and sounds), motion, spinning in place, and any combination of actions and (2) robot behavior/reward being successful or not. Success was defined by any child moving towards the robot during the two seconds following the robot action.

3 RESULTS AND DISCUSSION

All studied robot behaviors functioned correctly during all three play sessions, with the exception of the bubble rewards (which were out of operation during Session 3). The video coding results show the following overall success rates for singular robot behaviors across all sessions: 39% for lights, 82% for bubbles, 22% for sounds, 29% for motion, and 18% for spinning. Although their interpretation is more complex, we also note the overall success of combinations of robot behaviors: 32% for motion + singular reward and 36% for any combination of individual rewards (e.g., lights + sounds). For these combinations, it is less clear how individual behaviors influenced child interest.

Table 1: Counts of robot actions for each play session.

	Lights	Bubbles	Sounds	Motion	Spin
Session 1	14	9	18	88	15
Session 2	13	4	17	91	36
Session 3	29	N/A	4	62	11

Since novelty can be a key factor in interactions with robots, we examined the success of each robot behavior by session. Table 1 shows counts of each individual action's use during every play session. Motion occurred most frequently as the operator moved the robot around the playgroup to interact with each child. As described in the protocol, reward actions occurred individually at least once per session per child (sometimes happening as part of a combination). As evidenced in Fig. 2, each action was successful at promoting child movement towards the robot at least once per session. The sound reward success increased from from 22% to 25% between Sessions 1 and 3, but singular sound rewards also occurred much less frequently during Session 3. All other actions were less successful during Session 3 than in Session 1; light success dropped from 43% to 28%, bubbles dropped from 88% to 75%, motion dropped from 57% to 19%, and spin dropped from 40% to 9%. Due to the corresponding change in frequency of each reward, the meaning of these trends is not totally clear; however, novelty may have played a role in child responses to the robot over repeated play sessions. We observed younger children frequently using the robot like a walker toy in Session 1, but less in Session 2 and 3, which may have influenced the observed trends.

We can also examine the changes in child responses to combinations of robot behaviors over time, with the same caveat as described previously. Motion + singular rewards succeeded 79% of the time in Session 1 (14 occurrences), 0% in Session 2 (8 occurrences), and 17% in Session 3 (29 occurrences). Combinations of rewards succeeded 67% of the time in Session 1 (3 occurrences), 0% in Session 2 (1 occurrence), and 40% in Session 3 (5 occurrences).

4 CONCLUSIONS AND FUTURE WORK

As part of our robotic system design, we conducted exploratory play sessions to determine the viability of the robot's built-in rewards when interacting with young children. The results indicate that bubbles and lights were the most consistently successful rewards for encouraging motion towards the robot and are viable options when interacting with young children. The sound reward showed limited success, which may be due to the presence of other sounds in the play space. We observed younger children grabbing the robot to walk around the play space, similarly to how a child would use a walker toy. Robot motion showed a decrease in success for Sessions 2 and 3.

Design implications of this work include that bubble rewards, which are not currently used in commercial mobility toys [2], can be a more effective strategy for generating interest in the robot than commonly used light and sound features. Additionally, having a robot that is infant-sized meant children could can use it similarly to a smart walker toy.

Key *strengths* of this work include that each reward was able to encourage child motion during all play sessions. Additionally,

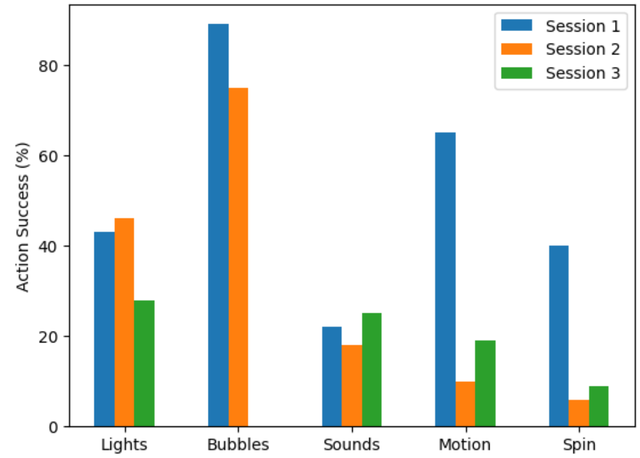

Figure 2: Robot action success by session.

we demonstrate that bubbles were an effective reward choice for drawing the interest of young children.

Limitations of this work include the low number of play sessions and small group size. It is also unclear how combinations of rewards impacted the change in success over repeated sessions. Our future studies will incorporate more sessions and larger sample sizes to further clarify reward effects.

In *future work*, we will consider the design of additional modular rewards (e.g., moving streamers or pinwheels), that are age-appropriate and enduringly interesting to children. We also plan to conduct future studies involving one-on-one child-robot interaction in lab, home, and clinical settings.

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REFERENCES

[1] Wilma A Bainbridge, Justin W Hart, Elizabeth S Kim, and Brian Scassellati. 2011. The benefits of interactions with physically present robots over video-displayed agents. *International Journal of Social Robotics* 3, 1 (2011), 41–52.
[2] Fisher-Price. 2021. Products for 12-18 Months. https://www.fisher-price.com/en-ca/shop/age/12-18-months
[3] Naomi T Fitter, Rebecca Funke, José Carlos Pulido, Lauren E Eisenman, Weiyang Deng, Marcelo R Rosales, Nina S Bradley, Barbara Sargent, Beth A Smith, and Maja J Matarić. 2019. Socially assistive infant-robot interaction: Using robots to encourage infant leg-motion training. *IEEE Robotics & Automation Magazine* 26, 2 (2019), 12–23.
[4] Pedro C Hallal, Lars Bo Andersen, Fiona C Bull, Regina Guthold, William Haskell, Ulf Ekelund, Lancet Physical Activity Series Working Group, et al. 2012. Global physical activity levels: Surveillance progress, pitfalls, and prospects. *The Lancet* 380, 9838 (2012), 247–257.
[5] Abby C King, Melicia C Whitt-Glover, David X Marquez, Matthew P Buman, Melissa A Napolitano, John Jakicic, Janet E Fulton, and Bethany L Tennant. 2019. Physical Activity Promotion: Highlights from the 2018 Physical Activity Guidelines Advisory Committee Systematic Review. *Medicine and Science in Sports and Exercise* 51, 6 (2019), 1340–1353.
[6] Elena Kokkoni, Effrosyni Mavroudi, Ashkan Zehfroosh, James C Galloway, Renè Vidal, Jeffrey Heinz, and Herbert G Tanner. 2020. GEARing smart environments for pediatric motor rehabilitation. *Journal of Neuroengineering and Rehabilitation* 17, 1 (2020), 16.
[7] Han Sloetjes and Peter Wittenburg. 2008. Annotation by category-ELAN and ISO DCR. In *Proc. of the International Conference on Language Resources and Evaluation (LREC)*. Max Planck Institute for Psycholinguistics, The Language Archive, Nijmegen, The Netherlands. https://archive.mpi.nl/tla/elan