Gabriela Zott for the degree of Master of Science in Kinesiology presented on May 21st, 2020.

Title: **Influence of Robot Motivation on Modified Ride-on Car Usage**.

Non-thesis Project

Approved by Dr. Samuel Logan

Introduction

Self-directed mobility is mobility controlled by the individual rather than others. This includes ambulation (walking) and both power/nonpower assistive devices (such as walkers, power wheelchairs, etc.) (Logan, Hospodar, Feldner, Huang & Galloway , 2018). Children without disabilities benefit from self-directed mobility with improvements in cognition, social skills, and communication (Anderson et al., 2013: Campos, Anderson, Barbu-Roth, Hubbard & Witherington, 2000). Infants specifically become more willing to do tasks, and are more autonomous, and more emotional (expressing anger and glee while being more sensitive to maternal separations) when they exhibit self-directed mobility (Campos et al., 2000).

Early childhood mobility is different for every child. Children with disabilities specifically are given less opportunities to explore their environment (Anderson et al., 2013). Often children with disabilities are expected to stay on pace with the motor development of their peers. This idea causes practitioners to focus on promoting walking first, despite known mobility disabilities (Logan et al., 2017). However, early power mobility research has shown many of the same benefits of walking, such as language acquisition and psychological advancements, while providing an all-inclusive alternative. Power mobility technology is defined as a device using battery power that is used by an individual to move (Logan, Feldner, Galloway & Huang, 2016). A modified ride-on car is an example of power mobility technology and often young children are excited to use them (Huang H.H., Chen & Huang H.W., 2017).

Modified ride-on cars (ROC) assist children with disabilities to have more access to the spaces and people around them (Logan et al., 2016). Modifications to ride-on cars often include changing the activation switch and seating support. Simple modifications include using PVC pipes, duct tape, swimming kickboards, Velcro, and a large/accessible steering wheel (Logan, Feldner, et al., 2017). The PVC pipes are often used to create added support around the seating of the car, the kickboards for back support, and the duct tape and Velcro to hold everything together. The steering wheel is typically used so that any child can simply press down on the button and move forward, rather than having to use some sort of switch and then steer. Once modified, ride-on cars allow all children to sit up and move around, providing visual and play opportunities not always available otherwise (Huang et al., 2017). One school-based study showed more peer play interactions in the modified ride-on car (the car in this study also included a standing function) compared to when the child used crutches (Logan et al., 2017). This suggests that using modified ride-on cars may help to close the gap in peer interaction between kids with and without disabilities. Modified ride-on cars also increase independent mobility (Logan, Huang, Stahilin & Galloway, 2014). Alongside increases in mobility seen using modified ride-on cars, children with disabilities can benefit from additional forms of assistive technology to maximize independence.

Robotics are another type of assistive technology that can be used to facilitate children's learning. Within physical therapy settings, researchers have seen improvements in motor development when using a robot for modeling/demonstrating behaviors instead of the regular therapy scheduling (Fridin & Belokopytov, 2014). In addition social robotics have been used to facilitate different types of learning in the classroom (Johnson, 2003). The most common usage for robots in education is for students receiving special education. Robots have been used as learning/instructional aides to assist children with disabilities such as autism spectrum disorder and learning disabilities. (Bharatharaj, Huang, Mohan, Al-Jumaily & Krageloh, 2017; Conti, Di

Nuovo S., Buono & Di Nuovo A., 2017; Mohammad, Khaksar, Slade, Wallace & Gurinder, 2019). Examples of this include repeating instructions, offering prompts, and giving off rewards for positive behaviors. While used for a variety of reasons, the main reason to use these social robots is to increase motivation of individuals in whatever task they are working on completing (Deublein et al., 2018; Fridin & Belokoptov, 2014; Johnson, 2003). A recent publication from Fitter and colleagues (2019) found that infants were motivated to move their limbs in response to motivation from a humanoid robot (meaning looks like a human in terms of limbs and appendages). This suggests that robot motivation should be explored further in early motor development.

Using robot motivation to see effects on modified ride-on car interaction has not yet been explored. Previous research has looked at the use of robots to encourage/motivate children (Bharatharaj et al., 2017; Conti et al., 2017; Johnson, 2003) and the benefits of using modified ride-on cars have also been previously explored (Feldner, 2019; Logan et al., 2016; Logan et al., 2017). Keeping this in mind, this study expands on previous research by looking at how using robot motivation influences modified ride-on car usage among young children.. With more access to self-directed mobility from modified ride-on cars and motivation from a robot, the question becomes “Will using a robot motivate children to change driving behaviors in the modified ride-on car?” Therefore, the purpose of this study is to describe the differences in driving behaviors of children using a modified ride-one car across three groups: control, movement, and movement + rewards.

Methods

Participants:

Six young children between the ages of 6-36 months with and without disabilities participated in this study (n=6). For the purpose of this study, a child with a disability included any child who showed a developmental delay through being unable to roll-over, sit, stand, and/or mobilize independently for exploratory play and peer interaction. Demographics of each participant can be found in table 1.

Treatment Group	**Control (n=1)**	**Movement (n=2)**		**Movement + Rewards (n=3)**		
ID	007	004	005	002	003	006
Age (mo)	35	32	14	29	12	-
Gender	male	male	male	male	male	male
Ethnicity	white	white	middle eastern	white	white	white
Height (in)	38	37	32	35	31.5	27
Weight (lbs)	34	28	21	30	22.8	16.5
Disability? (Y/N)	no	no	no	no	no	no
Lang Delay (Y/N)	no	yes (speech delay)	no	no	no	no
Mobility Delays (Y/N)	no	no	no	no	no	no
Preferred mobility?	walk independently	walk independently	walk independently	walk independently	crawl on hands and knees	crawl on hands and knees

Table 1: Participant demographics, organized by group.

Materials:

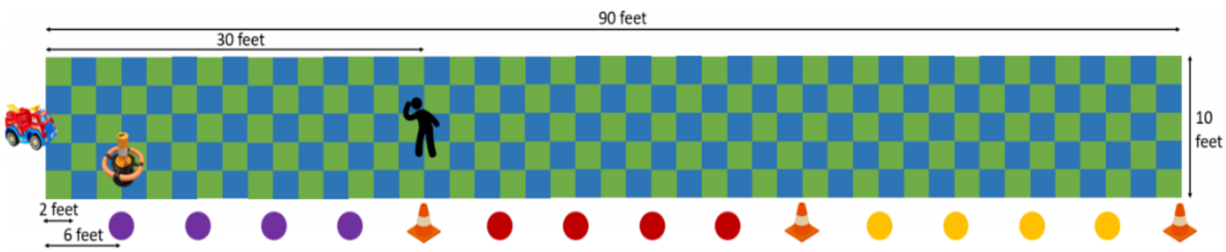
In collaboration with the robotics department at Oregon State University, a social robot was created by a graduate student for their master's project. The robot, seen in figure 1, was created using a Roomba vacuum cleaner for the base with an added cone on top made from a 3D printer. The robot was programmed to give off sound, light, and bubble rewards. Sound was programmed into the internal computer with over 200 choices of 'kid friendly sounds' including sounds from animals, babies, cars, etc. Lights are set off through the white a grey panel in the middle of the orange cone and can be set to display different colors and patterns depending on the child's preference/medical needs (e.g if a child had epilepsy, the lights could be programmed to go off in a consistent bout rather than flashing rapidly). As the third function, bubbles can also be released from a hole at the top of the cone in which a collection of bubble wands are being dipped in and out of a bubble solution. Once the wands move through the solution, they travel over a fan which 'blows' the bubbles outwards towards the ceiling. The robot functions and movement were controlled by a trained researcher through a modified gaming controller.

Figure 1. The social robot

The modified ride on car used for this study is pictured in figure 2. For this study the Paw Patrol model was used. This model is designed for children up to 36 months of age. The battery in the model was a 6-volt battery allowing children to move a maximum speed of two miles per hour forward. Modifications include PVC pipes for added support, a kickboard for back support, pool noodles for arm and neck padding, and a large accessible steering wheel which was zip-tied so the car would only go straight. In observing the interactions of the modified ride-on car and the robot, a Go-Pro (model) was attached to the back PVC pipe of the car. A handheld video camera was also used to get footage from other angles.

Figure 2: Modified ROC

The final important materials used in this study were green and blue 2x2 tiles, poly spots, and cones. Several green and blue tiles were pieced together and set out to create a 90-foot



driving course on a gym floor. Poly spots were placed on the side of the course in 6-foot increments and three separate orange cones were placed along the course at 30 feet, 60 feet and 90 feet. This course, shown in figure 3 below, allowed researchers to easily measure driving distance and keep consistency with robot interactions.

(Figure 3. from Vinoo et. al, *In Review*)

Experimental Groups:

Control Group: The participant follows the procedures of the study with the robot staying in the same place for the duration of the study.

Movement Group: Participants follow the procedures of the study with the robot moving back to the next poly spot each time the child gets within one foot of the robot.

Movement + Rewards Group. Participants follow the procedures of the study with the robot moving back to the next poly spot each time the child gets within one foot. In this group, children also receive a reward (bubbles, lights, and sounds) when getting within one foot of the robot.

Procedures:

Children participated in 3 blocks of driving sessions with 5 trials each. The length of each trial was 90 seconds, until the child completed the 90-foot course, or until the child attempted to exit the modified ride-on car. The 3 blocks included baseline, treatment, and retention. For baseline trials, the child was placed in the modified ride-on car with their parent 30 feet away. No verbal or physical instructions were provided by the parents on what to do with the activation switch. The child was then encouraged by the parent to come forward. The goal of each driving trial was for the child to activate the switch of the modified ride-on car and drive towards their parent. The mobile robot was be placed approximately 6 feet from the child and did not move or provide any type of reward. When the child drove within approximately 5 feet of their parent, they received praise and then the parent moved another 30 feet back.

The treatment trials followed these same procedures except the robot interaction varied depending on group. For the control group, procedures were identical to baseline. For the movement group, procedures stayed the same except that when the child got within 2 feet of the robot, the robot moved 6 feet back. In the movement + rewards group, the procedures were the same as the movement group except that when the child came within 2 feet, the robot gave off all three rewards before moving back. Rewards included lights, child-friendly sounds, and bubbles. The robot was controlled by a trained graduate researcher.

If the child showed signs of distress (such as crying) for at least 1-minute, then they were taken out of the modified ride-on car for a 5-minute rest period. A new attempt was made to place the child in the device. If the child still was in distress, a maximum of 3 separate 5-minute attempts were made to provide an opportunity for the child to resume the study before their session was ended. Field notes were taken throughout data collection to record observations from the parents and research team.

Description of Outcomes:

The participants in the movement + rewards group are 002, 003, and 006. The participants for the movement group are 004 and 005. Lastly, the participant in the control group is 007. There were 5 dependent measures in this study, including (a) average distance, (b) distance traveled per trial, (c) total duration of activation switch press, (d) number of times the activation switch is pressed, and (e) average duration of switch press activation. Distance traveled per trial was maxed out at 90 feet. Average distance per trial was calculated for total number of trials (not all participants finished all 15). Total duration and number of times for activation switch press per trial were examined to account for any modified ride-on car specific issues (battery dying, wheels veering sideways, etc).

Average Distance: Figure 4 shows the average distance traveled for each participant. All participants traveled at least an average of 30 feet during the study. This includes participants who did not complete all 15 trials (participants 002,004, 007). All participants of the movement and movement + rewards groups were within 20 ft of average distance per trial. The control group participant went the full 90 ft each trial.

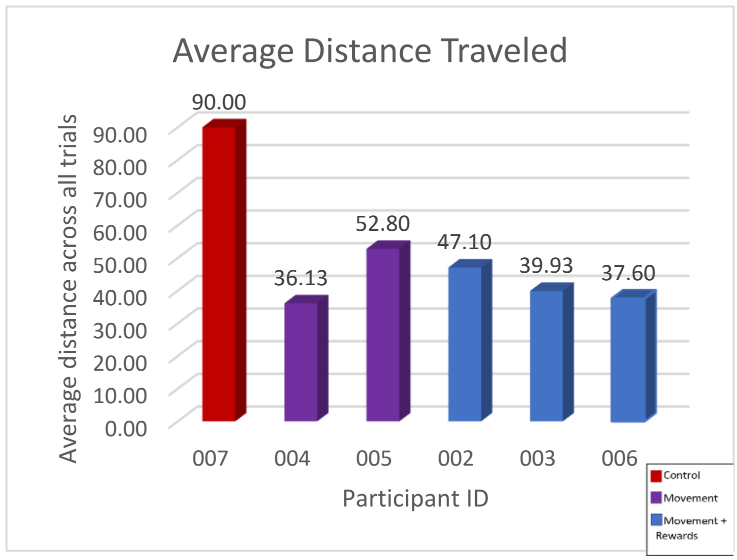


Figure 4: Average distance for each participant across all trials **not all participants completed all trials.**

Distance Per Trial: Table 2 shows the breakdown of distance traveled per trial by each individual participant. The last column shows the total distance traveled by that participant. Three of the participants had their furthest distance either in the treatment or retention phase (indicated with an Asterix). Boxes left blank indicate that the participants chose to no longer engage in the study.

Distance Traveled per trial (ft)																
		1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***	***15***	***Total***
Control	007	*90	*90	*90	*90	*90	*90	*90	*90	*90	*90	-	-	-	-	-	900
Movement	004	*80	66	72	60	30	18	8	36	52	40	18	14	-	-	-	494
	005	66	48	48	82	54	12	56	58	82	48	22	*90	40	68	18	792
Movement + Rewards	002	*65	60	62	54	24	64	50	30	28	34	-	-	-	-	-	471
	003	22	0	26	64	*90	0	87	0	84	0	86	22	28	60	30	599
	006	*90	60	32	0	56	34	0	18	90	68	0	12	46	0	58	564

Table 2: Distance traveled per trial by each participant. *The participants' furthest distance

Average Duration of Switch Press: Figure 5 shows the average duration of activation switch press. The participants in the movement + rewards group had higher times than the movement group participants. The participant from the control group had the highest average duration.

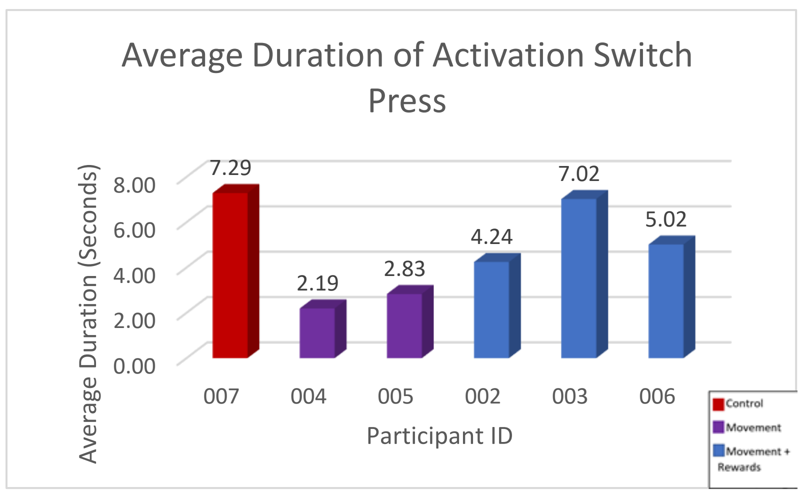
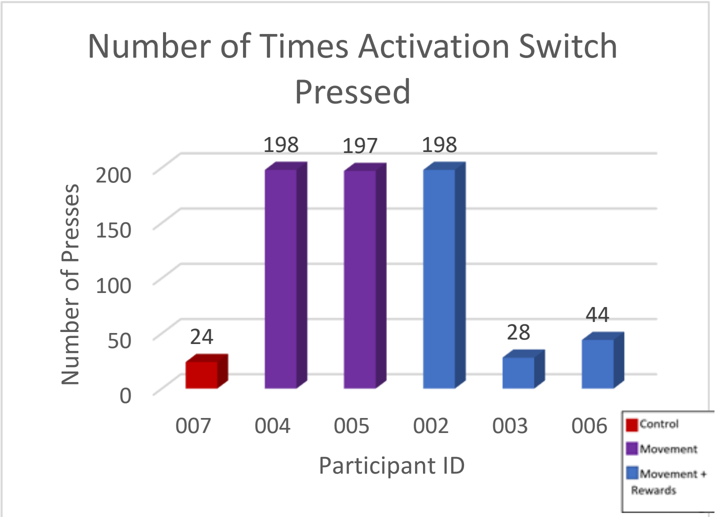


Figure 5: The average duration of activation switch press for each participant across all trials



Times of Switch Press: Figure 6 shows the number of times the activation switch was pressed across all trials. The participant in the control group had the lowest number of times the activation switch was pressed while participants in the movement group had the highest number of presses.

Figure 6: The number of activation switch presses for each participant across all trials.

Total Duration of Switch Press: Figure 7 shows the total duration of activation switch press across all trials. Participant 002 has the highest total duration of activation switch press while the others in that treatment group having some of the lowest times. The participant in the control group has the lowest times of all participants on this measure.

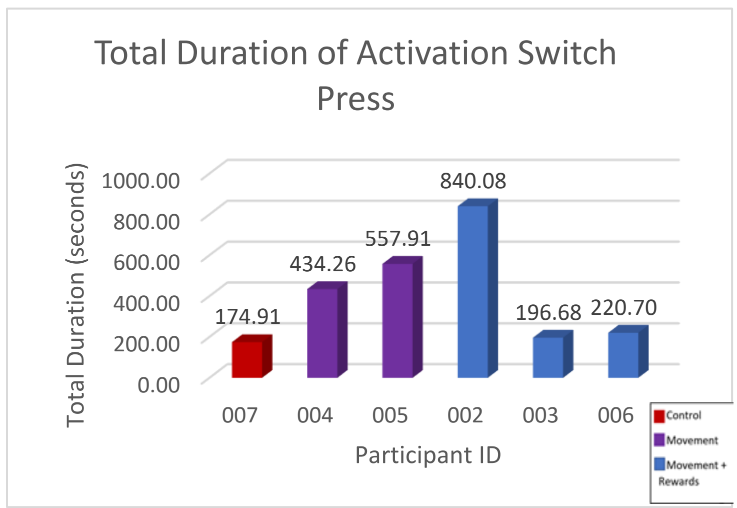


Figure 7: The total duration of activation switch press for each participant across all trials

Discussion:

This study addressed using social-robot motivation for modified ride-on car usage. The purpose of this study was to describe the differences in driving behaviors across three different groups, control, movement, and movement + rewards. In describing the dependent measures, five key indicators were covered: average distance, distance per trial, average duration of switch press, number of switch presses, and total duration of switch press.

Average Distance: Participant 007 in the control group demonstrated the highest average distance for all trials, and participants in the treatment groups demonstrated lower average distances. Participant 005 drove the furthest (52.80 ft) on average of the children in the treatment groups. Of children in the treatment groups, this participant also drove the furthest total distance (792 ft). In some of the field notes, it was written that this child has a particular interest in technology; the parents of this participant mentioned that they had access to electronic toys at home. This could explain the participant's driving behavior, especially already having exposure to a Roomba robot in the home.

Distance Per Trial: The furthest distance for one of the three movement + rewards participants (006) was in the extinction phase (90ft). This could suggest motivation from the robot rewards having an influence on the outcome of driving behavior. However, the furthest distance being in the extinction phase was only the case for one of the three movement + rewards participants. Therefore, suggesting the robot rewards have an influence on distance traveled should be explored further. Also, the only control group member (007) drove the full 90ft in all trials. This child has a sibling who has been a part of modified ride-on car studies in the past and thus their prior experience could have led to their better results.

Average Duration of Switch Press: The average duration of activation switch press was longer in the movement + rewards group –participants 002 (4.24 s), 003 (7.02 s), and 006 (5.02s)—than those in the movement group. Average duration of switch press indicates how long the child held down the switch, which could be linked to their driving motivation changing from the robot rewards. The robot motivation appears to have encouraged the children to press and hold the switch; this result is in line with the hypothesis that there would be differences between groups. This is in line with previous work, which suggested increased outcomes (outcomes included mimicking the robot) with robot motivations (Fitter et al., 2019). The control participant (007) had the highest average duration, but this again could be linked to previous experience with the modified ride-on cars.

Times of Switch Press: Two of the three children in the movement + rewards group pressed the switch the fewest number of times (participant 003, 28 presses; participant 006, 44 presses). Field notes showed the third participant in this group (002) repeatedly pressing the switch. This was also the case for the children in the movement group. Going back to the logic from Fitter and colleagues (2019), offering rewards as well as robot movement helped children in this group to understand that the number of presses does not equal movement forward. Also for this measure, the child in the control group (007) had the lowest number of switch presses, again suggesting prior experience with the modified ride-on cars.

Total Duration of Switch Press: Interestingly, participant 002 had highest total duration of switch press (840.08 seconds) with only completing 2 blocks of the trial. Being in the movement

+ rewards group, this participant pressing the switch the longest might indicate that the children in this group are engaging with the switch more. They might be learning about the car and figuring out how to move forward because of robot motivation. However, the other two children in the movement + rewards group had some of the lowest times for total duration. This suggests that this measure might not represent the effects from robot motivation as well as other measures.

Intersections of Dependent Measures: There were many interactions between dependent measures. First, the participant with the highest number of switch presses (002, 198 presses) and total duration of switch press (840.08 seconds) was not the highest for average or total distance (47.10, 471 feet, respectively). Second, the participants in the movement + rewards group, who had the highest average duration of the switch press (002, 4.24 s, 003, 7.02 s; 006, 5.02s), were not the group that traveled the furthest overall on average or total distance. This could suggest that learning about the cars involves not only pressing the activation switch, but also understanding how it works relative to how far the car is moving. There is not enough data here to make any conclusions, but this is something to take into account for future studies.

A third intersection was that two of the three children from the movement + rewards group had the lowest number of times that the activation switch was pressed (003, 28 times, 006 44 times) with the longest treatment times for activation switch press duration (003, 7.02 sec, 006, 5.02 sec). Logically speaking, the longer one holds down the switch in a trial, the less times they will press on the switch.

The final interactions of dependent measures involve the control group participant (007). Participant 007, interestingly, had the lowest total duration of activation switch press (174.91 seconds), despite having the highest average and total distance (90, 900 feet respectively). This could be because they knew the cars well and thus completed the trials quickly. Also, this participant had the lowest number of switch presses (24 times) and highest average duration of switch press (7.29 seconds) suggesting they understood the car and study objectives well.

Outcomes Compared to Background Knowledge: We know that modified ride-on cars offer self-directed mobility for all. The benefits of self-directed mobility have been shown in children (Anderson et al., 2013) and modified ride-on cars help level the playing field by providing equal visual and play opportunities (Huang et al., 2017). Modified ride-one cars are especially useful for children who are not yet walking**.** In this study, two participants were not yet walking at time of data collection (003 and 006). These were also the two treatment participants with the highest average duration of switch press. It thus seems that modified ride-on cars allowed them to move about more quickly and gave them the opportunity to explore their surroundings independently.

We also know that robots can help with motivation. Social robots have been shown to give motivation to individuals in a variety of settings and tasks (Deublein et al., 2018; Fridin & Belokoptov, 2014; Johnson, 2003). A recent publication from Fitter and colleagues (2019) found that infants were motivated to move their limbs in response to motivation from a humanoid robot. When offered rewards in this study, the participants in this group were expected to drive more because of the Fitter and colleagues (2019) study. With pilot data, we cannot claim any relationships. However, the higher average duration of switch press from children in the movement + rewards group may suggest that robot-specific rewards are motivating or interesting to young children.

Limitations and Future Directions: One limitation was that the small sample size limited the ability to thoroughly analyze the data. However, this study is pilot work for future studies.

Intersections between dependent measures serve as a roadmap to what future work will examine. Another limitation was that skill level and exposure to modified ride-on cars prior to study were not controlled for because of non-random assignment of groups. Non-random assignment was used in order to see at least one child per each group. Moving forward, this will be controlled for by random assignment of groups to help reduce these issues. Also, another document could be added to the pre-study packet asking about previous experience with modified ride-on cars. A third limitation was that all 6 participants were males. There may be sex differences in terms of interest in toy cars and robots, thus future work should specifically target young females to explore this. From this study, there is already one outcome of a manuscript submitted to a robotics conference (Vinoo, Case, Zott, Logan, & Fitter, *In Review*). In the future, we hope to publish this current document in order to further support research with these measures.

Conclusion:

This study looked at the influence of robot motivation on modified ride on-car driving behavior. Implications of this initial work are that the outcomes have informed us for future research. Of all the dependent measures, the average duration of switch press being higher among children in the movement + rewards group should be expanded upon to determine a relationship between variables. All other measures should be explored deeper to fully understand the effects of robot motivation on modified ride-on car driving behaviors. The path towards self-directed mobility for all is not an easy road to travel, however the outcomes of this study suggest that robot motivation might just help us continue to make strides.

References:

Anderson, D. I., Campos, J. J., Witherington, D. C., Dahl, A., Rivera, M., He, M., Uchiyama, I., & Barbu-Roth, M. (2013). The role of locomotion in psychological development. *Frontiers in Psychology*, *4*. https://doi.org/10.3389/fpsyg.2013.00440

Bharatharaj, J., Huang, L., Mohan, R., Al-Jumaily, A., & Krägeloh, C. (2017). Robot-Assisted Therapy for Learning and Social Interaction of Children with Autism Spectrum Disorder. *Robotics*, *6*(1), 4. https://doi.org/10.3390/robotics6010004

Campos, J. J., Anderson, D. I., Barbu-Roth, M. A., Hubbard, E. M., & Witherington, D. (2000). Travel broadens the mind. *Infancy*, *1*(2), 149–219.

Conti, D., Di Nuovo, S., Buono, S., & Di Nuovo, A. (2017). Robots in Education and Care of Children with Developmental Disabilities: A Study on Acceptance by Experienced and Future Professionals. *International Journal of Social Robotics*, *9*(1), 51–62. https://doi.org/10.1007/s12369-016-0359-6

Deublein, A., Pfeifer, A., Merbach, K., Bruckner, K., Mengelkamp, C., & Lugrin, B. (2018). Scaffolding of motivation in learning using a social robot. *Computers & Education*, *125*, 182–190. https://doi.org/10.1016/j.compedu.2018.06.015

Feldner, H. (2019). Impacts of early powered mobility provision on disability identity: A case study. *Rehabilitation Psychology*, *64*(2), 130–145. https://doi.org/10.1037/rep0000259

Feldner, H. A., Logan, S. W., & Galloway, J. C. (2016). Why the time is right for a radical paradigm shift in early powered mobility: The role of powered mobility technology devices, policy and stakeholders. *Disability and Rehabilitation: Assistive Technology*, *11*(2), 89–102. https://doi.org/10.3109/17483107.2015.1079651

Fitter, N. T., Funke, R., Pulido, J. C., Eisenman, L. E., Deng, W., Rosales, M. R., Bradley, N. S., Sargent, B., Smith, B. A., & Mataric, M. J. (2019). Socially Assistive Infant-Robot Interaction: Using Robots to Encourage Infant Leg-Motion Training. *IEEE Robotics & Automation Magazine*, *26*(2), 12–23. https://doi.org/10.1109/MRA.2019.2905644

Fridin, M., & Belokopytov, M. (2014). Embodied Robot versus Virtual Agent: Involvement of Preschool Children in Motor Task Performance. *International Journal of Human-Computer Interaction*, *30*(6), 459–469. https://doi.org/10.1080/10447318.2014.888500

Huang, H., Chen, Y.-M., & Huang, H.-W. (2017). Ride-On Car Training for Behavioral Changes in Mobility and Socialization Among Young Children With Disabilities: *Pediatric Physical Therapy*, *29*(3), 207–213. https://doi.org/10.1097/PEP.0000000000000426

Johnson, J. (2003). Children, robotics, and education. *Artificial Life and Robotics*, *7*(1–2), 16–21. https://doi.org/10.1007/BF02480880

Logan, S. W., Feldner, H. A., Bogart, K. R., Goodwin, B., Ross, S. M., Catena, M. A., Whitesell, A. A., Zefton, Z. J., Smart, W. D., & Galloway, J. C. (2017). Toy-Based Technologies for Children with Disabilities Simultaneously Supporting Self-Directed Mobility, Participation, and Function: A Tech Report. *Frontiers in Robotics and AI*, *4*. https://doi.org/10.3389/frobt.2017.00007

Logan, S. W., Feldner, H. A., Galloway, J. C., & Huang, H.-H. (2016). Modified Ride-on Car Use by Children With Complex Medical Needs: *Pediatric Physical Therapy*, *28*(1), 100–107. https://doi.org/10.1097/PEP.0000000000000210

Logan, S. W., Hospodar, C. M., Feldner, H. A., Huang, H.-H., & Galloway, J. C. (2018). Modified Ride-On Car Use by Young Children With Disabilities: *Pediatric Physical Therapy*, *30*(1), 50–56. https://doi.org/10.1097/PEP.0000000000000468

Logan, S. W., Huang, H.-H., Stahlin, K., & Galloway, J. C. (2014). Modified Ride-on Car for Mobility and Socialization: Single-Case Study of an Infant With Down Syndrome. *Pediatric Physical Therapy*, *26*(4), 418–426. https://doi.org/10.1097/PEP.0000000000000070

Logan, S. W., Lobo, M. A., Feldner, H. A., Schreiber, M., MacDonald, M., Winden, H. N., Stoner, T., & Galloway, J. C. (2017). Power-Up: Exploration and Play in a Novel Modified Ride-On Car for Standing. *Pediatric Physical Therapy*, *29*(1), 30–37. https://doi.org/10.1097/PEP.0000000000000336

Mohammad, S., Khaksar, S., Slade, B., Wallace, J., & Gurinder, K. (2019). Critical success factors for application of social robots in special developmental schools: Development, adoption and implementation. *International Journal of Educational Management*, *ahead-of-print*(ahead-of-print). https://doi.org/10.1108/IJEM-08-2019-0304

Vinoo, A., Case, L. K., Zott, G. R., Logan S. W., & Fitter, N. T. (*In Review*) Design and Piloting of an Assistive Robot for Infant Driving Practice.