

A Stand-Up Guy: Effect of a Sit-to-Stand Modified Ride-on-Car on a Child with Down
Syndrome

by

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A THESIS

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Abstract approved:

Dr. Samuel Logan, PhD

Purpose: The purpose of this study is to determine the feasibility for an infant with Down syndrome to use a modified ride-on car that encourages the physical skills of pulling from sit-to-stand and standing with assistance. **Method:** An 8 month old boy, Child B, was video recorded during the 11 month study, using his modified sit-to-stand ride-on car. **Results:** For a majority of the study, Child B demonstrated increased movement, including transitions to standing, increased socialization, and general enjoyment when using the modified ride-on car. **Conclusions:** The sit-to-stand modified ride-on car is a feasible assistive technology for children with Down syndrome under the age of 1, as it helps keep the child in an upright position and the child enjoys using the car in their daily lives. *Key words: mobility, Down syndrome, male, infant, single-subject research design, socialization, ride-on car.*

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I understand that my project will become part of the permanent collection of Oregon State University, Honors College. My signature below authorizes release of my project to any reader upon request.

Aparna Govindan, Author

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A Stand-Up Guy: Effect of a Sit-to-Stand Modified Ride-on-Car on a Child with Down Syndrome

INTRODUCTION

Physical activity can aid in improvement of social and cognitive skills, especially in developing children¹. In addition to social and cognitive development, children who engaged in physical activity early on demonstrate long lasting skeletal benefits, such as healthy bone mass^{2,3}. Typically developing children progress naturally through motor development, and thus are able to obtain known benefits of age-related motor behaviors. Children, especially infants, use locomotion, object interaction and sitting to explore their environment and gain knowledge³. Children with disabilities, however, may have limited mobility and thus often experience developmental delays⁴. One population that experiences delays in the onset of independent locomotion is children with Down syndrome².

Down Syndrome

Down syndrome is a relatively common chromosomal anomaly, and occurs when there is an additional chromosome or half chromosome copy of Chromosome 21⁴. This additional genetic material leads to common physical features such as small stature and reduced muscle tone among other health complications⁴. This is one of the few genetic disabilities that is clearly identified at birth⁴. According to the Center for Disease Control and Prevention (2017), about one in 700 infants are born with Down syndrome, with about six thousand infants born with the condition every year³.

Children with Down syndrome experience developmental and learning delays. Though not all areas are affected equally, children with Down syndrome experience cognitive, behavioral and social delays compared to typically developing children⁵. Cognition includes mental

processes such as those involved in perception, socialization, memory, and language¹². Children with Down syndrome can additionally present with delays in language development and comprehension. Social development can be relatively less delayed than other types of development, as infants with Down syndrome can generally babble and gesture in social situations. Infants with Down syndrome also experience delays in motor development which generally affects their ability to sit, stand, and explore their environment relative to typically developing children.

Children with Down syndrome are often at greater risk of fractures because they do not utilize their lower limbs as often as typically developing children⁵. In addition to experiencing delays in motor development, children with Down syndrome are often less active than typically developing peers⁵. Delay in motor skill development can additionally lead to decreased balance, as well as lack of postural control, which can restrict movements and keep the child from exploring their environment¹⁰.

Early physical activity is important for the overall motor development of a child⁴. The earlier children demonstrate active motor behaviors, the sooner they generally start to walk⁴. Studies have shown that once a child begins to sit up, they are then able to come to a standing position⁴. Then, the ability to stand leads to the child starting to take their first steps.⁴ Typically developing children often begin to independently walk between 10-14 months of age⁴. Children with Down syndrome do not begin to walk, on average, until 24 months of age or later⁴. There are several interventions that exist for development of motor abilities, including supported stander programs and treadmill interventions.

Standers

There are several devices that help children with various disabilities to engage in the physical skill of standing, a precursor to independent walking. To assist in the development of mobility in a child with a disability, for example Down syndrome, passive standers have been used⁵. Standers can be used as early as 9 to 10 months of age¹⁴. The standers consist of support straps, a flat surface to support the spinal cord, and the ability to tilt the flat surface into vertical position⁵. Passive standers are used to place non-ambulatory children into an upright position to encourage weight bearing with the intention of providing mechanical forces necessary for healthy bones⁵. The use of standers has also been found to improve the range of motion of children's lower extremities, hip biomechanics, and spasticity¹⁴.

In a study conducted by Herman, et al. (2007)⁵ weight-bearing loads by children with cerebral palsy in the standers were continuously measured in 19 children, ages ranged from 2 to 4, during routine thirty minute standing sessions⁵. These standers were selected for each individual child by a physical therapist⁵. Results suggested that the type of standers used can affect the ability to hold weight-bearing loads, therefore the immediate results of the study were inconclusive⁵. However, the study suggested that reported benefits of the standers include diminished spasticity, improved circulation, improved behavior, and more rapid gross motor development⁵. Similarly, supported standing programs for people with spinal cord injuries or mobility related disabilities allowed for improved range of motion and reflex responses⁶.

Prolonged standing can either be defined as active or passive standing⁶. Active standing refers to the involvement of muscles to help and maintain the standing position, through the use of assistive devices, such as crutches or braces⁶. Passive standing refers to standing that depends on a device to bring them to standing position and to hold them passively in that position, such as a standing frame⁶. In addition to the development of healthy lower limbs and trunk, the use of a

device to encourage prolonged standing can also reduce swelling, assist in reduction of muscle spasms, and allow for better self-care, such as better breathing and digestion⁶.

There are some reported limitations to the use of support standing programs. When using a stander children often experience limitation in movement, as the child moves slowly and not far¹¹. Some standers also may not be practical to be used in the child's everyday life, due to the size of the stander or the design¹¹. There is also no set standing program, and often the type of standing intervention used depends on the child¹⁴. Another type of intervention has focused on promoting the onset of independent walking through body weight supported treadmill training with infants with Down syndrome.

Treadmill

A study conducted by Lloyd et al. (2007) included infants with Down syndrome randomly assigned to two different treadmill interventions designed to promote walking⁷. Participants were put in a high intensity and a low-intensity training group. The high intensity group used the treadmill intervention by progressively increasing the belt speed, time, and the addition of ankle weights⁷. The low-generalized intensity group used the treadmill intervention at a lower speed, for less time⁷. Their results indicated that there is a relationship between doing high intensity leg movements at 12 and 14 months and the ability to walk earlier in life in infants with Down syndrome⁷. This study also indicated that in children with and without Down syndrome, the earlier leg activity and development that they have, the sooner the attainment of independent walking⁴. More extensive activity with the child's leg was the main factor that significantly related to the onset of walking. It was also hypothesized that the lower intensity treatment would result in a slight delay in the early stages of walking⁷. The higher intensity treatments could possibly allow for the emergence of better motor skills allowing for more

complex movements and activities by the child⁷. This study illustrates the importance of treadmill interventions in children with Down syndrome, as well as the benefits of physical activity⁷.

Body weight supported treadmill training is becoming a more popular form of pediatric physical therapy to develop motor skills and encourage the onset of independent walking⁴. This type of intervention can help improve self-generated and spontaneous movements, which can influence the development of critical subsystems for motor development⁴. Angulo-Barroso and colleagues conducted a study (2007) that included children with Down syndrome were followed longitudinally from initial enrollment in the study to until 12 months of independent walking experience. Infants were divided into the higher or lower intensity groups. Physical assessments occurred about every 2 months and the infants' parents were asked to record an activity log for each session. The treadmill intervention for both groups ended when the infants could take three individual steps on the ground⁴. The results of the study indicated that the children given the higher intensity treadmill intervention demonstrated an earlier onset of independent walking⁴. The treadmill intervention was given in addition regular pediatric physical therapy, and was able to stimulate a physical drive in these infants⁴. The authors speculate that increased endurance, increased muscle strength, and better movement efficiency is causing this physical drive⁴. Over the course of the study, a year, the magnitude of trunk and leg activity increased⁴. The treadmill intervention illustrates the impact that a stronger trunk can have on a child's ability to walk, and also highlights the need for more ways to develop this strength⁴. Limitations with this type of intervention include the child being limited to a specific area without being able to explore their environment, and the treadmill cuts down on the amount of social interactions the child could have in a public setting¹². Treadmills also average around \$1,200 for one device, making it inaccessible for many children and their families⁴. One way to develop trunk strength and have the child physically move to new locations could be through the use of modified ride-on cars. An emerging intervention that attempts to replicate the supported standing, leg movements, and

supported body weight in the treadmill interventions is through the use of a novel modified ride-on car that is used for mobility and standing⁸.

Modified Ride on Cars

Modified ride-on cars can be used for increased mobility, and allow children with various disabilities to socialize with family and peers⁸. There are no commercially available powered mobility devices, such as motorized wheelchairs, for children 2 years old and younger⁸. Modified ride-on cars developed by the Go Baby Go⁸ organization feature cars that can be used with children younger than 2 years old, and they can be individually modified to suit each child's disability. Go Baby Go is a community based outreach, research and treatment program that works with families and clinicians in order to provide pediatric equipment to children with disabilities to encourage movement, mobility and socialization⁹.

Modified ride-on car designs range from cars that have been electrically modified to move with the push of a button, to cars that have a switch located in the seat that, when the child stands up, allows the car to move. Depending on the type of disability that the child has, each of the cars can be modified to help improve development. Ride-on cars can be purchased from any toy store and electrically and mechanically modified as needed. One big button is installed to activate the car, and PVC, swimming kickboards, and velcro are used for seating support. Pool noodles are also added to the cars to provide back support and comfort as well. The total cost of these modified cars comes to about \$200 dollars, which, compared to the cost of an average assisted mobility device⁸ can make this an affordable, easy option for families with children with disabilities. The cars can also easily be modified by the child's parents and come with modification instructions from the Go Baby Go organization⁹.

Besides physical mobility, the use of the modified ride-on car can have a profound influence on the social interactions of a child. In past studies, children that have used the modified ride-on cars have experienced more attention from their peers, as well as better connection with their siblings. This can be demonstrated in a case study by Logan et al. (2014)⁸ where a 13 month old girl with Down syndrome, Natalie, and her family were video recorded during the 28 week study while she used her modified ride-on car in her own home and in her neighborhood⁷. The child was surrounded by her friends and family when she used the car. At the start of the study, she could independently sit and she crawled as her primary means of getting around⁷. She utilized a modified ride-on car with an altered activation switch, supported seating and adapted steering⁷. There were three main periods during the case study. During the baseline period, the first 12 weeks, Natalie was introduced to the car and modifications were made⁷. The modified ride-on car was not left with the child, but the researcher brought the car with them each visit to lead the recording, car play sessions⁷. The intervention period consisted of another 12 weeks, which was split into two main components, education of the family involved to use the car on their own, and training when the parents were encouraged to work with the child and provide the opportunity for her to use the car daily for about twenty to thirty minutes⁷. The retention period was four weeks long, when the car was removed from the home and once a week, the researcher would return with the car and video record the natural play and car play sessions⁷. These videos were coded for several measures of mobility and socialization. The results of the study indicated that she was approached more by her peers when she was in the car⁷. Additionally, she showed signs of increased mobility and physical capabilities after ride-on car use, and seemed more active and social⁷. This case study clearly illustrates the benefits that a modified ride-on can have for individuals with disabilities.

Another benefit of these cars is that they are also easily transportable, and they can be used in different social settings to encourage interaction between the children with the disability

and typically developing children. The use of these cars on the playground will allow the child's peers to approach and interact with them⁸.

The effect of having the modified cars in a setting such as a playground be demonstrated in a study conducted by Logan, et al. in which social interactions between a group of 42 typically developing preschool children and a 4.5 year old preschooler with a disability (Child A) were monitored in different school settings while the child either used forearm crutches or a modified sit to stand ride-on car⁹. Video recording of the children and Child A were taken in a classroom, where children spent majority of their day, the gymnasium and the playground⁹. Child A typically used crutches in the classroom in order to move around, taking about 4 to 5 steps before leaning on a weight bearing surface. In the gymnasium, when Child A used crutches to move around, they did not interact with their peers much and instead had more teacher interaction and solitary play⁹. This study found that the use of the modified ride-on car in the gym had similar results with little peer interactions occurring. On the playground, when child A used crutches, they spent more time sitting down than standing or moving. The use of the modified ride-on cars, however, allowed the child to engage in 10% more peer interactions when compared to the crutches, as well as 11% decreased teacher interactions⁹. This could have occurred because of the open space of the playground and the car's ability to travel a larger distance than the child would have traveled with the crutches. This study highlights the benefit of using the modified ride-on car for a child with a disability, as it has proved to be a creative assistive technology that can rival existing, traditional assistive technologies such as crutches or walkers.

The combination of a modified ride-on a car and a device to assist in standing led to the development of the sit-to-stand car, which aligns with the outcomes of the passive standers. The button used for the movement of the car can be placed under the child's seat⁹. When the car is in "stand mode", the car will only be able to move when the child is weight bearing and holding

themselves up, off of the seat⁹. When the child sits back down, the car stops moving because the button is pressed, thus encouraging the children to continually stand to keep the car moving. The frequent and prolonged standing may help the children to develop better bone density, as well as encourage the muscle movements of the trunk of their bodies and their lower limbs. Children quickly learn the movements required to move the car and adjust their behavior accordingly. The development of the lower extremities and trunk is crucial for the development of mobility and walking. The ride-on aspect of the car can additionally allow children to engage in social interactions with their peers, and to not only have their peers approach the cars, but they can be used to encourage children with disabilities to use the car to keep up with their peers. Even if the car is not being driven, children would still approach the cars to play with the child⁸. By moving towards or away from their peers, they start to learn how to engage with their parents and their peers and to observe and engage with their surroundings.

PURPOSE OF STUDY

The purpose of this study is to determine the feasibility for an infant with Down syndrome to use a modified ride-on car that encourages the physical skills of pulling from sit-to-stand and standing with support. It was hypothesized that an infant with Down syndrome will (1) demonstrate independent mobility while using the modified ride-on car in the seated and standing modes; (2) enjoy modified ride-on car use; and (3) demonstrate advances in physical, cognitive, and social development. This study tracked behavior of the infant using the cars through ride-on car behavior coding, such as noting when the child is interacting with their peers, vocalizing or learning to drive the car on their own. This descriptive case study is part of a larger study aimed at examining the effects of the sit-to-stand modified ride-on cars for young children with Down syndrome.

Inclusion Criteria:

The child must be 7 months old at the start and entry into the study, with a diagnosis of Down syndrome. The child must have the ability to sit with support. Parents must have time available to participate in the study and consent to video and audio recording. The home assessment criteria have been met and the house is safe for the child to participate in the study.

DESCRIPTION OF THE CASE**Participant:**

This descriptive, longitudinal case report involves an 8-month-old boy, Child B. Informed parental consent and permission for the name and picture to be used in the study was obtained prior to start of study. The family became aware of his diagnosis of Down syndrome when Child B was born at 35 weeks gestation. He had early intervention physical therapy sessions once a month prior to the start of the study. At the start of this study, Child B had limited mobility, only being able to sit without support for 5 seconds. Child B spent a majority of his day with his mom and his older brother, who was 3 years old at the time of the start of the study. The parents chose to participate in the study due to the fact that both children were interested in exploring their surroundings, but Child B was limited in the places he could crawl or due to his limited mobility. His parents were also interested in participating in this study because they wanted to provide Child B with the ability to interact with his peers and family and wanted to increase his mobility as he grew older.

Description of Modified Ride-On Car

The sit-to-stand modified ride-on car model was made from off-the-shelf, 6V battery operated, ride-on car⁹. The car used in this study is a Fisher-Price “Mater” car. These style cars usually have the activation switch on the handlebars to move the car while seated⁹.The switch

needed to be pressed by the child in order to move forward. To modify the drive system, a SparkFun© Big Dome momentary push button (\$9.95 typically)⁹. The internal switch from the push button was removed and placed underneath the seat⁹. This switch is unique in that the switch circuit is closed, meaning the switch when pressed is inactive⁹. For the car to move forward, the child needs to pull or move towards a standing position to activate the switch. There are several different positions to place the switch on the seat, accommodating children of various sizes. The major feature of the car's modifications is the installation of the "double pole, double throw" switch⁹. This toggle switch allows for the car to be used in standing mode, sitting mode, or completely off. The seating and support system is very similar to the seated, modified ride-on cars⁹. PVC pipe, kickboard, and feet support straps were added in order to help Child B remain in standing position without sliding down. Additionally, Velcro was available to help support at the pelvis and trunk to hold the child in an upright position.

Description of Study Periods

Initial visit

In the initial visit, the researcher brought along the sit-to-stand modified ride-on car to the first meeting. This allowed the child to explore the features of the car and become acquainted with its movements. The modified ride-on car was also adjusted to the child's personal needs, such as adding in PVC to physically support the child in the car, as well as seat belts. The researcher and family also determined where the modified ride-on car could be safely used, such as outside around the neighborhood community and different areas of their home.

Baseline (2 Month period)

During the baseline period, the car was not left with the child at home in order to monitor their movement before the use of the car. The researcher would continue to visit bi-weekly.

Intervention (11 Month period)

Child B's family was encouraged to provide him with daily 20 to 30 minutes of modified ride-on use that included time for exploration, goal oriented driving, and play-based activities with his brother, parents, and other family and friends. Each bi-weekly visit by the researcher included time to discuss Child B's driving experiences and to work together to create new and interesting activities. Child B's family was encouraged to gradually shift Child B's use of the modified ride-on car from the seated mode to the standing mode as his physical skills developed.

PROCEDURE

All procedures were approved through the Oregon State University Institutional Review Board. For the first two months, the car was left in the child's home, and the child drove the car whenever they had free time. During this time, their parents were to monitor and track their driving, with the goal being for the child to drive the car for at least 30 minutes per day, 5 to 6 days a week. The researcher, biweekly, would then record the child using the modified sit-to-stand ride-on cars in order to behavior video code. The recordings were 10 minutes long, and featured the child interacting with the car, driving the car, and responding to the people around them. During these videos, the children are encouraged to interact with their environment while in the car, such as reaching for toys and specifically driving towards people or objects. Monthly physical assessments were done to monitor the child's developmental progress (Appendix 2).

Dependent Measures:

Videos of 10 minutes were coded as well as standardized assessments to track Child B's mobility and socialization. Child B's parents completed a daily activity log throughout the study. Measures are reported below and were obtained through video coding of the sessions.

Mobility Measures:

1. Driving categories: Percentage of time and total time (minutes and seconds) of a 10 minute Car Play session that Child B spent in the following categories:
 - a) *Independent mobility*: Child B drove the ride-on car by independently activating the switch without adult assistance.
 - b) *Assisted mobility*: Child B independently drove the ride-on car after an adult initiated switch activation for the sit/stand mode.
 - c) *Caregiver mobility*: Child B drove the ride-on car with an adult's direct assistance, either holding his hand down on the switch or holding him in a standing position.

Socialization Measures:

1. Social Interaction: The number of times that the child either initiated interaction with an adult or a peer, or had an adult or peer initiate interaction with them.
 - a) *Peer-peer initiated*: A peer initiated contact with Child B for longer than 3 seconds
 - b) *Peer-subject initiated*: Number of times Child B initiated interaction with his peers.
 - c) *Adult-adult initiated*: An adult initiated interaction with Child B, ex. Handing a toy to him, waving at him, and talking to him directly.
 - d) *Adult-subject initiated*: Child B communicated with an adult during the session directly. Ex. Handing a toy to them, holding their hand or giving a hug.
2. Positive Facial Expressions: The number of positive facial expressions including smiling or laughing.
3. Negative Facial expressions: The number of negative facial expressions including signs of discomfort or crying.

Daily Activity Log and Questionnaires

The daily activity log included a fun index to reflect daily training time, the location of driving for that day, and general activities that might have occurred when the child was in the car. This index was used to reflect how their parents viewed their enjoyment during the driving sessions. Parents were able to score each play session from 1 to 10, with 10 representing the highest level of fun (Appendix 3).

The Coding Manual

The coding manual used for this study is included in Appendix 2. This manual states the guidelines for the inter-coders for this study to standardize behavior coding. The 10 minute videos were broken into a maximum of 1 minute periods, noting whether or not the child was using the cars. Mobility was determined if the child was able to drive the car for longer than 5 seconds. Any less than 5 seconds, and mobility was not counted. If the videos were longer than 10 minutes, coders stopped video coding at 10 minutes. During this coding, a number of categories were coded for, including time spent driving, gestures the child makes, if they drive towards a goal (such as a parent or object), how often they are prompted by their families and their overall visual attention.

Coder's Criteria

Three student researchers established intra- and inter- rater reliability for behavior coding. Each of the student coders were asked to code the same small number (10%) of videos as the lead researcher. During these videos, the coders monitored the child's behavior and coded according to the different categories given in the coding manual. The coders then compared the numbers of each category they had against the numbers of the lead researcher. If the student researcher had about 85% of their overall coding the same as the researcher, they were

determined to be reliable. They were then allowed to code videos of the children themselves, using the coding manual as guideline.

Video Behavior Coding

For the purposes of this paper, three main coding dimensions of the sit-to-stand behavior coding was focused on, such as 1) The child’s ability to drive, either independently, assisted by their caregiver or with complete dependence on their caregiver, 2) The social interactions that occurred when the child was with the car during the 10 minute coding session, either with their peers or an adult, 3) The child’s facial expressions during the 10 minutes, whether the expressions were negative or positive The daily activity log was also used, or a “fun index” to determine daily training time, location of the driving, and general activities of the child.

RESULTS:

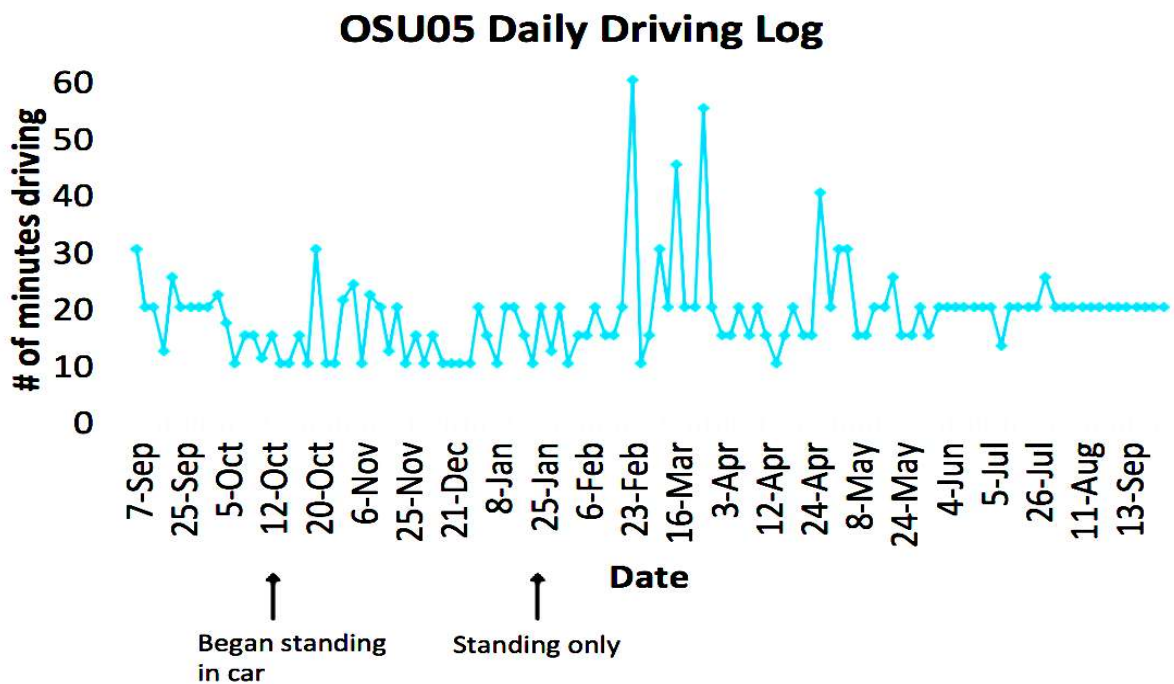


Figure (1): Driving log: The minutes that Child B drove per session over the course of the study is plotted here. This log tracks his daily modified ride-on car usage at home over the course of the study, when he was not being video recorded. This is when the child was not being video recorded, but rather when the child was using the ride-on car at home over the course of the study.

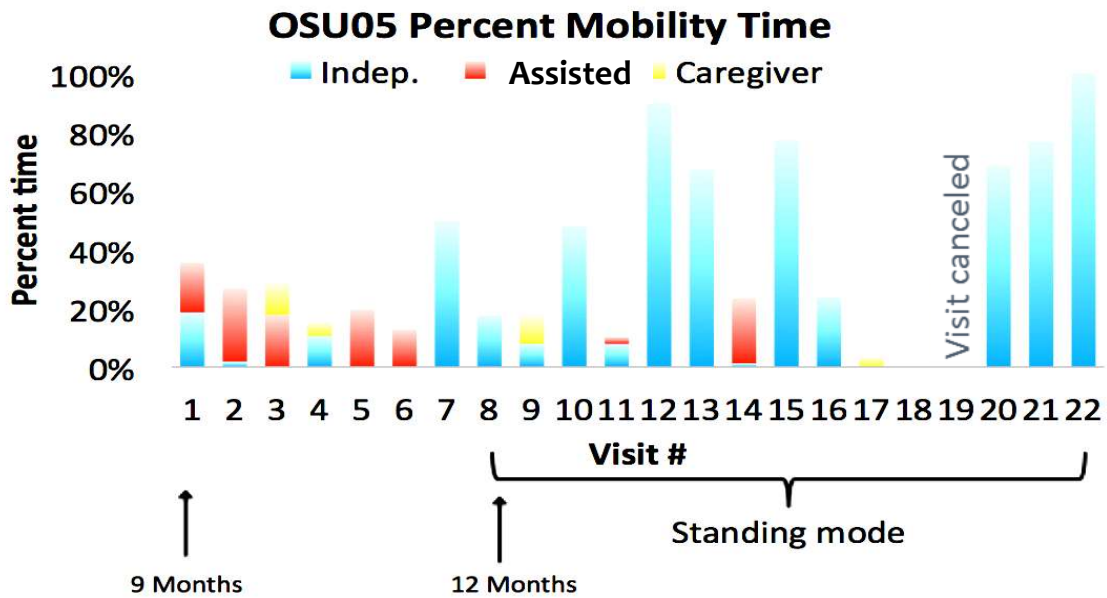


Figure (2): Type of Mobility: mobility that occurred during each of the video recorded driving sessions, in percentages of driving time in each mode. There were a total of 19 sessions, with 10 minutes coded for. A trend can be observed as Child B, as he started independently driving after session 6, after using the assisted driving mode from sessions 1-5. In session 18, there was no significant driving time recorded.

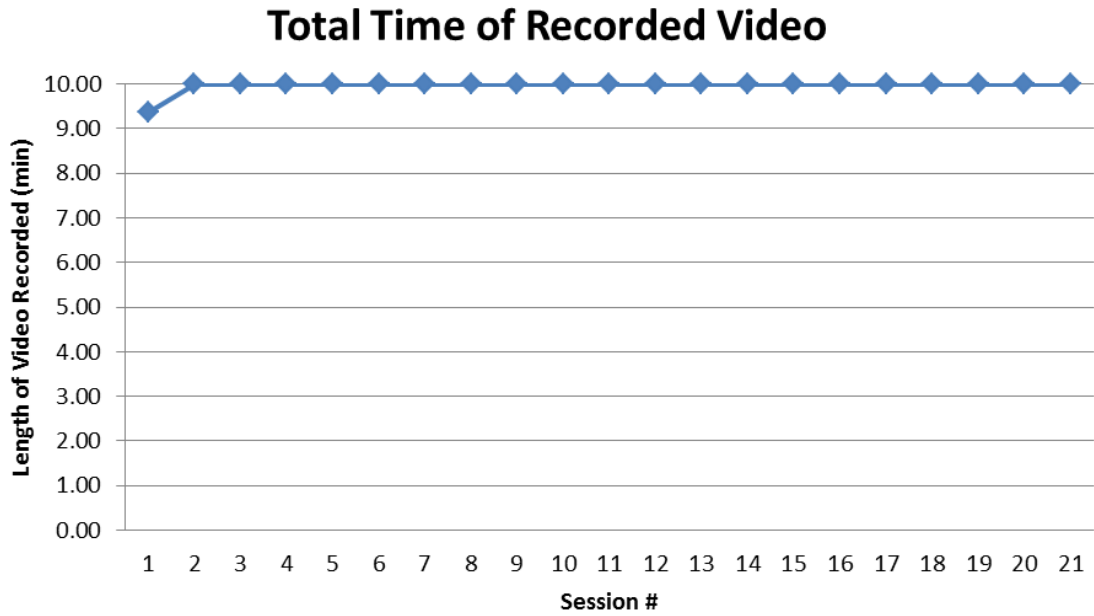


Figure (3): Total length of the video's recorded in minutes. The initial video recorded last about 9 minutes and 36 seconds, while every recording session after that lasted the full 10 minutes.

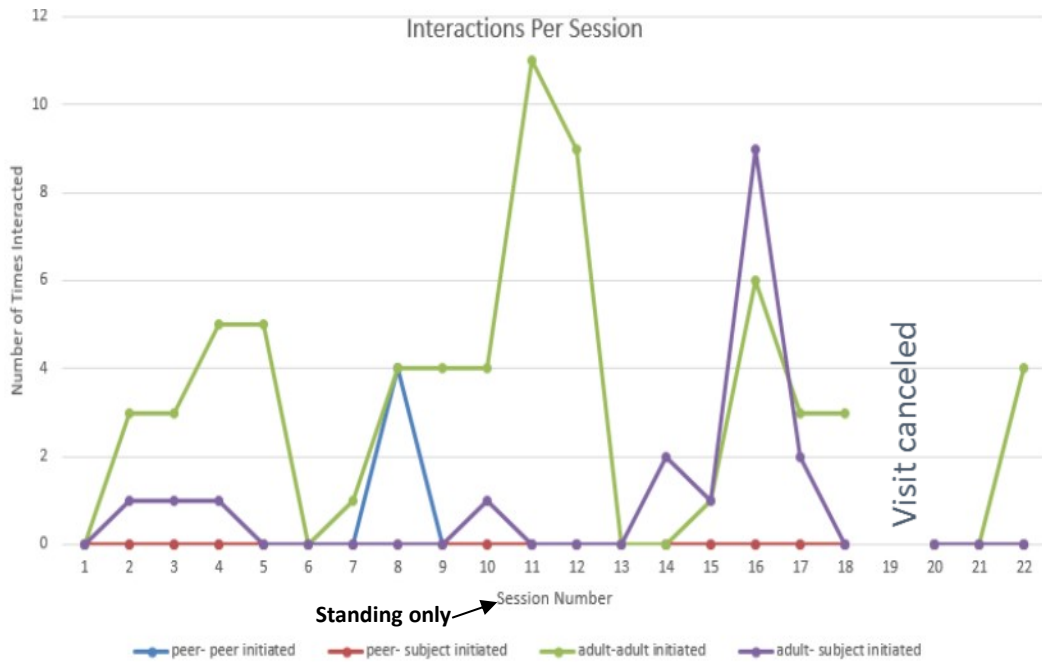


Figure (4): Social interactions that occurred during the sessions: Child B was with his mother for a majority of the sessions, and as he drove around his neighborhood, he often interacted with other children and with other adults as well. The green trend represents the communication that he had with his mother, such as her handing him a toy bat, smiling at him, talking to him or helping him navigate or drive during the sessions.

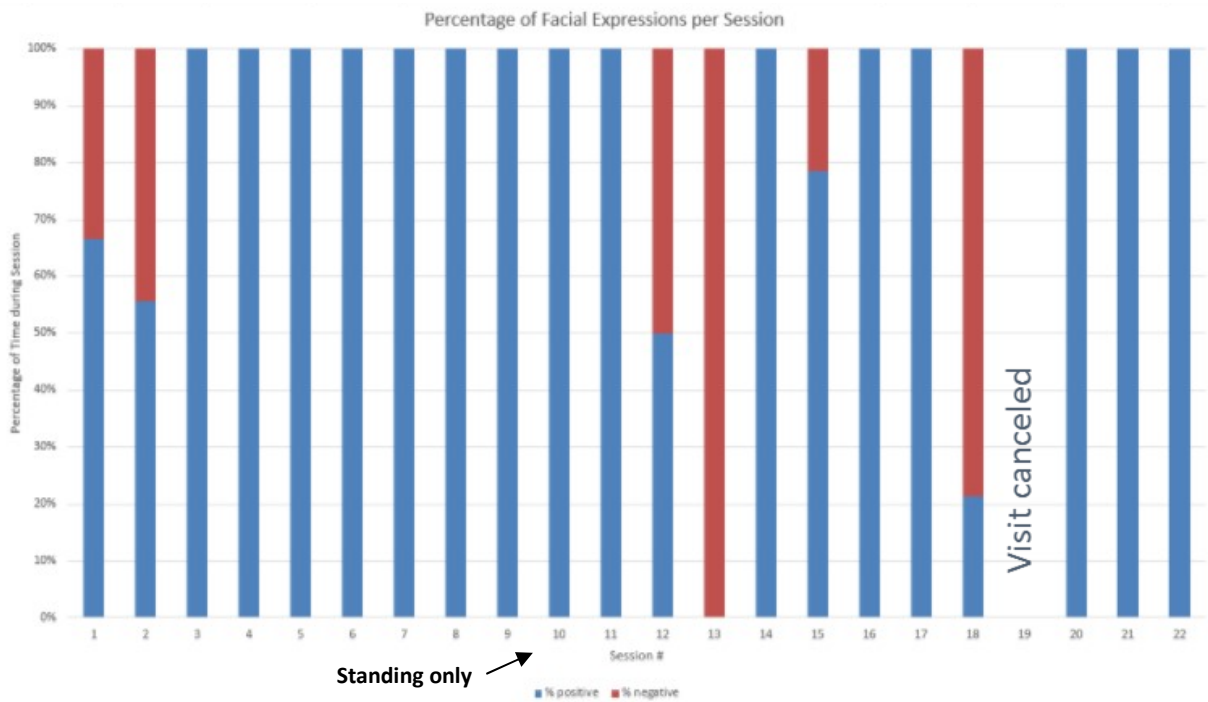


Figure (5): Facial Expressions: Child B's positive and negative facial expressions are plotted here. Around session 12, when Child B switched to spending a majority of time in the standing mode, there is a large spike in positive expressions.

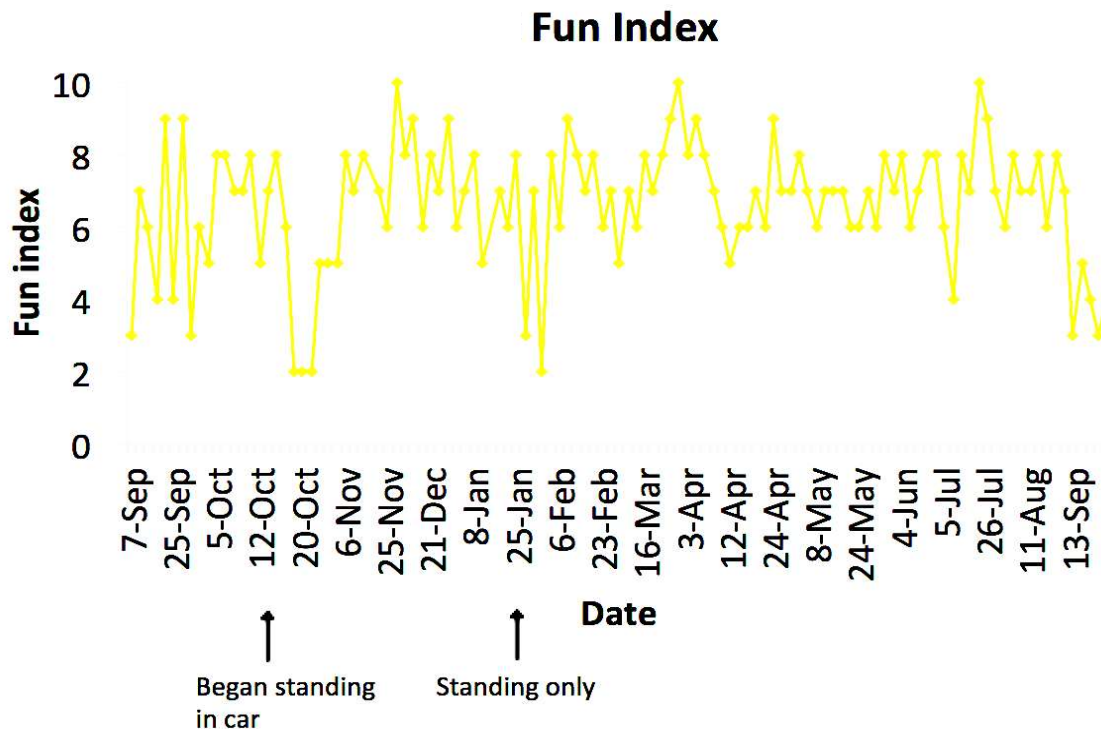


Figure (6): Fun Index: The minutes spent driving is plotted against the number that the parents indicated in their daily surveys, with one number from 1-10 indicating the level of fun that Child B had. This is when the child was not being video recorded, but rather when the child was using the car at home over the course of the study. The days indicated correlate with the driving log in Figure 1. The results indicate that Child B’s fun index was rated at a mean of 6.6 throughout the study, indicating a relatively higher rate of fun as he drove.

DISCUSSION

The purpose of this study was to determine the feasibility for an infant with Down syndrome to use a modified ride-on car that encourages the physical skills of pulling from sit-to-stand and standing with assistance.

It was hypothesized that an infant with Down syndrome would demonstrate independent mobility while using the modified ride-on car in the seated and standing modes. As indicated in

Figure 1, it was observed that Child B switched to standing more after January 25nd, roughly halfway into the study. After the switch occurred, Child B mostly spent the rest of the study in standing mode. Session 11, according to Figure 5, indicated a higher percentage of assisted standing mode in which his mom helped him move to standing position. After session 11, Child B was able to come to a standing position on his own and continued to move each session. He began to walk on his own around the age of 24 months, which was determined by the researcher when he was able to take three independent steps. Children with Down syndrome typically start to walk around when they are around 24-28 months old⁸.

It was also hypothesized that the child will enjoy modified ride-on car use throughout the study. This is evident in Child B's driving log. Child B's family reported that much of the driving, due to the limited spaces in the house, was done around the neighborhood and in a park by the house. The most frequently reported activity was driving through the park with his mom and his older brother in the afternoon or morning. Child B spent time driving his modified ride-on car each week except in cases when he was too sick, tired, or uncompliant. His family reported a total of 2146 minutes over the span of 80 days. The days are non-consecutive, meaning that recording or use of the fun index was not entirely consistent. The parent-rated fun index shows that Child B enjoyed driving during his modified ride-on car sessions, illustrated by a fun index mean of 6.6 ± 1.0 (Figure 5). Additionally, Child B's facial expressions throughout the study, as seen in Figure 4, were mainly positive with the exception of a few days where Child B was noncompliant due to tiredness. The large spike in the number of positive facial expressions around session 14 is around the same time that he switched to standing for the majority of recording time. The number of positive facial expressions Child B exhibited illustrates the overall enjoyment that he had when he was using the car.

The amount of socializations with his family and peers was improved as he moved around with the modified ride-on car. When the child, around 12 months of age, switched to standing mode, he initially interacted with his mom more, as she was encouraging him to move to a standing position. As he continued to drive in standing mode, there was a spike in subject initiated adult interaction. This could indicate that because the child was confident enough to move to and remain in an upright position, he was able to focus on the people around him, thus increasing his socialization.

The use of the modified ride-on car is particularly beneficial for child with Down syndrome, who are non-traditional candidates for power mobility⁵. This study not only focuses on social benefit from using the modified sit-to-stand ride-on car, but it also focuses on the child's enjoyment as well as the ability of the child to move to a standing position.

Modified, seated ride-on cars have previously been studied by Logan, et al (2014) in which Natalie, a child with Down syndrome was video recorded during a 28 week study using her modified ride-on car in their home and community. The study consisted of a baseline period where modifications were made to the car, and the car was not left with the child, an intervention period when the car was left with the family and the child was encouraged to drive 20 to 30 minutes per day. The following retention period was when the car was removed from the home, only brought during the 10 minute recording sessions, and Natalie's mobility and socialization were observed to determine the importance of the modified ride-on car during a period when she did not have daily access to it. This study found that Natalie's independent mobility increased over the course of the study, as well as her total driving time. This could indicate that she enjoyed using the car, as her positive facial expressions also increased over the course of the study. It was also noted that during the retention period, Natalie and her family were affected because she lost the freedom to explore and had to be pushed in a stroller at all times outside, and she had negative

facial expressions due to lack of ability to choose her desired direction when walking around her neighborhood. This study was important in illustrating the effect that ride-on cars have on a child with Down syndrome's mobility, as well as the feasibility of using these cars as an assistive technology.

The only other sit-to-stand ride-on car study that has been conducted was the Logan, et al (2017) playground study with a 4.5 year old with a physical disability previously discussed, and mainly focused on social interactions of the child. The comparison in that study was how his social interactions differed when the child used crutches versus the modified ride-on car in different spaces in the child's school, like the gymnasium, classroom or playground⁸. It was found that in the gymnasium, the child engaged in less solitary play when he was using the ride-on car than with the crutches⁸. On the playground, Child B engaged in 10% more peer interaction when using the modified ride-on car, and had 11% less teacher interaction than when he used the crutches⁸. The results indicate the convenience and effect of the modified ride-on car in the child's life. This study, while using the sit to stand car, focused solely on the social interactions and general movement of the car, but not the child's own mobility.

Compared to these other modified ride-on car studies, as well as other studies involving leg movements, this sit-to-stand study is unique in several ways. Child B, at the start of the study, was 8 months old. No studies have been conducted with observing ride-on car use with a child his age group, so this study also studied the feasibility of using the car as assistive tool for younger children. Natalie was about 13 months at the start of the study in the modified, seated ride-on car study⁷. In comparison, children involved in the treadmill training study by Ulrich, et al (2001) were about 2.5 years old; passive standers are typically used when the child is around 2.5 to 3 years of age⁵. Child B was also able to move into standing mode for the majority of the sessions and used the car for a longer amount of time.

In addition to mobility, this study observed how much the child enjoyed using the modified ride-on car. Child B's positive facial expressions and fun index (average of 6.6) increased through the study, determining that for the majority of the study, Child B seemed to enjoy his time with the car. Additionally, the design of the sit-to-stand car tests cognitive ability of the child to move from a seated position to a standing position. Beyond the researcher visits, Child B and his family reported that he drove an additional 2146 minutes. This is comparable to the amount of time that children with treadmill training spent with their device, which was about 8 minutes per day for 5 days a week for the intervention period, but did not use the device outside of their observed sessions. This amount of time could indicate that Child B enjoyed using the toy car, and was interested in driving it around. Through his interest in playing with the car and using it, he was working on developing his physical strength as well.

This illustrates the large potential that the sit-to-stand ride-on car has as an alternative assistive technology. The design of the car, as well as the ability to use it in any setting, was instrumental in allowing him to not only develop physically and walk earlier, but also move to a setting that encourages him to interact with the people around him.

Studies involving movement of the legs of children with various disabilities, including Down syndrome, have been previously conducted. A study conducted by Chen, et al. (2010) focused on a design of a novel mobility device for infants, a mobile robot that was activated by a child's kicking and feet movements¹². They found that the subject progressed continually in social and cognitive skills over the course of the study. The physical device design differed from Child B's model, as the child was laid down on the device, with the ability to freely kick their legs. The car would then sense the leg movements and move forward, and the child would use the joystick to steer the car in a desired direction¹². This was thought to be a suitable way to improve leg strength, as leg movements require gross movement instead of fine motor abilities¹⁵.

Similarly, in “Design of a novel mobility device controlled by the feet motion of a standing child: a feasibility study” by Schoepflin et al. (2011), children with various disabilities were placed in either a standing or a sitting position, and required minimal leg movements that mimicked walking in order to activate the car¹³. The car was a two wheeled driven system, with sensors used to track movements of the child. The child could then lean on the robot for partial or complete body support¹³. The data suggested that the child with the disability was not necessarily hindered in driving the assistive device as one might have initially believed¹³. All of the children were able to purposefully drive the device, suggesting that the device was easy to use¹³. The physical design of the car, however, could be frightening to the child because the shape of it is not something that a child would immediately recognize due to the clunky metal supporting the frame. This device might also draw attention to the child because it does not look like something that a child would typically use in their everyday life.

In comparison to Child B’s car, the car used by Chen et al., was larger and involved hooking up the child’s feet to the robotic sensor¹². The car and research design also focused on the movement of the child’s leg, instead of developing the strength of the child to pull themselves up to a standing position as this sit-to-stand study did. Compared to Schoepflin’s novel mobility device, Child B’s car is easily recognizable, as any modifications are made directly on a commercially available ride-on car. His car could also blend into their everyday settings and children around them would immediately recognize it as a toy. Not only could these proven beneficial assistive cars help a child physical develop, but they can help a child engage more with the people around them, while enjoying the use of the cars in familiar settings.

CONCLUSION

The results from this study illustrated the importance of understanding how mobility affects social communication, cognitive abilities, and physical development in a child with Down

syndrome. This case study provides evidence of how the modified ride on cars helped Child B interact with the people around him and practice switching from sitting to standing, while having fun using the car. This lends to the idea that developing more assistive technologies such as these modified cars and conducting further research into these technologies can be beneficial to the development of children with disabilities early on in their lives.

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APPENDICES

Appendix 1: Coding Manual

Sit-to-Stand Ride on Car Project: Coding Manual

- What you will need to start:
 - Paper coding template
 - Found in pink binder on desk in lab labeled “STS blank data sheets”
 - Pencil
 - This coding manual
- Start by:
 - Find the hard drive labeled “STS #1”
 - Log into the computer that you signed up to use for coding today.
 - Login: student
 - Password: socialmobilitylab
 - Plug in the hard drive via USB to the computer. It is called LaCie.
 - Open the folder named “STS to code” on the hard drive.
 - Select a video from this folder and record the information at the top of the data template as described below.
 - Please note is there is a clip number for the video. This will be at the end of the name of the video (i.e 1-2, 2-2, 4-5, etc.), if so please code all the clips for the video.
 - I recommend using Quicktime.
 - Note: if there are multiple students coding at the same time, please communicate before you begin for the day which videos you will be coding to avoid replication.

- On top of every template page, write:
 - Today’s date
 - Your name (coder name)
 - Subject ID
- For every video, record:
 - Date of video
 - Visit number (i.e. A1, D3, etc.)
 - Clip number (i.e 1-2, 2-2, 4-5, etc.), if applicable
 - This information should all be included in the title of the video file
- Time Frame
 - Every second of each video should be recorded on the coding log.

- The start of one time frame should be the same as the stop for the previous recorded time frame.
 - Each video will only be coded for 10 minutes total time.
 - If the video is longer than 10 minutes, stop coding at the 10-minute mark and make a note of the total video time in the notes section.
 - Start and stop times will be recorded in reference to when mobility starts and stops.
 - Mobility=car moving.
 - Move to a new time frame only when there has been a change in mobility for greater than 5 seconds.
 - i.e. mobility/driving for greater than 5 seconds will be a new time frame.
 - If there is no change in mobility for greater than 1:00 start a new time frame.
 - i.e. the child drives for greater than one minute or the child is not driving for greater than 1 minute.
 - If there are a large number of tallies within a given 1 minute interval, the time frame can be further subdivided into 30 second intervals at the coder's discretion.
 - ex: a child sits in the car for 5 minutes without driving, this would amount to five 1 minutes time frames.
 - You will record time frames and corresponding information in the odd numbered (unshaded) rows.
 - The even numbered (shaded) rows will be used for checking your work, by rewatching a time frame and recording in the shaded row, you can double check that your tallies are the same.
- Notes section
 - Throughout coding include descriptive information for each time frame.
 - This will help to give a better idea of what is happening during the time frame, it does not replace the tallies or coding, but gives a more subjective description.
 - ex: what the child is looking at (enviro. Specific #9d), reached out towards Mom (gesture #8)

Coding will include the following elements:

1. Mobility

- If this time frame is during driving place a check mark in the appropriate type as described below:
 - a. **Independent Mobility:**
 - Independent mobility is when the child is driving after an independent switch contact. If the child places his or her hand on the switch independently and begins to drive, count that as independent driving.

b. Assisted Mobility:

- Assisted mobility again follows an assisted switch contact. This time, though, the person removes their hand and the child is able to drive without additional help. In summary, someone puts their hand on the switch, but then removes their hand and the child is able to drive independently.

c. Caregiver Mobility:

- Caregiver mobility is when the child is driving after an assisted switch contact and someone holds the child's hand on the switch the entire time to help them drive.

2.

Prompted Mobility (Tally):

a. **Total # prompts**

- For every time someone encourages the child to drive (ex. By saying, "come here," "press the button," "get the toy") tally that under the total number for prompted mobility.

b. **# Successful:**

- For every time the child responds to the command by doing as told (ex. By pushing the button, driving to the car), this will be tallied under # successful.

3. **Goal Oriented driving**

- Goal oriented driving refers to the way that the child stops driving the car at a target.
 - The type of mobility used to begin driving (see #1) may differ from the type of goal oriented driving.
 - For instance if a child is given assistance to move their hand to the switch to begin driving, that is coded in mobility #1b as assisted driving, and then stops without verbal cues, it is coded here as independent goal oriented driving.
- If the child stops at a target place a check mark in the appropriate type as described below:

a. **Independent:**

- The child is either given a goal to stop at in advance or goes over to an object they are interested in and stops *without* being told to and *without* any tactile contact to their hand.
- Example: A child sees a toy and begins driving toward it. If they stop at that toy without being told and without anyone's hand on their hand, this would be considered independent.

b. Assisted (giving hints):

- **With Verbal Cue-** In this case, when the child stops at a given goal after only being told verbally to stop at that spot.
 - Example: A child is told to drive to a toy and stop there. If the child is driving and is told to stop right now, that is considered assisted with verbal cue.

- **With verbal + Tactile Cues:** When the child stops at a goal after both verbally being told to stop **and** someone tapping their hand to initiate stopping. This type of goal oriented driving will be considered “Assisted with verbal + tactile contact.”
 - Example: Child is driving to a goal but needs someone saying “stop,” or “take your hand off the switch” combined with someone tapping their hand in order to actually stop at the goal.

c. Caregiver:

- If the child is driving to a goal but needs someone to physically take his or her hand off the switch in order to stop, this would be considered “Caregiver Goal-oriented Driving.”

4. Switch Contact (Tally):

a. Independent Switch Contacts:

- For every time the child touched the switch or button **without** assistance, that is considered an independent contact.
 - If the child is repeatedly hitting the switch (Ex. If there is spasticity) only count that as one touch.
 - Allow at least 3 seconds between these touches before counting a second touch.

b. Assisted Switch Contact:

- For every time the child touches the switch with verbal cues or a tap to the hand.
- **With Verbal Cue-** In this case, tally the amount of times the child touches the button after only being told verbally.
 - Example: A child is told to drive to a toy and stop there. If the child is driving and is told to stop right now, that is considered assisted with verbal cue.
- **With verbal + Tactile Cues:** Tally the amount of times the child touches the button after both verbally being told to stop **and** someone tapping their hand. . This type of switch contact will be considered “Assisted with verbal + tactile contact.”

c. Caregiver Switch Contact:

- For every time the child touches the switch with assistance (ex. Someone putting his or her hand on it).

5. Social Interactions (Tally)

- Play behaviors were defined according to Howes’ Peer Play Scale.³²
- All play-based, not driving related, social interactions will be tallied in the appropriate column.

a. Peer

- Defined as direct verbal and/or physical interaction with a peer.

- Tally the number of times in each time frame a social interaction is observed either
 - Initiated by the peer
 - Initiated by the subject

b. Adult

- Defined as direct verbal and/or physical interaction with a parent or other adult.
- Tally the number of times in each time frame a social interaction is observed either:
 - Initiated by the adult
 - Initiated by the subject

6. Facial Expressions (Tally):

a. Positive

- **Tally** the amount of times the child makes positive facial expressions, for example, they smile. If the child remains smiling over a period of time, that still remains the same tally.
- Allow **at least 3** seconds between two positive facial expressions before tallying it as a second.
- Example: The child is smiling for several seconds and then her face goes neutral. If the smile begins again immediately, count that as the same tally. However, if a full 3 seconds pass between the expressions, it can be counted as a second.

b. Negative

- Apply the same rules for positive facial expressions to this measure, as well. However, this time record negative facial expressions such as frowning.

7. Vocalization (tally):

- Whenever the child expresses a desire verbally, cries, or makes another sound that demonstrates they are trying to express something, **tally** that under vocalization.
- Allow **at least 3** seconds between two verbalizations before tallying it as a second.

8. Gesture (tally):

- When the child points or motions for something, this will be considered a gesture. When they are continually gesturing for the same thing, that will still only be considered one tally.
- Example: Child is pointing at a toy. That will be considered a gesture. If the child is continuing to point at the toy because someone doesn't understand what he or she are asking for, it is still only considered one tally.

- When possible, describe the gesture or what the child is reaching towards in the notes section.

9. Visual Attention (tally)

- Visual attention is a tally of the frequency that the child looks at something. The three-second rule will be applied.

a. Switch:

- Whenever the child makes eye contact with the switch, this is considered visual attention to the switch.
- Allow **at least 3** seconds before tallying it as a second.

b. Person

- Similar to visual attention to the switch.
- Whenever the child makes eye contact with another person this is considered visual attention to another person.
- Specify the person in the notes section in this time frame.

c. Car

- Similar to visual attention to the switch.
- The child is making eye contact/looking at something on the car that is not the switch.

d. Note any other objects of visual interest in the notes section

- Similar to visual attention to the switch.
- The child is making eye contact/looking at something on the car that is not the switch.

10. Drive mode

- Place a check mark to indicate child is driving in either sitting mode or standing mode for that time frame.

11. Driving Location

- Circle the appropriate location in the notes header to describe the environment where the driving is taking place in the video.

12. People present

- Circle all that apply for other people present during the video in the notes header section.

When finished:

- Put completed data sheet in purple binder labeled “STS completed coding data sheets”
- Record your time in the lab on the tracking sheet in the green binder labeled “Student coding hours tracking”

- Move the video that you coded today to the folder on the hard drive labeled “STS coded by students”
- Eject the hard drive from the computer and then unplug it.
- Log out of the computer.
- Put the hard drive away.

Appendix 2: Monthly Assessment

Ride-On Car Home Assessment Agreement

Date: _____ Participant's Initials: _____ Assessor: _____

Appropriate (check off)	Location	Space		Stairs	Objects <i>Bump test</i>	Furniture <i>Bump test</i>	Uneven Surface
		Drive Straight	Turn				
	Basement						
	Living Room						
	Kitchen						
	Bed Rooms						
	Community Space (listed individually)						

Specific Instructions on Appropriate Spaces based on above assessment:

While providing your child opportunities to drive the car in agreed upon safe driving locations, the car must be used appropriately at all times. Examples of inappropriate car use includes allowing siblings or other children to drive the car, otherwise modifying the car, or not directly supervising your child at an arm's length at all times while your child is driving.

Signature for parent agreements on driving areas:

I, _____, voluntarily agree to allow my child to drive only within the locations described above. I understand the risks of allowing my child to drive the car in inappropriate areas. I also understand that the research team can stop the training at any time if there is any inappropriate use of the car during the study period.

(Signature of parent or guardian)

(Date)

SAMPLE

Ride On Car Home Assessment Agreement

Date: _____ Participant's Initials: _____ Assessor: _____

Appropriate (check off)	Location	Space		Stairs	Objects <i>Bump test</i>	Furniture <i>Bump test</i>	Uneven Surface
		Drive Straight	Turn				
XXX	Basement	ok	ok	yes	1	2	3
Ok	Living Room	ok	ok	no	Ok	Ok	No
Ok	Kitchen	ok	ok	no	Ok	Ok	No
Ok	Bed Rooms	ok	ok	no	Ok	Ok	No

Ok	Community Space (listed individually) 4) 345 Valley Ave. playground						
----	--	--	--	--	--	--	--

Specific Instructions on Appropriate Spaces based on above assessment:

- 1) Basement: several lawn care equipments that will be removed before start training.
- 2) Two tool cabinets that may fall that will be removed before the start of training.
- 3) One step down to yard that will be covered by plywood to make a smooth little ramp to enter/exit basement from yard to be placed and remain throughout training.
- 4) 345 Valley Ave playground is a small grassy playground that appears appropriate.

While providing your child opportunities to drive the car in agreed upon safe driving locations, the car must be used appropriately at all times. Examples of inappropriate car use includes allowing siblings or other children to drive the car, otherwise modifying the car, or not directly supervising your child at an arm's length at all times while your child is driving.

Signature for parent agreements on driving areas:

I, _____, voluntarily agree to allow my child to drive only within the locations described above. I understand the risks of allowing my child to drive the toy car in inappropriate areas. I also understand that the research team can stop the training at any time if there is any inappropriate use of the toy car during the study period.

(Signature of parent or guardian)

(Date)

Appendix 3: Fun Index Form Used By Parents

Ride-on Car Caregiver Log Sheet

Participant ID _____ Week _____

Date	Location	Activities	Time-Start	Time-Stop	Time engaged (total minutes)	Notes	Fun Index (1-10)

