Using Simple, Low Cost, Technology to Enable Children with Physical Limitations to Develop and Express their Artistic Talents:

Language development, decision making, and improved academic performance, are some of the vast benefits of practicing the arts. Unfortunately, a lack of upper extremities mobility and strength, forces disabled students to rely on nurses to move their hands to draw. Three different devices were constructed to allow these students to create artwork. These devices all used the technique of adapting r/c cars into tools for drawing. First adaptations were made to the remote transmitters. The first transmitter was adapted by merging orthoplast, cylindrical pipes, and a cut open tennis ball, to create a joystick. This was modeled after the manual joystick commonly used in electric wheelchairs. For students lacking dexterity skills to control a joystick, two new remote transmitters were created. Adaptations to these transmitters were primarily made on the circuit board of the remotes using soldering techniques to extend the circuit to a mono-jack(s). The mono-jack(s) allowed the cars to be controlled by any specialized switches such as a micro light or jelly bean switch. Finally Velcro and Foam grips were used to allow markers to be attached to the r/c cars. This low cost, biomedical engineering project has the potential to make artwork accessible to all.

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Rationale:

Artwork has long been shown to foster brain development in children and teenagers, especially of the creative and critical thinking functions in the brain. Several studies by major universities suggest that the incorporation of artwork into a developing child's life has immense benefits later on, including increased feelings of satisfaction and happiness. Language development, decision making, motor skills, and even improved academic performance, all have been seen as direct benefits of practicing the arts (Lynch). Therefore it is vital that artwork be presented as an opportunity to all. Unfortunately today, there are people who are unable to perform artwork independently, due to their physical and mental limitations. In turn, their satisfaction and flow experienced is greatly diminished as they constantly have to seek help to move a pen or brush. While working with special needs children, it was noticed that there was a strong desire to create artwork without assistance from anyone else. The main barrier for these students, however, was a lack of coordination and finger dexterity. This bioengineering project was consequently undertaken to create inexpensive, individualized adaptations that would enable these students to draw and paint independently, taking into account their strengths and limitations.

Review of Literature:

This project was designed to help students with Cerebral Palsy, Muscular Dystrophy, head injuries or spinal cord injuries and a variety of other limitations.

Cerebral palsy is the effect of injury to brain before, during, or after birth which mostly affects movement control. As a result the child may have poor coordination, balance, abnormal movements, and / or problems with posture. (Miller) These problems can be classified as stiff muscles (spasticity) uncontrolled movements (dyskinesia) or poor balance and coordination (ataxia) - most common of which is the spastic kind. Ataxia which affects fine motor coordination is seen in 15% of cases frequently involving upper limbs, but may also involve lower limbs and trunk. (Seay)

Muscular Dystrophy is an inherited disorder due to mutations in the genes critical to muscle integrity. This causes progressive weakness of the muscles. Duchenne's muscular dystrophy is linked to an x-link recessive gene (usually familial) which affects the male child (Stewart). This is the most common muscular dystrophy which affects kids, and is due to an absence of a muscle protein called dystrophin which keeps the muscles healthy and strong. Children suffering from muscular dystrophy usually start to show signs of muscle weakness when they to start to walk as a toddler and progressively become weaker as their muscles are unable to develop normally. By the age of 12-13, they are usually wheelchair bound and the disease may even progress further to breathing difficulties. (Lemley)

Head injuries and spinal cord injuries can lead to mental changes affecting motor and sensory weakness, including hemiparesis, confusion, headaches, memory disturbance and neurological deficits. Prognosis will vary depending on the injury. For example a complete transection of the spinal cord can have a very poor prognosis and recovery. (Seay) These reviews indicate varied motor weakness and incoordination affecting nerves and muscles causing limited motion. These patients can have learning disabilities due to their sensory deficits and contractures.

Purpose:

Today, not everyone is able to create drawings and practice art. Due to a lack of mobility and strength in the upper extremities and limited coordination, students with severe physical disabilities are unable to produce artwork independently from their teachers. Instead these students are forced to rely on personal nurses and teaching assistants to guide their hands to draw. These projects were created to explore the different ways students could create drawings, with minimum outside help.

Materials and Methods:

Medical research, on different diseases that impair motor skills, was reviewed in order to gain valuable insight into the physical limitations of the students. My mentor, an occupational therapist, then assessed the range of motion and muscle strength of the students to determine their strengths and abilities, and provide feedback on what kind of access was appropriate for the particular student. Three different devices were subsequently constructed, to allow the majority of students to draw and paint. The first device created was joystick operated, the second single switch operated, and the third double switch operated, which matched the different capabilities of the different students. The devices although different, all had in common the basic radio control design, which adapted simple r/c model cars into tools for drawing. These adaptations enabled the students with physical limitations to create artwork of their own. Adaptations in the remote transmitter of the car enabled students with diminished finger strength to operate and control model r/c cars and adaptations in the cars themselves allowed these cars to be used as tools for artwork.

The following steps were undertaken:

1. Creation of a workspace
2. Attachment of pens and brushes to r/c cars
3. Modifying the r/c car's wireless remote to allow a special needs child to control the r/c cars movements and thus create artwork.

- **Step 1: Create an Art Workspace**

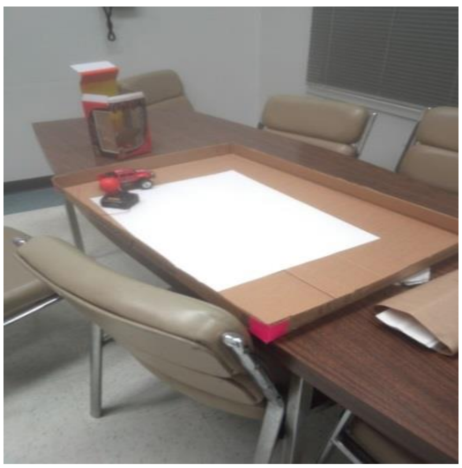


Figure 1: Cardboard Platform with borders

Due to the use of remote control cars in a classroom environment, a workspace was constructed out of cardboard in order to secure the art paper and to keep the cars from tumbling off the desk.

- **Step 2: Attach Drawing Tools to the Remote Control Cars**

Adaptations were then constructed for the r/c car itself. Foam pencil grips were used in combination with Velcro to create a placeholder for the markers on the car. Additional Velcro was then used to attach the placeholder to the car, at an angle for marking. Some cars had multiple places where markers could be attached – in the back and /or in the front. The angle and positioning of the markers allowed users to create different strokes with the cars. Additional Velcro straps could be used to secure the marker in place.

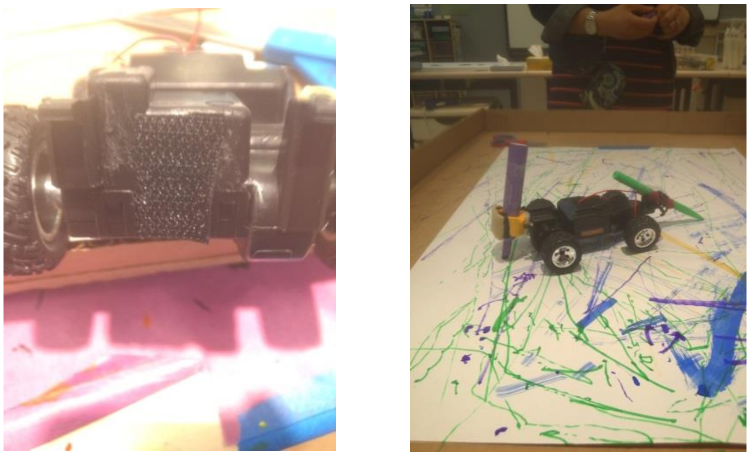


Figure 2a & 2b: Velcro attached to car for interchangeable use of markers.

Figure 2c – 2e: Interchangeable markers fastened to cars with Velcro and foam grips.

The markers had Velcro receptor ends to allow them to be attached to the adapted cars. Students could choose and change the colors they wanted to draw with.

Figure 2f: Selection of markers with Velcro receptor ends.

When the students used their adaptive transmitters to control the car, the marker attached would move and create artwork. Furthermore, the Velcro design allowed for an interchangeable use of colors and markers on the car.

- ## Step 3: Adapt the Remote Control to the Capabilities of the Students

Three different types of remote controls were modified – joystick, single switch and double switch. These modifications are described below.

Joystick Adaptation to the Remote of an R/C Car:

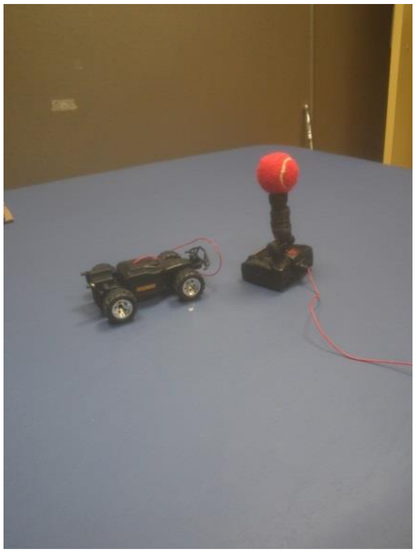


Fig 3a: Splinting pan used to heat water to mold orthoplast.

Fig 3b: Orthoplast forming a bridge between the two levers of a remote

Fig 3c: Tubing attached to Orthoplast Bridge

Fig 3d: Tennis ball attached to top of tubing

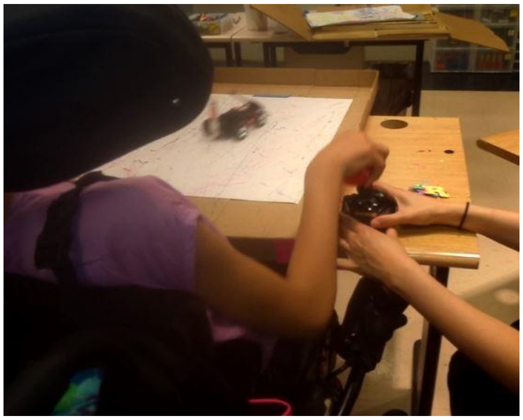


Figure 3e: Student using joystick adaptation to control r/c car and draw.

Due to limited hand strength, some students were unable to grip utensils for drawing or painting. Nonetheless they were able to maneuver their powered wheelchairs using joysticks. Remote control cars available on the market however, were unfortunately manufactured with small levers or knobs. These levers and knobs needed fine motor coordination and finger dexterity which these students lacked.

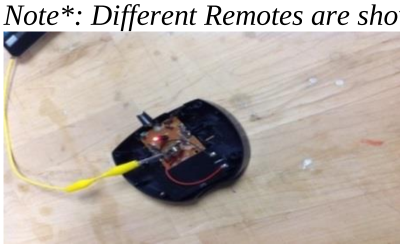
The first transmitter was adapted by merging orthoplast (a material that is easily molded at high temperatures but strong and sturdy when cooled) a cylindrical pipe, and a cut open tennis ball to create a joystick. This resulted in a design that modeled after the manual joystick commonly used in electrically powered wheelchairs. This joystick-operated specialized transmitter allowed for students who lacked the fine strength to grip a paintbrush, to control the car, thus enabling them to create artwork.

Adaptations to the Remote for Single Switch Access:

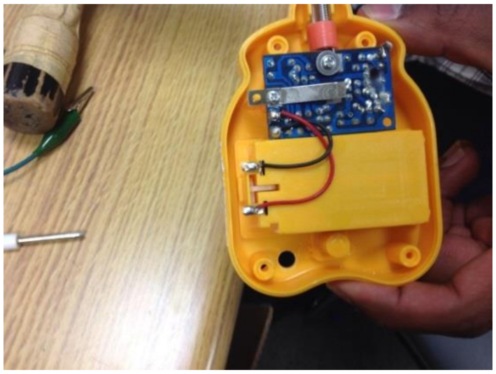
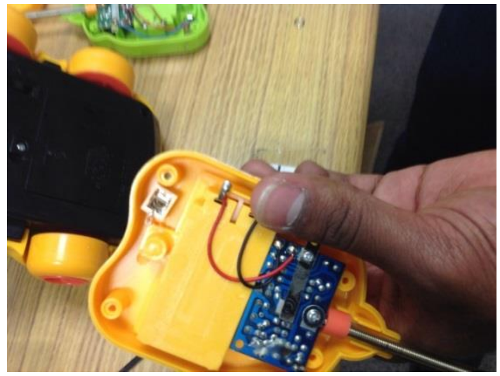
Adaptive Design in New York City is an organization that adapts equipment and toys for people with physical impairments. They make furniture out of cardboard and are equipped with advanced technology such as a 3-d printer. While in New York, a workshop was attended to learn about developing and designing modes for access.

*Note: Adaptive Design provided information and training only. Not affiliated with this project.

The following show step by step adaptations to single switch remotes.
Note: Different Remotes are shown below but process is same.*



Figures 4a: Exposed motherboards of opened up remotes. Points which operate car are tested through the use of alligator switches.

Figures 4b & 4c: Hole drilled through exterior of remote to make room for a mono jack panel mount. Mono Jack Panel Mount is placed in the hole drilled.

Keyword: mono jack panel mount – a screw and mount nut that can be attached to any hole with soldering receptors for wires. (Functions as a socket for adaptive switches)*

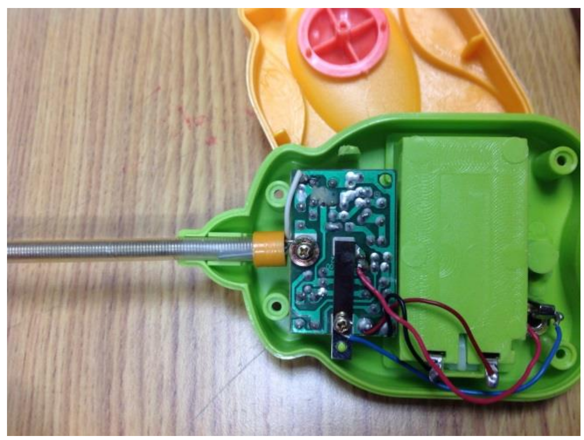



Figure 4d: Additional, outside wires are soldered to the receptors of the monojack.

Note: For Monojacks with three receptors like the one shown below it is important to solder at the two ends and skip the middle receptor.*

Figure 4f: Points are soldered onto the two sides of the mono jack and the points on the circuit board which operate the car. This extends the circuit to the mono jack thus allowing adaptive switches to be plugged in and control the car.

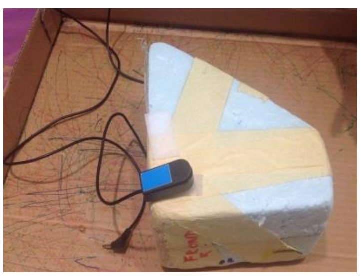
Note: The two remotes shown above are of the same model but have used different types of mono jacks. The process is the same regardless.*

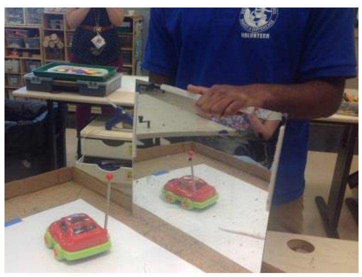
Figures 5a and 5b: The figures above show a completed adaptation to the transmitter of a remote. Now the remote is ready to be plugged in by different types of adaptive switches, used by the students.

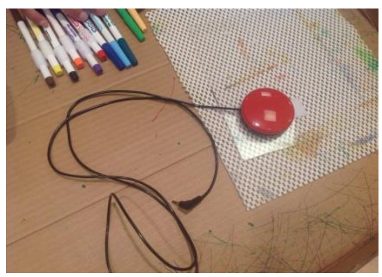
The Two Major Adaptive Switches Used:

Figure 6a: Micro light switch – A touch sensitive switch that can be operated with the slightest amount pressure. The Micro light switches allowed students with major paralysis to control the car.

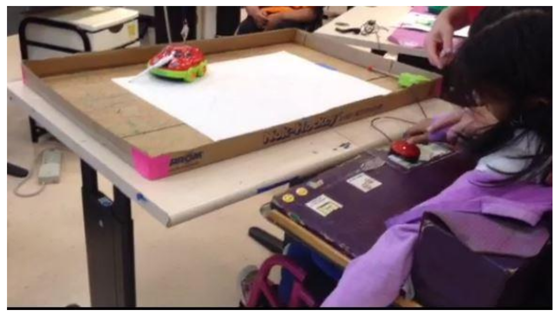
Figure 6b: Jelly Bean Button – A commonly used adaptive switch that allows students with limited fine motor skills, to operate adaptive toys. The Jelly Bean button will operate regardless of where it is pressed.







The two switches from above, the Jelly Bean button and the Micro Light switch are sometimes used in combination with other tools to provide more support for students with physical limitations. The leftmost picture, **Figure 7a,** shows a micro light switch attached to armrest, which enables more students to utilize the adaptive transmitters. In addition the middle picture, **Figure 7b,** makes use of a mirror so that students with mobility problems can see their artwork while drawing and operating the adaptive cars. Finally the rightmost picture, **Figure 7c,** uses a Jelly Bean button attached to a plexiglass screen to secure the button in place. (*See Further Uses of Plexiglass Below)*



Figures 8a and 8b: The figures above show the versatility of using plexiglass with the jelly bean button. In figure 8a, the plexiglass screen is attached underneath a student's tray allowing him to hit the button on the spot where his cup holder resides. Figure 8b shows the plexiglass screen being attached on top of the desk. Either way, these students are utilizing specialized adaptations that allow them to draw.

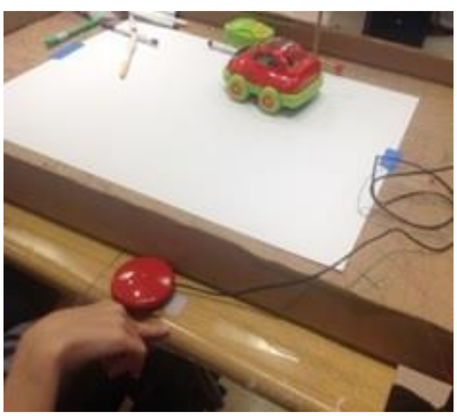


Figure 8c: The figure on the right illustrates a unique mode of access by a student: a head pointer is being used to press the jelly bean button. The student in that image had more control of head movements and thus the use of a pointer was appropriate.

Figures 8d & 8e: Modes of access used by some students: Small blue micro light switch attached to armrest.

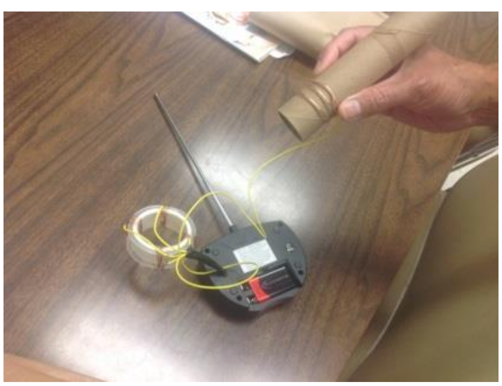
For students who lacked the dexterity skills to control a joystick, a new remote transmitter was created. Adaptations to this transmitter were primarily made on the circuit board of the remote. Soldering techniques were used on additional separate wires to extend the circuit to a new point of contact -- the mono jack (a universal socket that allows for any cable to be plugged in). These techniques made it possible for the remote of the car to be controlled by any independent device such as the micro light or jelly bean switch. By soldering and extending the circuit board of the remote, a new, highly versatile transmitter was created, which allowed different students to plug in and use their own specialized switches to operate the car.

Joystick Adaptations Part 2:

The first joystick made, was created by using orthoplast and making changes to the levers or external part of the remote. Although functional in its purpose, a new joystick was produced making changes to the circuit board or internal part of the remote. The changes to the remote of this car are shown below.

Figure 9a: Basic design for creating the joystick extension: Four points of contact on an outside ring, and an extension using a joystick from the commanding point.

Figures 9b & 9c: Alligator switches used to test the points on circuit board that operate the car. The alligator switches are attached to the circuit board and extended to four points on an outside ring. Additionally the part that controls the car is extended to a joystick. Thus when the joystick touches any of the four points on the aluminum ring the r/c car will move in a different way.



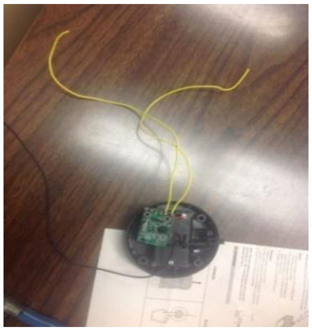
Figures 9d and 9e: Finished adaptation for the creation of a joystick operated control. Because aluminum foil was impractical to solder to, yellow wires were soldered to the circuit board and copper wires without its coating. Again when the copper around the joystick touched any of the four points of copper around the ring the car would move in a specific way.

The process to create a joystick operated car required aluminum foil, or bare copper wire, which acted as a conductor when attached to the circuit board of the remote. The joystick would be connected to one part of the toy's circuit and four wires would be extended from the circuit board to four points of aluminum or copper on a ring outside of the remote. When the joystick touched a part of the ring of the remote, the car's wheel would move. When it touched another, the other wheel would move and so on. The four different controls for the car (right wheel move forward, left wheel move forward, left back wheel turn and move, and right back wheel turn and move) would be controlled by which part of the circle the joystick would touch.

Double Switch Adaptations to the Remote of an R/C Car:

Figure 10a: R/c car that is going to be adapted with two switches. It currently is controlled by two controls – go forward and turn left while going back.

Figure 10b: Alligator switches testing the points of connectivity that operate the car.

Figures 10c & 10d: Outside yellow wires soldered to the points on the circuit board that operate the car. They are four wires (rather than two as in the single switch operated car) because the circuit is being extended to two points of contact rather than one. The other ends of these yellow wires will be soldered to two monojacks.

Figure 10e: Finished adaptation to interior of remote. The points that operate the car on the circuit board are soldered to yellow wires which are then soldered to the two ends of a monojack. This allows adaptive switches to be plugged in used by the students.

Switches Used:

The switches used for controlling this adaptive transmitter were the same ones that were used in the single switch remote (jelly bean button and micro light switch) however they were used in different ways.

- **The Headrest:**

Figures 11a & 11b: Two jelly bean buttons were attached to the sides of students' headrests to allow them to use their head movements to draw. This design benefited kids with more control in their head the most.

- **The Leg Straps:**

Figure 11c: Two jelly bean buttons were attached to the legs of a student with vision impairment. The two button design allowed this student to use his hearing as an indicator of when to switch the button he was controlling. When the r/c car hit the boundary of the box station, the student would hear the collision and switch the button he was hitting. This exercise helped him develop using his sense of hearing while creating an art project for himself and his family to enjoy.

Uncoordinated movements of the arms, led to the creation of the last adaptive transmitter. This transmitter used the same soldering and extension techniques as in the single switch transmitter. In this device, however, two ports were created, allowing two separate switches to be operated by head movements. These switches were held in place with Velcro on both sides of a headrest of a wheelchair. This design benefited kids with uncontrolled hand movement the most. Its versatile design allowed them to use their head movements to operate the switches which in turn controlled the car.

Results:

During this past summer all three adaptive r/c cars have been successfully used in the art department of a school for children with severe disabilities. The specialized transmitters created have been instrumental in allowing the students to produce artwork of their own. Further exploration into adaptive design must occur in order to create a more efficient and specific-oriented device. These adaptive cars have great potential to make artwork universal to all.

Overall, this project was a huge success. Students were very excited at the prospect of painting independently, and parents inquired about the possibility of using these cars at home. Therefore an information guide was compiled with step by step directions on how to adapt these cars.

Discussion:

In order to improve on these prototype adaptations and create a design that is more specific oriented to the task the following improvements should be considered. First future studies should be conducted to determine what speed the r/c car should be adjusted to, in order to allow users the most detail in their drawing. A slower speed of the car would give more users precision in their strokes and control of their shapes.

Next a specific holder should be built into the car, with the same interchangeable use of utensils that the Velcro design provided. However the holder should hold the drawing utensil more securely than Velcro and minimize slippage of the marker. A car design with built in different color markers is suggested.

Further for the visually impaired, who still have a desire to create artwork of their own, audio sounds should be incorporated into the car or remote. The sounds should direct the visually impaired if the car is going straight, turning left or right, or going backward or forward. By providing different sounds for the different directions the r/c car is moving towards, the blind will be able to use their sense of hearing to create patterns and shapes of their liking.

Finally future models must be developed in order to improve the aesthetic appeal and cost-effectiveness of the cars. Currently a website is being formed to allow parents to send their regular off the shelf remote control cars to be adapted. The process for adapting these cars manually; however, is still somewhat expensive (for a mass scale) and tedious. If a manufacturing company would assist in the creation of these specific oriented devices, cars would be able to reach more special needs students at a lower cost.

Conclusion:

Artwork is crucial for brain development, self-expression, critical thinking, and creativity in children and adolescents. Therefore it is important for a society to make the arts accessible to all. Genetic conditions and physical limitations were seen as the chief obstacles in preventing artwork to be created by children with special needs. As seen in this paper, however, these obstacles can be overcome. These adaptations serve as just a starting point in the challenge to make the arts accessible to everyone.

Important Note: This project is solely a bioengineering project. All human interactions were performed by the occupational therapist.

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