Proximity Activated Stimuli on Modified Ride-On-Cars for Children with Disabilities

by
Thomas S. Weathers

A THESIS

submitted to

Oregon State University

Honors College

in partial fulfillment of
the requirements for the
degree of

Honors Baccalaureate of Science in Computer Science
(Honors Scholar)

Presented June 4, 2019
Commencement June 2021

AN ABSTRACT OF THE THESIS OF

Thomas S. Weathers for the degree of Honors Baccalaureate of Science in Computer Science presented on June 4, 2019. Title: Proximity Activated Stimuli on Modified Ride-On-Cars for Children with Disabilities

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Abstract approved:____

Sam Logan

This thesis describes the implementation of ultrasonic sensors to trigger a stimulus to increase peer interaction for children with disabilities using modified ride-on-cars for mobility. Modified ride-on-car technology has improved mobility for children with disabilities by effectively replicating the social benefits of a powered mobility device, yet there are opportunities to increase group-play among these children. Additionally, this thesis outlines the modifications made to the ride-on-car for future replication by families of children with disabilities. Instructions are provided in the appendix that outline step-by-step directions for completing modifications. When within a specified distance of another object – as detected by the ultrasonic sensors – the stimulus will be activated, ideally attracting other nearby children and encouraging peer interaction. This design is a feasible improvement to modified ride-on-car technology that can be replicated by families.

Key Words: Ride-on-car, Disability, Modification, Group-Play, Proximity

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APPROVED:

Sam Logan, Mentor, representing Kinesiology

Joshua Gess, Committee Member, representing Mechanical Engineering

Naomi Fitter, Committee Member, representing Robotics

Toni Doolen, Dean, Oregon State University Honors College

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.

Thomas S. Weathers, Author

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I would like to thank Dr. Logan and the Social Mobility Laboratory for becoming a second home to me at Oregon State University. You have pushed me to be a better researcher, professional, and human being. Dr. Logan and the Social Mobility Laboratory have provided me the utmost support and mentorship to push myself professionally and explore my passion for humanitarian work. From providing every opportunity to learn more at conferences, to making sure my work was recognized with every “shout-out” from Dr. Logan as a keynote speaker across the country, I have been empowered greatly. Lastly, thank you for helping me to realize that my disability is a valuable and unique perspective that is an asset rather than a hinderance.

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1. Introduction

1.1 Background

Many children with disabilities experience developmental motor delays –where they begin showing motor-development milestones at a later than usual time –which can inhibit their development in comparison to their peers. Locomotion is one of the most vital human developmental milestones because of the wide range of effects it has on children [1]. Locomotion allows for a drastic increase of social interactions for the child, simply by allowing the child to move to initiate communication [1]. In many cases when children under the age of five experience motor-delays as a result of disability which limit their locomotion, medical professionals refrain from issuing powered mobility devices, such as motorized wheelchairs [2]. There have been few alternatives to the use of powered mobility devices, yet research on the use of inexpensive and customizable solutions has progressed greatly. The use of modified children's ride-on-cars has shown promise in solving this issue. Ride-on-cars are very scalable in nature and can be equipped with many modifications to increase mobility.

1.2 Powered Mobility Devices

Powered mobility devices (PMD's) are electrically powered assistive devices designed for people with disabilities. PMD's come in many shapes and forms and have been changing drastically over the last thirty years but have become incredibly hard to obtain for children with disabilities under the age of five [2]. The main barriers of obtaining a PMD for children under the age of five include their high cost and the rapid growth that occurs within children at this age resulting in a need for a new device [2, 3]. The cost of PMD's is far beyond what is reasonable for a family facing disability can afford to pay [4]. Prices for PMD's have risen to upwards of $30,000 when customized for a child's needs [3]. This cost is not manageable for a family with a child who will grow beyond the confines of the chair in a few years' time. For the same reason, this cost is rarely approved by insurance for children under the age of five [2].

In many cases, the professionals who choose to postpone prescribing a PMD for children with disabilities and the insurance companies who refuse to fund them, hold back the children who can benefit most from increased mobility [5]. The current practice within the medical industry is to refrain from issuing a PMD until it is seen as last resort [5]. This lack of understanding of the most recent published literature on early childhood mobility for children with disabilities stints the possibilities of advancing social and physical development for children with disabilities [2]. Abandoning this current frame-of-mind for the most recent medical discoveries of utilizing PMD's at a younger age would serve the best interest of the children [2].

PMD's have served many different purposes in assisting the development of children with disabilities [6]. In the cases where PMD's are implemented, most times they serve as the main mode of mobility for children with disabilities. In many previous studies, PMD's have enabled children with disabilities to collaboratively play with their peers more despite their mobility difficulties [7, 8, 9]. Access to a PMD also increases the socialization of the children within the chair [7, 9]. Although PMD's are very helpful for the users' and their mobility, they are not practical because they are expensive and are unable to cater to the rapid growth of children at this age. There have been few alternatives to the use of PMD's, yet research on the use of inexpensive and customizable solutions has progressed greatly [2, 10, 11].

1.3 Modified Ride-On-Cars

One emerging technology to combat restricted mobility for children with disabilities is the use of modified ride-on-cars [2, 10, 11]. Ride-on-cars are small toy electric vehicles which are usually operated by a foot pedal. These ride-on-cars are typically modified with harnesses, alternative activation mechanisms, and safety improvements. Ride-on-cars are very scalable in nature and can be equipped with many modifications to increase mobility, social and cognition skills [10, 11]. Similar to PMD's, modified ride-on-cars appear to increase mobility for children with disabilities [12]. Studies have been conducted introducing ride-on-cars to children with disabilities, and there is an overwhelming positive reaction to them that suggests this is a viable option [13, 14, 15]. Independent mobility with a modified ride-on-car is comparable to mobility with a PMD because they both lack the necessity for caregiver assistance. Modified ride-on-cars are fun alternatives to PMD's that increase the mobility of children, while also encouraging social interaction with children without disabilities, because they are seen as less socially stigmatic. The common stigma associated with PMD's is present not only in children, but in parents as well. This stigma is visibly less – as shown through the reduced stress levels observed – in parents of different modified ride-on-car interventions [16]. Increased peer interaction with the use of modified ride-on-cars is the largest signal that ride-on-cars are perceived as more socially acceptable to other children. In one example, an observed playgroup was hosted where children with disabilities interacted with peers using modified ride-on-cars for mobility [17]. Three children with disabilities had positive changes in select play behaviors when using modified ride-on-cars in comparison to children not using them [17]. The modifications made to these ride-on-cars are the key to providing independent mobility to these children while keeping them safe.

All of the ride-on-cars previously used for children with disabilities have been purchased though common retail avenues, where they can be accessed by any family hoping to increase the mobility of their child with a disability. Because these modified ride-on-cars start as simple common consumer products, it is easier for families to purchase these modified ride-on-cars on their own and make their own modifications. This simplicity has allowed research with modification options for ride-on-cars to be documented in two published technical reports, where the focus of these reports is solely on the added accessibility features [10,11].

The first technical report outlined the most standard modifications made to the ride-on-cars: seating alterations, as well as steering and drivetrain alterations [10]. The standard modifications made to the seat of the ride-on-car were meant to provide stability, support, and safety for the children operating the them [10]. Common installations to ensure safety were seatbelts made of Velcro, roll-cages made of PVC pipe, and polyethylene foam pool noodles used as supports [10]. Drivetrain and steering installations were installed with the intention of increasing practicality, accessibility, and ease-of-use for both the child operating the modified ride-on-car, and the parent who is supervising the child during driving-sessions [10]. Various systems were implemented to allow the child to operate the modified ride-on-car without using the pre-installed foot pedal for the throttle control, such as a large button mounted to the steering wheel, and a joystick [10]. The installation of turning-handlebars provided accommodations to enable steering capabilities for children who may not possess sufficient grip and/or arm control.

The second technical report outlined further exploration into modifications made to encourage leg muscle use with the Sit-To-Stand modified ride-on-car, as well as facilitating peer-interactive scenarios for children utilizing the modified ride-on car cars with the Throw-Baby-Throw technology [11]. The Sit-To-Stand ride-on-car is based around the premise of an All-Terrain Vehicle (ATV) -style car, which allows the child to be standing when operating the modified ride-on-car, rather than seated [11]. This is accomplished by utilizing an installed large button that sits on the seat of the modified ride-on-car to act as the throttle [11].This method activates the modified ride-on-car when the button is not pressed, opposite from the previous implementation of a red button as the throttle. The car is operated by the child standing and using leg muscles to remain standing, therefore conditioning the child to use their legs for movement capabilities [11]. The Throw-Baby-Throw car on the other hand, focuses on the importance of peer interaction for children with disabilities at these pivotal years of development [11]. This is achieved by attaching a Fisher Price© Triple Hit Baseball toy pitching machine, to the side of the car, which is activated by a button mounted to the opposite side of the car [11]. When this button is pressed a ball is launched from the pitching machine, providing a stimulus for reaction from peers [11]. Although two reports have been written on the technical modifications of ride-on-cars, further technological development may help optimize the potential social benefits gained.

The purpose of this project is to further the technological development of modified ride-on-cars through implementation of ultrasonic sensors that provide motivation to facilitate social interactions between children with and without disabilities. Ultrasonic sensors will be programmed to trigger a stimulus that is also mounted to the modified ride-on-car when they are within a certain set distance to another object. Objects that are large enough to reflect a sound wave back towards the modified ride-on-car will be able to trigger the sensors when they are within the set distance away. Modified ride-on-cars equipped with ultrasonic sensors that trigger a stimulus on the car could potentially improve the socialization between children with and without disabilities as they could become more inclined to interact with one another when a fun stimulus is present.

2. Car Design

2.1 Modification Summary

The goal of this project is to modify a ride-on-car to use proximity detection to trigger a stimulus that will engage the child driving the car when near another object. For example, when a child is driving a modified ride-on-car equipped with a bubble-toy activated by proximity to its surroundings, the bubble toy will begin firing and the child will be more inclined to interact with their environment. This may increase interest in the modified ride-on-car, while also increasing socialization through peer interaction and group-play. This proximity detection will be accomplished with the use of four ultrasonic sensors mounted to the modified ride-on-car which are controlled by an Arduino microcontroller. The Arduino microcontroller will read input from the ultrasonic sensors while also providing the power to the sensors. Once the input is received from the sensors, if the received distance value is below our target proximity –which we initialized to 5 feet (60 inches) – an electrical signal is sent to our servo actuator mounted adjacent to the bubble toy. Once activated, the servo will rotate to an on-position: pulling back the trigger of the bubble toy therefore causing bubbles to release into the air. Once the allotted time in the on-position has elapsed, the servo will return to the off-position, where the bubble toy halts dispensing bubbles and no tension remains on the trigger. Lights and sirens built into the bubble toy will also activate once the servo is in the on-position.

2.2 Initial Design and Observations

This concept for a modified ride-on-car with these modifications was first designed and constructed for the 2018 Toyota unlimited Mobility Challenge. In collaboration with the University of Washington, the first model of this modified ride-on-car was constructed with three ultrasonic sensors and a mounted bubble-gun. In testing this design with children with disabilities in 2018, flaws in the detection of objects approaching from the corners of the modified ride-on-car and electrical connections were discovered. These shortcomings were used for inspiration in the design of this modified ride-on-car. Instead of three ultrasonic sensors, four ultrasonic sensors aimed in more significant directions were used in this model. Other significant changes to the original model include: increased stability and electrical connection strength with heat-shrink and soldering. These changes should improve the durability of the modified ride-on-car as well as the functionality of the ultrasonic sensing capabilities.

2.3 Sensor Design

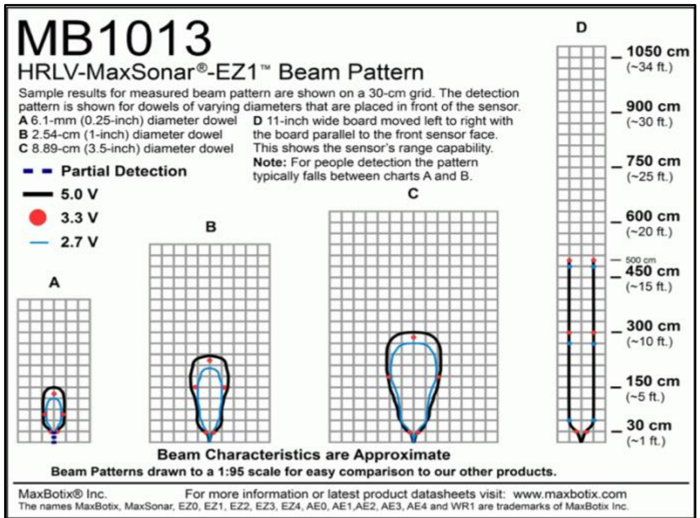

Figure 1: This diagram is the beam pattern of each individual Ultrasonic Sensor used on the car. Our proximity reach distance is 5 feet: where pattern A, B, and C (above) are most applicable. Our vehicle used 5.0v, therefore the black lines reflect our used beam pattern. [22]

Ultrasonic sensors are able to calculate many different values with the emission of a high frequency sound-wave. This sound-wave is exerted when an electrical-current triggers the pulse-pin on the sensor. At this time, the sensor begins a very precise timer. As the timer is running, the sound wave will travel outward at a specific pattern –the beam pattern –which depends on the model of the sensor. When the sound wave reaches a flat object, it will bounce off of that object and reflect back towards the sensor. The sensor will next receive the same sound wave that it launched previously and stop the timer. Using the formula to calculate distance: distance equals the product of the time the sensor took to receive the wave and the speed of sound all divided by two, the sensor can effectively calculate the distance to a nearest object.

Each of the ultrasonic sensors used in this project have a maximum range of approximately 15 feet, where the beam is non-linear. See **Fig. 1** for beam pattern. Four ultrasonic sensors are mounted to the front grill and front fenders of the modified ride-on-car to provide a well-spaced area of detection that is representative of where we predict the child will be looking while operating the car. The ultrasonic sensors are best suited to be directed where the car is facing when coming in near contact with other children and ride-on-cars. The front half of the car serves this purpose best. As the child is operating the modified ride-on-car, their attention will most likely be directed forward or slightly to one side – when they might be turning. See **Fig. 2** for sensor placement.

Figure 2: Ultrasonic sensors mounted to the modified ride-on-car are delineated by the red arrows. Four ultrasonic sensors are located on the front half of the modified ride-on-car.

2.4 Power Supply Design

Figure 3: 9V Battery used as Arduino power source.

The Arduino will be powered by a single 9V battery. Because it is so common, using a 9V battery ensures easy replacement when it runs out of energy. This circuit will include an on/off toggle switch that will be run in between the battery and the Arduino. This 9V battery (as seen in **Fig. 3**) will be secured near the Arduino in the cavity under the rear of the car with the use of Velcro. A secondary power source (a four AA battery pack) will power the servo that activates the bubble toy. The four AA battery pack outputs 6v of electricity, which is the maximum voltage for our servo. This battery pack will be mounted under the front-right fender of the car to be easily accessible to parents/guardians to toggle the power. This secondary power source has its own built-in on/off switch. We utilize a second power source instead of using the Arduino's 5v power output because wiring the ultrasonic sensors and servo actuator to the same power source can have adverse effects, such as unexpected Arduino resets and low voltage readings.

2.5 Control System Placement/Design

The Arduino Microcontroller will be secured to the back of the driver seat compartment under the shell of the car. There is an open cavity in front of the rear axle and under the trunk of the car with sufficient room for the Arduino to be attached. This area also possesses enough room for wires to be manipulated to connect to the Arduino.

Because the Arduino will be located in the rear-half of the car and the sensors will be located in the front-half of the car, wires will need to be run up and down the length of the car. Because the car is nearly four feet long, this will not be an issue of connectivity or resistance, but the wires will need to be strategically placed to not interfere with the regular car functionality and driver's use. The best option is to run the wires in bundles sealed with zip-ties and electrical tape along the sides of the car under the door panels. There are two empty corridors of space under the shell of the car that run along the sides of the driver's seat that are protected from the functionality of the car. These corridors will serve as the best route for wires to travel the length of the car in a safe, efficient, and organized manner.

2.6 Accessibility Modifications

To increase the accessibility of the ride-on-car we will implement a large button that is to be mounted to the steering wheel to serve as a throttle for the car instead of the traditional foot pedal. This will enable those without lower limb functionality to drive the modified ride-on-car at the best of their capabilities.

3. Materials

3.1 Costway™ 12V Battery Powered Kids Ride-on Car

Figure 4: Costway™ 12V Battery Powered Kids Ride-on Car.

The Costway™ 12V Battery Powered Kids Ride-on Car will serve as the base car to be modified for this project (as shown in **Fig. 4**). This model of ride-on-car is easily found for purchase by a large retailer, in this case Walmart™, for convenient future replication of these modifications by users. This car is the ideal model for these modifications because of the hollow areas of space located under the front hood of the car, behind the front fenders of the car, and behind the driver's seat of the car. These will provide ample room for electronics to be wired and stored. This car also provides a large seating cabin for the child driver, which will accommodate for their possible difficulties entering and exiting the modified ride-on-car. Another beneficial feature of this modified ride-on-car is the remote-control functionality that is already implemented into the car. If the child is still unable to control the modified ride-on-car with the added throttle mechanism, then the child's caregiver or an adult can control it remotely. This could still provide the other potential benefits of interacting with other children and modified ride-on-cars, even without the child's direct control.

3.2 Arduino™ Uno R3 Microcontroller

Figure 5: Arduino™ Uno R3 Microcontroller encapsulated by SunFounder™ Case

The Arduino™ Uno Microcontroller serves the purpose of controlling the electrical components of this project (see **Fig. 5**). The Arduino is responsible for reading in input for our ultrasonic sensors, while also activating the servo when the ultrasonic readings are within a set range. The Arduino is powered by either a computer (during testing and code exporting), or an external power source. When on the modified ride on car, we will use an external power source: the 9V battery. The Arduino is programmed with the use of the free Arduino Integrated Development Environment, which can be downloaded to any computer. An Integrated Development Environment is a text editor and testing environment for writing code. The code for this project is located in **Appendix A.**

3.3 SunFounder™ Uno R3 Case Enclosure

The SunFounder™ Uno R3 Case Enclosure is a clear plastic case that encloses the Arduino Microcontroller to offer protection and easier access for mounting. This case is completely translucent, so it is still easy to recognize the numbers for each pin on the Arduino, making assembly of the pins simpler. The case also provides a smooth surface to attach an adhesive to the back of the Arduino, which will be secured to the underside of the Ride-On-Car. This case has small slits where wires can be entered to reach the pins of the Arduino, while being grasped by the case to ensure their attachment to the Arduino pins. See **Fig. 5** for image of SunFounder™ Uno R3 Case.

3.4 MaxSonar®MB1013 HRLV Ultrasonic Sensor

The MaxSonar® MB1013 HRLV ultrasonic sensor will provide the proximity detection aspect of this project. These sensors have different pin locations on them for different types of readings as well as for power supply. The MaxSonar® MB1013 HRLV model (as shown in **Fig. 6**) is ideal for our project, because its beam pattern reflects our range of use. A beam pattern is the shape at which a sound wave is released from a specific ultrasonic sensor. The beam pattern of this sensor is accurate at relatively short ranges, while providing a wide pulse to fully capture nearby objects.

Figure 6: MaxSonar® MB1013 HRLV Ultrasonic Sensor

3.5 HackToys™ Bubble Gun

The HackToys™ Bubble Gun serves as the stimulus for this project. When the car is within our desired distance from another object, the bubble toy will be activated and capture the attention of the child. The bubble toy is designed to captivate the child and provide a desirable sense of accomplishment for them. This model of bubble toy served the interests of this project perfectly. The 3D-printed mount was already sized for this bubble toy, proving to be an easy and sturdy attachment. This model of bubble toy is very inexpensive and has built-in additional stimuli: lights and sirens that activate in parallel with the release of bubbles. These additional stimuli will assist in providing enjoyment for the child.

Figure 7: HackToys™ Bubble-Gun equipped with 3D-Printed Bubble-Gun Mount

3.6 3D-Printed Bubble-Gun Mount

The 3D-printed servo mount for the bubble toy was printed in our laboratory out of PLA plastic. This model was found online from Thingiverse.com, where the user “toemat” published the design for a servo-powered bubble toy (See **Appendix B** for QR code to this design)**.** This mount will surround the handle of the bubble toy, where it will be fastened to the handle by zip-ties. There is a gap in the side of the mount, which fits the size parameters of the servo, as well as screw holes for the servo to secure to. The zip-tie connection to the bubble toy is ideal for this project because it allows for easy removal of the bubble toy for maintenance. The PLA plastic material will provide the strength we need when holding the bubble toy in place, while also being easy to produce for replication. See **Fig. 7** for image of 3D-printed bubble-gun mount.

3.7 AbleNet™ Big Red Button

The AbleNet™ Big Red Button (as shown in **Fig. 8**) serves as our main accessibility-improving modification for this ride-on-car. The button will be wired to activate the throttle function of the car and provide movement by the push of the button rather than the foot pedal. This will be mounted to the steering wheel to provide easy reach by the child while still turning the steering wheel for directional movement.

Figure 8: AbleNet™ Big Red Button

4. Assembly

4.1 Ride-On-Car Assembly

The instructions provided with the ride-on-car were followed according to the manufacturer’s guidelines to assemble the vehicle. This required a screwdriver and double AA batteries aside from what was provided with them modified ride-on car.

4.2 AbleNet™ Big Red Button Installation

The Big Red Button contains two wires that protrude from the main housing, which are loosely connected by the wire coating. These two wires can be pulled apart from each other to be separated into their own individual wires. These wires are going to be connected to the electrical port where the foot pedal’s wires currently reside.

First, we need to make a point of entry from the top of the car to the underside of the shell, where the throttle connection is located. Drill a hole, approximately 1 cm in diameter on the floorboard of the car, located near the foot pedal, but out of the way as to not interfere with the child's legroom. See **Fig. 9**.

Figure 9: Hole drilled into floorboard near foot pedal.

Flip the car over onto its side, where the throttle connection is visible and easily accessible. From there, locate the electrical port where the throttle connection is located. The electrical port may be underneath a rectangular piece of plastic secured by four screws. The electrical port should be directly behind the foot pedal on the inside of the car. There should be two maroon wires attached to a terminal, where they lead down a sheathed route to other wires, which leads to the center of the car. See **Fig. 10**.

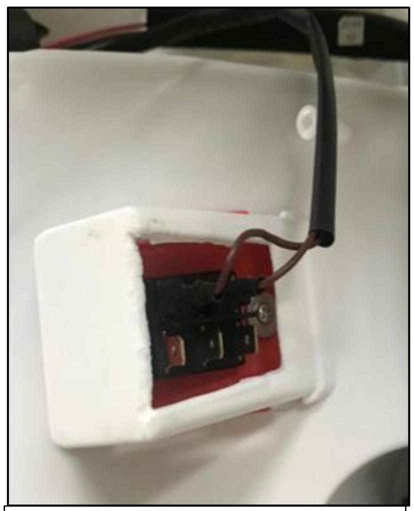

Figure 10: Electrical port for throttle connection.

These two maroon wires should have clip-on attachments to the electrical terminals, so they can be pulled out without the use of a screwdriver. Pull these two maroon wires from their connections, so that they are freestanding, and no connections remain to the foot pedal.

The next step is cut off the port connection at the end of these two maroon wires. Using wire cutters, snip these pieces off, leaving one end of each wire exposed.

Using a wire stripper, find the best fit size of the wire. Make a cut nearly 1/2 inch from the exposed end and strip the wire of its covering, exposing the metallic core of the wire (this process is known as stripping the wire).

Next the two separated wires from the Big Red Button, should be run through the hole we made in the main cabin of the car, to the underside of the car. These two wires should then be stripped as well, the same way we did with the two maroon wires.

Once we have four exposed wire ends, slip on one piece of heat shrink onto each of the maroon wires. Let it slide down the wire away from the exposed end. Next, solder the wires together: one maroon wire to one black wire from the Big Red Button, and the other maroon wire to the other black wire (see **Appendix C** for soldering instructions). To prevent these wires from shorting out, we will move the heat shrink over the newly-soldered connection and use a heat gun to secure the rubber heat-shrink (see **Appendix D** for heat gun instructions**)**. See **Fig. 11** for final results.

Figure 11: AbleNet™ Big Red Button wires soldered and sealed to throttle wires from ride-on-car.

Next, align the big red button over the steering wheel, so that it covers the inner portion of the steering wheel. The Big Red Button should be a close fit to the size of the center of the steering wheel. Run three zip-ties through the screw holes on the edge of the Big Red Button. Place these same zip-ties through the openings in the steering wheel and secure the connection by tightening the zip-ties as tight as possible. This should keep the Big Red Button secure and not able to be removed from the steering wheel. See **Fig. 12** for completed attachment.

Figure 12: AbleNet™ Big Red Button

To secure the dangling wires below the car that we recently attached to the maroon wires, zip-tie them in a bundle and use electrical tape to secure the wires to the underside of the car. This is to prevent the dragging of these wires on the ground below the care and keep them as contained as possible.

4.3 Ultrasonic Sensor Installation

We will need to run wires from the rear end of the car, where the Arduino will be mounted, to the ultrasonic sensors located in the front of the car to read in input.

There are seven pins on the Ultrasonic sensors that we are using for this project. As seen in **Fig. 13**, there are five input pins, a power pin labeled V+, and a ground pin labeled GND. For this project, we need to use pin 2, the V+ pin, and the GND pin. The V+ pin will provide power, the GND pin will give us the ground for our power, and Pin 2 will send the correct measurements back to the Arduino.

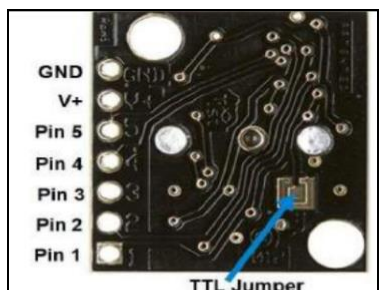

Figure 13: MaxSonar® MB1013 HRLV Ultrasonic Sensor pin documentation [21]

We will use three different color wires for these sensors, to not confuse them when traveling the length of the car to the Arduino. Common practice for electrical wiring is to use a red wire for power, a black wire for ground, and other colored wires for input/output. We will follow this model in this project.

Since, we are replicating this process four times, once for each of our four different Ultrasonic sensors, we will need to cut four of each wire. Measure out the length of the car using the wires, and cut four red wires, four black wires, and four yellow wires to this length. This will ensure the wires are long enough to reach the Arduino from their secured location on the front of the modified ride-on-car.

Next, we need to strip both ends of each of these wires, following the same routine we used to strip the wires earlier on. We will next connect the wires to the ultrasonic sensors by soldering them carefully to the pins. These pins are cut-out circles on the ultrasonic sensor's electrical board, where the inner ring of the circle is a conductive metal. The best way to solder our wires to these pins is the run the stripped end of the wire through the pin and fold it back around to touch itself again. See **Fig. 14**. Then, when introducing solder to this connection, the solder will fill the gap surrounding the wire connecting the wire to the conductive metal ring in the pin. This is a tedious process that requires careful placement of solder and caution not to burn any other part of the sensor. See **Fig. 15** for desired results.

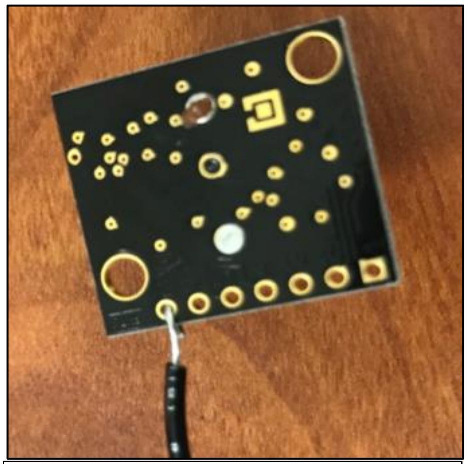

Figure 14: Stripped end of black wire is folded through pin of ultrasonic sensor.

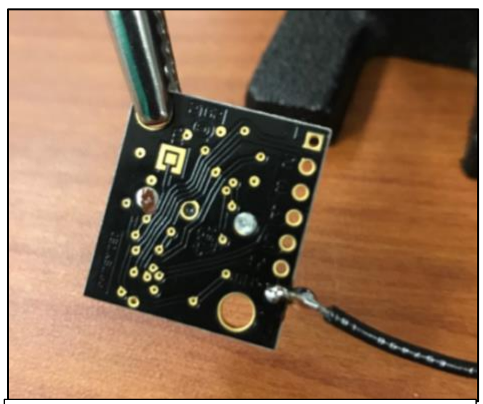

Figure 15: Wire successfully soldered to pin of ultrasonic sensor.

Proceed with this process until all four of the ultrasonic sensors have three separate connected wires. The yellow wires should be connected to pin 2, the black wires to pin GND, and the red wires to pin V+.

One important suggestion to note is to be careful not to solder adjacent pins and wires together when soldering the wires to the ultrasonic sensor. If two pieces of solder are too close to each other, feel free to cut a small piece of electrical tape and use it as a barrier between the adjacent conductive materials.

The next step is to secure the ultrasonic sensors to the ride-on-car. The location that we have chosen for the sensors to be mounted on the car is: one on each front fender pointing outward from the driver left and right and one on each end of the front grill pointing forward. See below figures for placement of sensors.

At each of these locations, drill a hole large enough for the extruding piece of the ultrasonic sensor to fit through, but not the flat circuit board section of the sensor.

Push the ultrasonic sensors through the hole from the inside of the shell pointing outwards and turn them in a direction where the wires will not be exposed to the wheel of the car. Once they are situated in this location, we want to use a hot glue gun to secure the sensors to the shell of the car. Hot glue will not conduct electricity and will not interfere with the circuit board of the sensors, so we can glue directly onto the circuit board. Place a substantial amount of hot glue on the side of the flat circuit board facing the shell of the car, in the same direction the sensor is facing, then press the sensor to the shell of the car for a minute until it has dried. See **Fig. 16** for desired end goal.

Figure 16: Ultrasonic sensor successfully connected to the right front fender of the ride-on-car.

The last connections we need to make for the sensors are the bundling of the power and ground wires. To do this, we will want to flip the car on its side, so we can see all of the wires at once and manipulate them easily. Be sure to put a block, or some support under the edge of the car so that the weight of the car does not rest on the extruding ultrasonic sensor.

We want to solder all of the ultrasonic sensors' power wires together and connect them to a header wire, so that the connection to the Arduino's 5v power pin is secure. We will need to strip the ends of the four power and ground wires, a little farther than usual, so there is room to wire them to each other. Strip the opposite end of the header wire. Next, twist all four wires into a bundle then solder this bundled end to the exposed end of the header wire. This soldering should be done towards the rear of the car, where the wires all meet under the shell of the car, behind the seat of the driver. This should lead to having four power wires all connected to one header wire. We will repeat this process with the ground wires, so that all of the ground and power wires from the four sensors, are reduced to two wires which are able to be plugged into the Arduino. See **Fig. 17** for desired power and ground wire configurations.

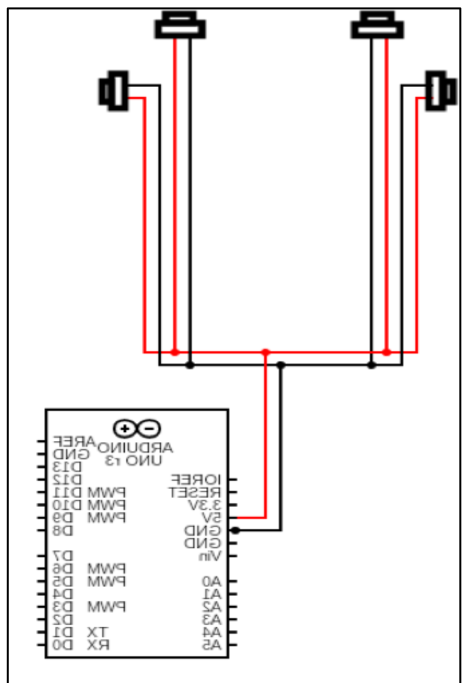

Figure 17: Power (Red) and Ground (Black) wiring schematic.

4.4 Powering the Arduino

The Arduino needs a power source since it will not be connected to a computer when moving with the ride-on-car. This power source will also supply power to the ultrasonic sensors through the power output of the Arduino. Whenever the power is triggered on or off, the Arduino will begin running its code, and the sensors will begin to take in input.

First, we need to separate the two extruding wires from our toggle switch. Similar to the Big Red Button, they will be loosely connected because their wire casings stick together, but they can be easily pulled apart with your fingers. The colors of these two wires are of no importance for this project because the switch will simply connect these two wires in circuit once it is activated and halt them when switched off.

Once we have split these two wires, we need to strip the ends of both of these wires, so one can be attached to other wires. One of these wires will be running to the power wire from the battery, and the other will go directly to the Arduino.

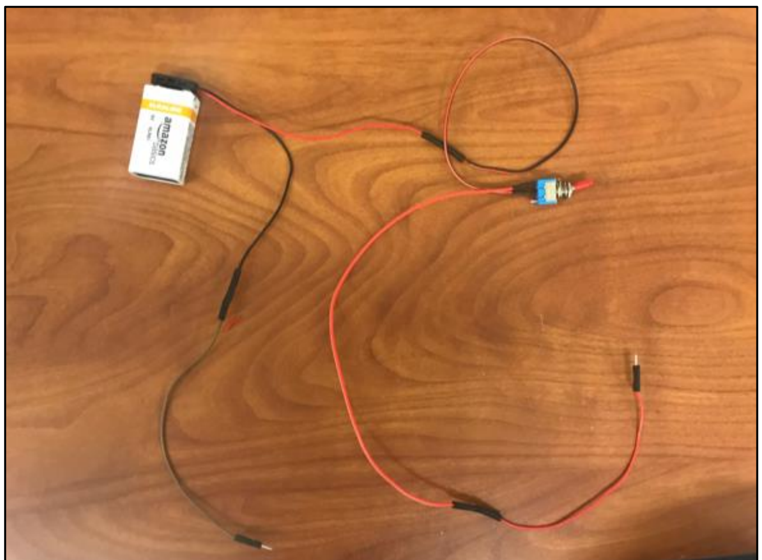

Figure 18: Circuit which connects power to Arduino via a toggle switch (top-right) and a 9V battery (top-right).

We next need to strip the ends of the wires from the battery connector as well. There should be two extruding wires from the connector to the 9V battery. One of which should be red, and one black, to symbolize ground and power. The power (red) wire, should be soldered to one of the wires from the switch that we just stripped prior. The ground (black) wire should be soldered to the end of a header wire. The last connection we need to make is the other available wire from the switch, which needs to be soldered to a header wire. Once this is done you should have a circuit that looks like **Fig. 18**. In **Fig. 18**, the black pin that is in the bottom-left of the photo will later connect to the GND pin of the Arduino, while the red wire will connect to the Vin pin. This will provide power to the Arduino whenever the switch is set to on.

The last step of this will be to attach the switch to the rear of the car. For this, we will need to drill a hole in the shell of the car, above the back bumper, where a child will not likely reach it while driving. The drilled hole should be the same size as the threading on the toggle switch, so that it can be connected sturdily with the provided bolt on the switch. When connected to the Arduino, this power circuit should resemble the circuit diagram shown in **Fig. 19**. See **Fig. 20** for the toggle switch successfully mounted to the car.

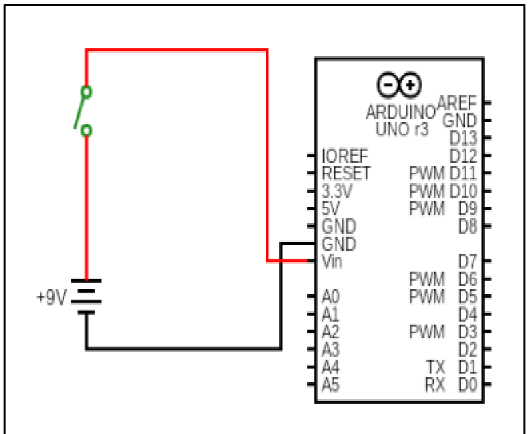

Figure 19: Circuit schematic for power to Arduino.

Figure 20: Toggle switch installed onto rear bumper of ride-on-car.

4.5 Bubble-Gun Installation

The bubble toy will be activated by the trigger pulled back from the servo actuator. The servo actuator will be activated by the Arduino, which will set it to an on-position for a few seconds, then return it to an off-position.

We will first need to drill a hole in the hood of the car, which the electrical wires from the servo will run through to reach the underside of the car. This hole should be placed a few inches off from center of the car, where the hood meets the windshield. This is the ideal location because it will be less visible, and it is only one piece of plastic between the underside and the top of the car, the hood.

First, run the attached wires from the servo through this hole, where the actuator still sits above the car.

Next, we want to cut one yellow wire, the length of the car. This will be the connection wire from the servo to the Arduino. Once we have cut this, we want to strip both ends of the wire. Solder one end of this wire to be connected to a header wire. This will be the end that connects to the Arduino pins. Solder the other end of the wire to the yellow wire that extrudes from the servo.

We next want to get our 4 AA battery pack and solder the red and black wires extruding from it to the red and black wires extruding from the servo. When the battery pack is turned on, this will power our Servo actuator. Once these wires have been soldered and secured with heat-shrink, we will get a piece of Velcro. Stick one end to the battery pack, and another end on the inside of the front fender, that is most near the servo. This will serve as the resting spot for the battery pack. This should keep it safe and hidden from children playing with the car, to not disturb them or their playing. See **Fig. 21** for the circuit diagram of the battery pack and servo.

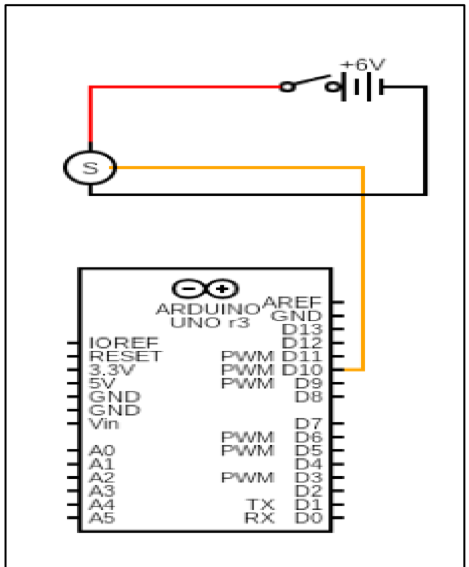

Figure 21: Circuit schematic of 4 AA battery pack (top-right), Servo (top-left), and Arduino.

Next, we want to secure the L-Bracket to the hood of the car. Use the provided screws to screw into the hood of the car. Align the L-Bracket in the center of the car, standing up vertically. We want the short end of the bracket pointed forward, with the long end sticking upwards. Using a power drill to do this will ensure the tightest connection to the hood of the car. The L-Bracket should be within 2 inches from the windshield, where it is standing at the most vertical position possible. See **Fig. 22** for desired end results.

Figure 22: L-Bracket mounted to hood of ride-on-car.

Once the L-Bracket it secured, we want to secure the 3D-printed mount to the bubble toy. To do this, we need to place the clamping pieces around the handle of the bubble toy, and secure them with a Zip-tie, in the designated locations on the 3d print. These locations are in the openings between the two L-shaped grasping frames. Lastly, we need to run the 3D-printed beam through the trigger opening of the bubble-gun and then connect it to the 3D printed mount that has already been secured. Use a bended paperclip as a pivot for the trigger mechanism, where the trigger mechanism can still move back and forth.

Next, we need to attach the servo to the 3d printed mount and secure it. The Servo actuator comes with four screws that are designed for mounting. These fit perfectly into the holes of the servo, and the 3d print on the right side, where there is a rectangular mount for the servo.

Once this piece is connected, we want to bend another paper clip to cover the distance between the other end of the 3d printed trigger mechanism and the servo. When the servo turns, this paper clip will be pulled tighter and this will pull the 3D-printed beam laying across the trigger. The paper clip needs to be attached to the servo so that it is tight when the servo is at a resting position and the actuator is facing forward.

Figure 23: Bubble-gun and 3D-printed servo mount attached to the ride-on-car.

Once the servo has been attached effectively, we need to mount this whole piece, consisting of the servo, bubble toy, and bubble toy mount to the l-bracket. We can do this by using more Zip-ties, securing them at the very bottom of the bubble toy, and also one underneath the housing of the 3d print. See **Fig. 23** for result.

Lastly, run the yellow wire that is under the car and connected to the servo, down the length of the car back towards where the Arduino will be located. This will make our step of wiring the Arduino more organized.

4.6 Arduino Installation

First, we want to download the code for this project onto the Arduino. We are going to do this by connecting the Arduino into our computers and opening the Arduino file found in **Appendix A**. We want to upload and verify this code to the Arduino, and then unplug the Arduino from the computer.

Next, we want to install the case around the Arduino. Use the provided pieces of clear plastic and fit them around the Arduino in a snug manner. Be careful not to put pressure on the pins of the Arduino in this process. Secure the pieces of the case with the given screws, so that it is tight and will not move. The Arduino and case should resemble **Fig. 24**.

Figure 24: Properly assembled SunFounder™ Arduino case.

Next, we want to plug in all of the wires to the Arduino. the pins should be connected as follows:

Arduino Pin	**Wire**
3	Left fender sensor (yellow)
5	Left center sensor (yellow)
6	Right center sensor (yellow)
7	Right fender sensor (yellow)
10	Servo (yellow)
GND	9V Battery GND (black)
vin	Switch power (red)
GND	All sensors GND (black)
5v	All sensors power (red)

See **Fig. 25, 26, and 27** for connection diagrams to the Arduino from the ultrasonic sensors, servo motor, and 9V power source.

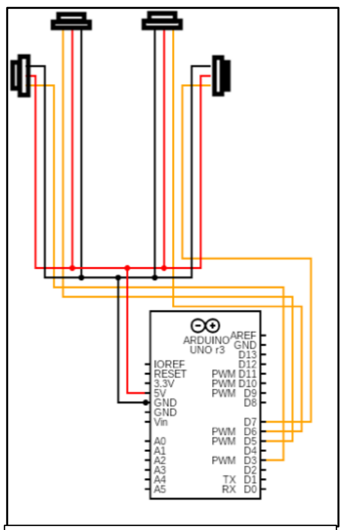

Figure 25: Ultrasonic sensor wiring schematic to Arduino.

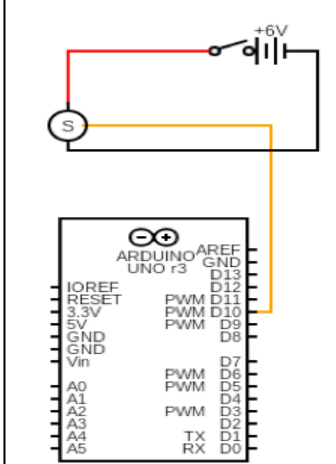

Figure 26: Circuit schematic of 4 AA battery pack (top-right), Servo (top-left), and Arduino.

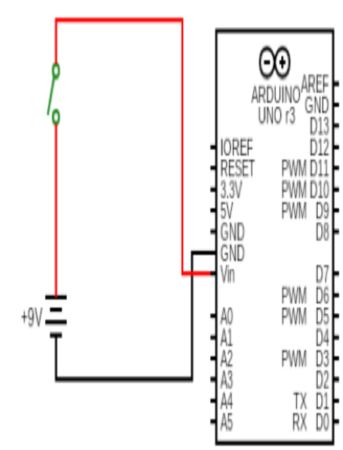

Figure 27: Circuit schematic for power to Arduino.

Next, we want to secure the Arduino to the back of the car, under the shell. The Arduino will be mounted to the back of the driver's seat. This area looks like a clean wall of plastic, where we will secure the microcontroller. We want to cut a piece of

Velcro to the size of the Arduino, then stick one end to the car and one end to the back of the Arduino. This will hold the Arduino in place when the car is moving.

Cut one more piece of Velcro, the same size as a 9V battery, and connect this under the car against the inside of the back bumper. This will hold the 9V battery to the car when it is moving, while remaining close to the Arduino and easily removable when the battery dies.

Lastly, we want to clean up the wires that have been installed thus far. Using zip-ties and electrical tape, bundle up large clusters of wires that run the same routes throughout the distance of the car and tape them to the inside of the shell: out of sight and out of reach from children.

5. Testing

5.1 Goals

The goal of this testing was to prove the accuracy of the ultrasonic sensors, within a certain range of accuracy, and validate their ability to trigger the bubble toy under the desired range threshold (5 feet). I organized this testing to give us an accurate reading of the modified ride-on-car in a stationary position.

5.2 Procedure

To test the ultrasonic sensor's accuracy, I chose to park my modified ride-on-car and place another previously modified ride-on-car a measured distance from it. From here I connected a computer to the Arduino microcontroller and uploaded a script to display the distance reading (in inches) from a selected sensor pointing towards the other car. Comparing the actual distance to the sensed distance and whether or not the bubble toy was triggered at this distance gave a better visualization of the accuracy of the ultrasonic sensors. I chose to test two different cases, one distance below the range threshold, and another distance beyond the range threshold to trigger the bubble toy. These distances were 4 feet (48 inches), and 6 feet (72 inches) from the car. For each of these I collected data values over five returned sensor readings, to form an average returned distance. These two tests were labeled as "Scenario 1" and "Scenario 2".

5.3 Outcome

These tests yielded expected results in both "Scenario 1" and "Scenario 2".

For "Scenario 1" the second modified ride-on-car was parked 48 inches from my modified ride-on-car when the ultrasonic sensors were turned on. I expected to see a similar result in the sensor reading. The resulting average distance measured was 48.66 inches over five rounds of sensing. As expected, this triggered the Bubble Toy, causing lights, sounds, and bubbles to be produced. This suggests the ultrasonic sensors are accurate at this range and trigger the Bubble Toy effectively when expected.

In the second test, the second modified ride-on-car was parked 72 inches from my modified ride-on-car. I expected to see a similar actual reading, and for the Bubble Toy to not be triggered because this was beyond our target number of 60 inches (5 feet). This expected result was achieved. The Bubble Toy was not triggered, and the sensors read an average reading of 72.47 inches over five rounds of sensing.

Scenario	**Measured Distance (in)**	**Expected Sensor Reading (in)**	**Expected Trigger Output**	**Actual Sensor Reading Average (in)**	**Actual Trigger Output**
1	48	~ 48	Bubble Toy Triggered	48.66	Bubble Toy Triggered
2	72	~ 72	Bubble Toy Not Triggered	72.47	Bubble Toy Not Triggered

6. Discussion

6.1 Findings

The purpose of this thesis is to further the technology development of modified ride-on-cars through implementation of ultrasonic sensors that provide motivation to facilitate social interactions between children with and without disabilities. This project was designed with ease of replication in mind for families of children with disabilities depending upon their specific needs. The stimuli attached to this modified ride-on-car may serve as positive reinforcement to encourage social interaction among children with and without disabilities.

6.2 Effects on Social Interaction

Parallel to the use of mobility devices for children with disabilities, there is evidence that PMD's allow for increased social participation opportunities [18]. PMD's are also heavily connected to the normalization of social interaction, allowing for more comfort in interacting with peers in the future [18]. The goal of our modified ride-on-car is to serve the social interaction benefits of a PMD at a less expensive cost and with more customizable features. The modifications made to this ride-on-car aim to increase the amount of social interaction with other children. By intriguing other children in the vicinity of this modified ride-on-car through engagement of a toy triggered through proximity detection, it may encourage increased peer interaction with the child using a modified ride-on car and other children in the play environment.

6.3 Positive Reinforcement

Positive reinforcement is the psychological conditioning theory that if a reward follows a desired behavior, that behavior is associated with the reward and more likely to occur going forward [19]. Positive reinforcement was theorized by B.F Skinner who claimed there are four types of reinforcers: Natural Reinforcers, Token Reinforcers, Social Reinforcers, and Tangible Reinforcers. In the context of this project, the stimulus attached to the modified ride-on-car model serves the Tangible Reinforcer model because it is a tangible object – the bubbles in this case – which encourages the desired behavior of social interaction. In our case, we are conditioning children to interact with each other more, where the bubbles and sounds are the reward for doing so. This helps to make children more excited and comfortable interacting with one another, speeding up their social development with peer interaction.

6.4 Impact on Social Norms

Children with mobility impairments are more likely to be left out of social peer activities that involve physical activities [20]. The implementation of a modified ride-on-car with proximity triggered stimuli can assist the fostering of a more inclusive play environment. By encouraging the mobility of children who are unable to move independently, they may be capable of more interaction with their peers and their environment. This method may also be especially effective because it simultaneously promotes the interaction between children no matter their ability. This may help shift the social norms to promote inclusion of children with disabilities as common practice. If children learn to enjoy interacting with other children no matter their abilities, this will hypothetically carry over to other play scenarios with children of other differing physical capabilities.

6.5 Cost Analysis

Part Name	**Cost (USD)**
Arduino™ Uno R3 Microcontroller Board Base + USB Cable	16.98
SunFounder™ Uno R3 Case Enclosure	9.99
Costway™ 12V Battery Powered Kids ride-on-car	139.99
MaxSonar® MB1013 HRLV Ultrasonic Sensors	34.95 (4)
Hitec RCD USA HS-485HB Servo motor	22.33

4 x 1.5v AA battery case holder	9.99
AbleNet™ Big Red Button	59.99
L brackets and screws	12.99
3D-Printed bubble toy mount	1.00
Toggle Switch	1.00
Remington solid core wire, 22awg 100' length	10.68 (2)
HackToys™ Bubble gun	6.99
AmazonBasics 9V batteries, Pack of 8	9.99
Total Cost:	**$452.20**

The best possible outcome of this project is to have created a product that is inexpensive enough to be easily replicated by families to improve their child's mobility and social interaction. In building this modified ride-on-car we provide a proof of concept, showing that the modified ride-on-car can be created easily and without many barriers of entry, such as engineering experience. We attempted to take cost into consideration when designing the modifications to this ride-on-car, yet there is much room for improvement. The original design cost the user approximately $140.00. In this project, our total cost of materials was $452.20. This tells us that our modifications, if they were to be followed exactly to this project, would cost the user an extra $312.20. The most substantial of these costs would be the ultrasonic sensors themselves. The model that we used for this project, the MaxSonar® MB1013 ultrasonic sensors cost $34.95 each, in which we used four on our car, totaling $139.80. These sensors are the cornerstone of the project. This model of sensor was chosen specifically for its range and beam-pattern; yet, a less expensive solution would be in the better interest of the user going forward. Some other ultrasonic sensors that would serve this purpose effectively cost nearly $13 each. Another large cost to this modification is the Big Red Button that we added to the steering wheel for children who may not be capable of using their foot to activate the accelerator that comes stock with the ride-on-car. This piece alone was purchased for $59.99. This cost may not be necessary for those who are able to use their foot for the accelerator, yet this is a large cost still for this modification. In the previous research this same button has been used repeatedly, because no alternative has seen to be as easily operated by a child at a lesser cost.

Overall, the cost of this project is warranted by the need to find the most efficient methods for developing a modified ride-on-car that is capable of detecting nearby obstacles and triggering a bubble toy. This modified ride-on-car can be built with more efficient methods that are more cost-friendly. This project should be replicated in the future with more cost efficiency in mind, to further the general accessibility of social mobility of families of those with disabilities.

6.6 Replication of Modifications

Since this project was also designed with simplicity in mind, it would be in our best interest to make this as easy as possible for families to replicate. Some factors that would improve this replication process include access to easily understandable instructions, a video tutorial, a webpage with links to specific parts, and lastly an easily packaged and organized part-set that is ready for installation upon receival.

For this to be replicated efficiently by families, a straightforward set of instructions that they can follow for assembly is vital. Because we want this product to not be purchased as a whole, where overall cost would be higher than necessary for the already burdened community of disabled families, we hope to enable families to build this themselves and fit it to their own specifications for best use. The section entitled "**Assembly**" of this document serves as a strong starting point for a set of instructions to complete modifications. These instructions could be enhanced by providing an easier method of access for these future builders, such as the posting of the instructions on a webpage.

The process of user replication could also be improved by creating a video tutorial of the modification process. A video tutorial is in the best interest of the replicator, because there are some tactile and confusing portions of the modifications that would best be represented with visual and audible assistance. This video would also need to be posted on a webpage where families could easily access it.

A webpage dedicated to the building of this car specifically would serve the best interest of providing easy reproduction of this modified ride-on-car. The website would serve the purpose of being a hub for the previously stated instructions: a building manual and video tutorial, as well as providing links to other similar projects and where to order the parts for these modifications.

Lastly, one possible improvement to the modification process we could explore is the consolidation of all necessary parts for completing the modification and the selling of these parts for their same sum-part values. This would require more planning going forward, but this could ensure that the user does not make any mistakes in the parts they are purchasing while also ensuring they get the best possible price for their modifications. The only disadvantage to this idea is the lack of flexibility in how they implement the technology. By providing a "one-size-fits-all" kit of parts, the user is less likely to make modifications that are personalized to their needs or desires.

7. Future Directions

In keeping with the aim to provide mobility to children with disabilities to increase their social interaction, the future of this project revolves around increasing possible social interaction and making this product as accessible to the public as possible. This project is also centered around the idea that these modified ride-on-cars can be customized to accommodate for the child's specific needs and provide them with the technology to enable their movement and peer interaction. To make this modified ride-on-car with a full sensor suite more accessible to the public, we need to take into consideration the cost, ease of assembling the sensors, and ease of obtaining these parts. It may be intimidating to families to build such a project with no engineering experience, yet our goal is to reduce this fear and enable them to design a solution that is best fit for their needs.

7.1 Future Design Changes

There is a plethora of changes that could be made in the future depending on the child who needs the modifications and their medical needs. Children with different medical necessities will need to modify the car to their specific needs to cater to their physical limitations. The goal that runs at the heart of this project is to provide mobility to any child despite their disability. Differing physical limitations can be adapted to in their own distinct manner to reach this goal.

Some of these physical needs could require a different approach to powering the chair. For instance, if the push button were to be not reachable by the child, possibly for a multitude of differing reasons, designing a handle that serves as an activation switch may be more advantageous. Another approach to this possible future problem would be to implement a joystick to power the car, similar to technology report that was published previously for the ride-on-cars [11]. The implementation of a joystick could prove to be an overly-complex solution to this problem, depending on the abilities of the child. A more simplistic solution could be a mere knob or handle attached to the activation button of the car to provide more grip for a child.

Another area where the family-purchased ride-on-car could be inadequate in providing mobility to a child with a disability lies in the lack of trunk support in the seat of the car. In the future, modifications to the car could include building a customized support system to allow the child to support themselves safely within the car so that fear of collisions and injury within the car are reduced for the guardian of the child. Some options that would solve this problem would be using different sources of foam blocks and seatbelt harnesses. Some children, especially those with spinal injuries, could have difficulty maintaining balance within the car when the modified ride-on-car is moving or inevitably colliding with other objects. Most children of suitable age for operating the modified ride-on-car are unable to completely occupy the passenger cabin of the modified ride-on-car. This could prove to be problematic for those with weak balance, because there is room to slide and lose control of the steering wheel. By filling the extra seat space next to the child – between the child's sides and the doors of the car – with a comfortable yet supportive material, we can provide more stability to the child and increase the functionality of the modified ride-on-car while also reducing the chance of injury.

One foreseeable problem in the future use of this car is the vulnerability of the bubble toy. By mounting the bubble toy to the hood of the car without supports to cover the overall shape and figure of the toy, we risk children wanting to play with the bubble toy alone and attempting to remove it from the car. This problem could be solved by integrating the bubble toy under the frame of the car with a hole where bubbles would escape to the open air. This would still provide the same stimulation for the children, yet they may not be able to experience the sporadic light features that are imbedded within the bubble toy. We want the children to be stimulated by the bubble toy, yet this only achieves our goal if the child makes a mental connection between the cars and the bubble toy. If the child cognitively individualizes them, then the proximity of the cars will not encourage group-play among the children and will no longer serve its purpose.

The vulnerability of the bubble toy could also prove to be exposed to collisions with projectiles that are common in play scenarios. These projectiles could strike the bubble toy and halt the functionality of it by impacting the servo motor that pulls the trigger back. This possible problem would suggest that in the future more precautions could be taken to protect the bubble toy and the motor system. Some possible designs for this could be creating a barrier around the bubble toy or a sturdier housing that is mounted around the bubble toy atop the car.

7.2 Alternative Stimuli

This project could also be furthered into researching which stimuli provide the most enjoyment and peer interaction between children with disabilities who use the modified ride-on-cars. Different stimuli would prove to be more appropriate in different environments. For example, if a child was playing in a large classroom, loud sounds emanating from the car may be inappropriate and a distraction to whatever activity is happening in that vicinity.

Different stimuli have the possibility of intriguing children in different ways and could possibly encourage group-play more in different scenarios. The stimuli on the car could also be modified to be most effective depending on the child that operates the modified ride-on-car most frequently. Since the goal of the stimulus – in our case the bubble toy – is to grasp the child’s attention, using a stimulus that has a history of entertaining that specific child would be most ideal.

Some possible ideas for stimuli that could work as well or better than the bubble toy with lights and sounds that we utilized in this project are: lights and sirens (similar to those on a firetruck), interesting noise makers (such as a dinosaur roar, other animal sounds, or car noises), as well as other flashy light sources (such as a colored strobe light).

These different stimuli could correspond with the theme of the car – if one is present – to better reinforce the mental connection between the use of the cars and the social interaction of the stimulus.

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Appendices

Appendix A: Arduino Code

```
#include <Servo.h>
Servo servo;
const int off_position = 0;
const int on_position = 180;

const int snsr1pin = 3;
const int snsr2pin = 5;
const int snsr3pin = 6;
const int snsr4pin = 7;

const int servopin = 10;
const int TARGET_DISTANCE = 60; //this is the distance we want to trip off the sensors in inches
const int MILLISECONDS_ON = 5000;  //time that the bubble gun stays on   TIME IN MILLISECONDS
const int REFRESH_TIME = 10000;   //time delay before sensing begins again  TIME IN MILLISECONDS

long range1,range2,range3,range4,pulse,distance; //this declaration avoids the recreation of variables, saving memory

void setup() {
  servo.attach(servopin);
  if(!initialize_all()){    //if one of the sensors faults initializing
    stop_arduino();         //kill the process before the sensors begin looping
  }
  else{
    Serial.println("ARDUINO TESTED AND BEGINNING SCRIPT");
  }
}

void loop() {
  range1 = collect_range(snsr1pin);
  if(check_in_range(range1, snsr1pin)){
    activate_servo(MILLISECONDS_ON, REFRESH_TIME);
  }
  range2 = collect_range(snsr2pin);
  if(check_in_range(range2, snsr2pin)){
    activate_servo(MILLISECONDS_ON, REFRESH_TIME);
  }
  range3 = collect_range(snsr3pin);
  if(check_in_range(range3, snsr3pin)){
    activate_servo(MILLISECONDS_ON, REFRESH_TIME);
  }
  range4 = collect_range(snsr4pin);
  if(check_in_range(range4, snsr1pin)){
    activate_servo(MILLISECONDS_ON, REFRESH_TIME);
  }
}
```

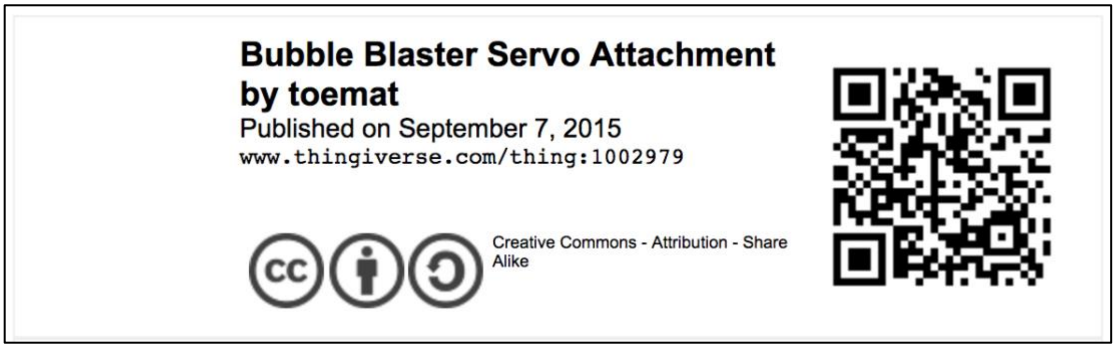
```
//************************************
//collect_range()
//description:  this function reads in distance by activating the sensor pin argument
//              then converts this number to inches and returns this number
//return:       integer distance in inches
//************************************
  long collect_range(int sensor_pin){
     pulse = pulseIn(sensor_pin,HIGH);   //collect reading
     Serial.print("pin: ");
     Serial.println(sensor_pin);
     distance =  pulse/ 25.4;            //convert to inches
     Serial.print("inches: ");
     Serial.println(distance);
     Serial.println();
     return distance;
  }
  //************************************
 //check_in_range()
 //description:  checks if the distance is less than the target distance
 //return:       boolean value true if less than global constant target_distance, else returns false
 //************************************
  bool check_in_range(long distance,int sensor_pin){
     if(distance < TARGET_DISTANCE){
         Serial.print(sensor_pin);
         Serial.println(" within range");
         return true;
     }
     return false;
  }
 //************************************
 //verify_sensor()
 //description:  runs the sensor once initially, and verify's that the reading is not faulting
 //return:       boolean value true if a reading is given, else returns false: error in wiring
 //************************************
  bool verify_sensor(int sensor_pin){
     Serial.println("INITIAL SENSOR TEST");    //start sensor validation testing
     int test = collect_range(sensor_pin);
     if(test == 0){
       Serial.print("SENSOR FAULT: ");     //error reading, check wire connections for sensor
       Serial.println(sensor_pin);
       return false;
     }
     return true;
  }
```

```
//**********************************
//activate-servo()
//description:  this will activate the global object servo, with given time and refresh time
//return:       n/a
//post: servo activated for given time, then return to off_position
//**********************************
 void activate_servo(int milliseconds, int refresh_time){
    servo.write(on_position);
    delay(milliseconds);           //keep the servo in the on position and shooting bubbles for this time
    servo.write(off_position);
    delay(refresh_time);           //have a delay period before sensing again immediately
 }

//**********************************
//stop_arduino()
//description:  end arduino functionality in endless loop
//return:       n/a
//post: arduino is deemed inactive from error
//**********************************
 void stop_arduino(){
  Serial.println("ARDUINO END LOOP INITIATED");
  while(1);
 }

//**********************************
//initialize_all()
//description:  runs the sensor once initially, and verify's that the reading is not faulting
//return:       boolean value true if a reading is given, else returns false: error in wiring
//**********************************
bool initialize_all(){
    servo.write(off_position);
    Serial.begin(9600);
    if(verify_sensor(snsr1pin) && verify_sensor(snsr2pin) && verify_sensor(snsr3pin) && verify_sensor(snsr4pin)){
      Serial.println("all sensors initialized successfully");
      return true;
    }
   return false;
}
```

Appendix B: 3D Printed Bubble-Gun Mount



Appendix C: How To Solder

When attaching two wires to one another, we use solder to make sure they are secure, and cannot be shifted apart from one another. The basic premise of soldering is to use a heated metal iron (a soldering iron) and melt a malleable metal, solder, which will then bind to the two wires and solidify to create a bond in which an electrical current can pass through, that will not be capable of breaking easily. To achieve this, we will strip ends of the two wires we are planning to append together, revealing the metal core that can be connected to another wire. Next to provide stability when melting the solder, it is best to use some sort of clamp to hold the two wires we wish to adjoin in a position where the two stripped ends are touching in a parallel orientation. Once this has occurred, we will touch the heated soldering iron to overlapping wires, so that both of them will become heated, therefore the solder can stick to them. We continue this for around thirty seconds, where at this time we will position the end of the solder to the edge of the iron that is touching the wires, at this conjunction. The solder will then melt, and with some movement of the soldering iron and solder along the touching wires, the solder will encapsulate the stripped ends of the wires. Within thirty seconds after the solder is melted, it will cool and become sturdy so that the wires cannot be separated. Lastly, we will cover the newly soldered area with either electrical tape or heat-shrink so that the wire will not transfer an electrical current to a wire that may be touching this vulnerable area.

Appendix D: How To Apply Heat-Shrink

When two wires are being soldered together and a new connection is formed a section of wire is usually left exposed. This exposed wire can short-out if it is touched to another source of power accidently. To prevent this, we want to use heat-shrink, a rubber tube which doesn't conduct electricity, and surround the exposed area.

Surround the exposed section of soldered wire with un-melted heat-shrink by sliding the cut piece of heat-shrink over the exposed area. Next, use a heat gun and point it at the heat-shrink. Turn heat gun on low heat and keep it pointed at the heat-shrink. Be careful not to point the heat gun at anything else because it is extremely hot and will melt other materials. Lastly once the heat shrink has shrunk to tightly surround the wire, turn off the heat gun and let the heat shrink cool off.