Design development and performance study of a novel assistive device for mobility of toddlers and children with visual impairments

Joowon Jun
CUNY City College

How does access to this work benefit you? Let us know!
Follow this and additional works at: http://academicworks.cuny.edu/cc_etds_theses

Part of the Biomechanics and Biotransport Commons, Biomedical Devices and Instrumentation Commons, and the Other Biomedical Engineering and Bioengineering Commons

Recommended Citation
http://academicworks.cuny.edu/cc_etds_theses/675

This Thesis is brought to you for free and open access by the City College of New York at CUNY Academic Works. It has been accepted for inclusion in Master's Theses by an authorized administrator of CUNY Academic Works. For more information, please contact AcademicWorks@cuny.edu.
Design development and performance study of a novel assistive device for mobility of toddlers and children with visual impairments

BY

JOOWON JUN

THESIS

Submitted in partial fulfillment of the requirements for the degree of Master of Science in Biomedical Engineering of the City College of the City University of New York, 2017

New York, New York

Approved:

____________________________________
Professor Marom Bikson, Thesis Advisor

____________________________________
Professor Mitchell Schaffler, Chairman

Department of Biomedical Engineering
ABSTRACT

Being able to see allows mankind tremendous access to learn about the world, and because so much learning comes visually, children with visual impairments are delayed in developing range of skills: learning own languages, doing activities, socializing with peers, and etc. While children with vision can do virtually all the activities and tasks for granted, children with visual impairment require different types of tools or materials to do same tasks most of time. Amongst all the disadvantages that children with visual impairment have, one of the most critical disadvantageous area that visual impairment brings to toddler is learning to walk.

This thesis presents the step-by-step development of a novel assistive device that could be used for toddlers and children with visual impairments to help them walking, while developing important skill sets in their early developmental milestone. In this paper, detailed construction methods for new conceptual designs are described, and how design was modified and implemented on to next design after tested for clinical trials with blind participants to approach to the final design. Moreover, underlying mechanisms that were adopted to resolve the initial and newly found constraints with performance of the device are presented in this paper. Device developing methods presented in this thesis are more likely based on trial-and-error, thus, technique of implementation on missing and lacking criteria on earlier versions and approach towards optimally functioning version was used.

The result of this research showed that improved performances of toddlers in walking more confidently and acquiring better realization on surrounding environment. This result implies that assistive mobility device would provide aid to blind toddlers and children to learn how to walk which is an essential part of gross motor skills in which development of gross motor skills plays crucial role in development of toddlers and children at their youthhood.\textsuperscript{1}
Development of this novel device and further improvements on the design would provide a fortunate light to unshed darkness that blocks toddlers with visual impairment and hopefully fill up those areas that visually impaired children are relatively slow in development.
AC Knowledgements

I would like to express my gratitude to my research advisor Dr. Marom Bikson for his endless support through teaching and showing a guidance to development of biomedical device and the stepwise processes related in manufacturing of device during this master thesis research. He has given our team confidences on developing a device which our team was struggling with difficulty of design construction since there is no similar product exist in the market that we could get the idea from. Also, I would like to thank Dr. Grace Ambrose-Zakan who first provided this lovely project and idea of creating a device to help toddlers and children with visual impairments learning to walk, and gave us a lot of support and advices on design construction. Moreover, I would like to thank for her patience in which she had to wait for the development of design and related modifications that took longer than expected. Furthermore, I would like to thank to my partner, Henry Bernstein, who has always been cooperative and helpful in this thesis research, and devoted lots of effort in design construction. Because of his passion on this research, our team could have a lively discussion to come up with new ideas of better way to modify the device. Lastly, I would like to thank to my loved ones who always supported me throughout my journey to get master degree. Without support from all my people, I wouldn’t be able to accomplish what I have done for this master research.
# TABLE OF CONTENTS

PREFACE .......................................................................................................................... vi

CHAPTER I. INTRODUCTION ......................................................................................... 1

CHAPTER II. BACKGROUND ........................................................................................... 3

CHAPTER III. METHODS AND MATERIALS ................................................................. 6

  Version I. Function allowing clearing obstacles away from the path ......................... 6

  Version II. Function allowing to roll over obstacles with certain height ................. 10

  Version III. Reduced mass weight and increased portability .................................. 16

  Version IV. Angle adjustment and harness-handle connection .............................. 22

  Calculations ................................................................................................................. 24

CHAPTER IV. RESULTS .................................................................................................. 27

  Trial I ......................................................................................................................... 27

  Trial II ....................................................................................................................... 29

CHAPTER V. CONCLUSION ........................................................................................... 30

REFERENCES ............................................................................................................... 34
CHAPTER I
INTRODUCTION

Being able to see allows mankind tremendous access in learning about the world. This privilege is thought as natural and taken as granted, but it is exceptional for those who were either with congenitally or acquired blindness. There are differences amongst blind people in terms of level of their vision, in which some are partially blind and some others are totally blind. Vision or sight, one of the five senses, serves as a critically important method to perceive data. Because so much learning comes visually, those who were congenitally blind are left behind and slow in developing broad ranges of skills that are crucial for living: learning own languages, doing activities, and etc.² While sighted person can do virtually all the activities and tasks for granted, visually impaired one cannot do many certain tasks without helps from others or tools. Thus, people with visual impairments need to become more independent in order to guarantee a fully social inclusion.³ Even elderly person still needs help and support for doing tasks that requires vision, it is more challenging for young ones, especially infants and toddlers.

One of the biggest challenge that young blind toddlers face is learning how to walk. It is known that infants start learning to walk in their age of one. There are already existing a lot of devices and tools to aid toddlers learn how to walk, however, not so much useful devices for blind toddlers. According to American Foundation for the Blind, there were estimated 455,000 children with serious vision difficulty in 2017, meaning that they are having difficulty seeing even with glasses.⁴ Furthermore, there were about 2,800 children at age around 3 to 5, and no existing data about younger children.⁵ This data was available because those with disabilities require special services such as education, U.S Department of Education requires every states to report how many were received special education and services which is under the Individuals
with Disabilities Education Act (IDEA). It is primarily because it is obvious that those with disabilities are slower in learning and developing skills than those without disabilities.

The most broadly used tool by people with visual impairment is probably a white cane. There are various of different types of white cane, and kiddie cane is the most commonly used by and designed for children. There are still disputes exist on the early use of cane by children. Even though blind children require special cares and attention from their parents and people around them, it is impossible for those care givers to focus on blind children all time. One of the way that toddlers and young children learn to react to surrounding is by experiencing and feeling, and the very first step of their adventure is learning to walk. However, learning to walk without aids or mechanical support becomes burden to visually impaired children, because they cannot know what exists near them. It is without doubt that they would be trapped and struggled with obstacles and structures around them, and likely to stumble over and fall easily. For those with vision, they would learn this experience as an alert, and adopt skills to avoid obstacles by seeing them. However, for those with visual impairment, they are also likely to learn stumbling and feeling pain as an alert and danger sign, but cannot avoid stumbling and falling over again without knowing there is an obstacle ahead of them. Thus, they need supports from either people or other forms of aids, but these experiences of facing dangers make them to become reluctant to walk and move around. Moreover, these can negatively affect toddlers to become passive resulting in reluctant behavior. This may become more serious and affect their social behaviors in interacting with peers when this developmental stage can change and affect rest of their lives. Therefore, guiding toddlers to learn how to walk with confidence is not only just teaching them how to toddle but also leading them for proper development steps in youth.
CHAPTER II
BACKGROUND

This project-based research was started for the request from Dr. Grace Ambrose-Zakan, an associate professor at Hunters College at City University of New York, to design and construct a device that could replace ordinary cane and be used by toddlers and children with visual impairments. She is a specialist in special education for blind children who has devoted her career on researches related to blindness and mobility of visually impaired people, especially toddlers and children. Current problems associated with toddlers and children with visual impairments are that toddlers do not have fully developed recognition and self-awareness of surrounding environments and it is likely that they would get hurt from falling or stumbling over obstacles such as toys. Preliminary purpose of her request was to develop a device that allows functions such as pushing obstacles away from pathway, changing direction as users change their direction without touching handles to move sideways, and etc. These functions are essential for helping toddlers and children with visual impairments to avoid dangers while they develop gross motor skills, such as to stand up, walk, and run. \textsuperscript{7,8} Because blindness impedes development of gross motor skills that usually occurs by the time children reach two years of age, visually impaired toddlers may not learn to walk at an appropriate age and will not develop skills properly.\textsuperscript{9}

As introduced in previous chapter, the United States provides special education services for students with disabilities under the Individuals with Disabilities Education Act. Because it is likely that students with disabilities would not easily follow the same education provided for students without disabilities. Part C of four parts of IDEA covers infants and toddlers with disabilities including children from birth to age three and this part provides proper
level of services that toddlers need.\textsuperscript{10} However, problem regarding toddlers comes outside of education. Every day is a challenge for visually impaired children especially those in younger ages whom require supports from their parents at various situations such as when they need to move from one place to another, because visually impaired children are living in a totally black world. It is highly challenging for toddlers and young children who have not yet acquire fully developed gross motor skills to even move around in their own houses, which may ultimately lead to development failure in their youth discussed in pervious chapter. Therefore, it is crucial to find a way to help children with visual impairments to adequately develop their gross motor skills, which development of new type of assistive device that enhances visually impaired children to learn to walk would solve the problem.

In this specially requested research, Dr. Grace Ambrose-Zakan wanted us to design a new type of assistive device that functions perfectly without making users to use their hands to move the device. Because ordinary white canes are designed to have a grip making users to use one of their hands to hold, however, since the main target of this research is visually impaired toddlers and children who do not have precognitive knowledges on the way to use white cane where they have not adopted fully developed gross motor skills. To learn proper way of walking, the posture of toddlers is required to maintain balance in which it is necessary for toddlers to move their hands freely.

Alternative designs of white cane currently being sold in the market are mainly focused on blind people who already know the usage of cane, and those designs are simply made to provide better mobility for users. Designs of new types incorporate electronic signals, acoustics, and such else which is an addition onto already existing white cane.\textsuperscript{11,12} Alternative methods that have been widely studied are guiding system using multi-sonar, navigation digital-map software, but these methods are in developmental stage and have not been proven for
effectiveness and efficiency.\textsuperscript{13,14} Some other studies have found to incorporate obstacle sensing technology adopted into the cane\textsuperscript{15}, requiring electronic intervention and efficacy trials.\textsuperscript{16,17} Only type of white cane that is focused on children is called kiddie cane, and it is just shorter version of regular white cane that has relatively shorter shaft to fit the size of children. Only method exists as of now to guide visually impaired children is teaching them how to properly use cane according to RL Pogrund et al., but there are some traditional arguments against early cane usage.\textsuperscript{18} Additionally, there are some types of walking assistive devices such as toddler walker which could be used for indoor purposes, but it is hard to be used by toddler with no vision, thus, an alternative design of walking assistive mobility device is needed for blind toddlers and children.
CHAPTER III
METHODS AND MATERIALS

Experimental design construction

A participant, a 5 year old almost fully blind girl, was measured in prior to check overall lengths of her body to construct a custom-made device. Shoulder-to-shoulder width, distance from shoulder to waist and waist to feet, circumference of her waist and chest, distance from one side of waist to other side, size of palm and finger, and length of her arm were measured prior to visualize expected dimension of the device.

Version I. Function allowing clearing objects away from the path

The preliminary focus of the earliest design was on the function and ability of the device to clear and push away objects that had height sizes greater than 1 inches, in which objects with higher height dimension could possibly cause toddlers to step on and stumble over easily. Even tiny little cracks on the street can be trouble for toddlers in age around 2~3 and cause damages if they trip over cracks. Especially considering toddlers’ behavior and age, it is highly likely that there would be tiny toys all over the place in the house. Therefore, a carbon fiber bar used for pole of cane was added between two poles around 25mm high from the ground. Two canes were used in this preliminary design to provide stability of the device and support for subjects when using, and furthermore, to give more detailed sensation in contrast to situation when subject is using only one cane. Two canes were located separately at distance of subject’s shoulder width, which this shoulder width does not vary much considering subject’s age.
Additionally, connection between toddler and the device was taken in consideration. The main reason of using cane is to sense and understand if there is any object on the path and if so to imagine how far the object is from one, and possibly details of it. However, toddlers in their skill developmental level are unlikely to have same level of sensation as grown-ups have. Because the translation of sensation using ordinary cane takes multiple steps; 1) sense the target with the end of cane tip, 2) perceive that sensation through the connection between the handle of cane and grabbing hand, and 3) understand the perception through sensory motor in the brain. Blind people sense and understand the object by matters such as appearance and texture using skills they acquire throughout their experiences, and toddlers in developmental steps might not be able to fully translate what they are feeling with cane tips. Therefore, the most effective way to feel something is using the whole body, especially around torso area.

However, direct connection of cane to body could possibly and most likely to cause troubles because if subject runs into stationary object, the connected area would cause impact and damage subject’s body. Therefore, each end of two cane poles was connected to both left and right side of the “hoop” where hoop is attached with handles and this hoop is connected to the vest that subject would wear by using bungee cords. The hoop was constructed based on the circumferential dimension of waist of the subject, making it an oval shape structure with width length of 230mm and height length of 80mm, so that the hoop stays around the waist. The hoop consisted of four different parts, in which originally the hoop was made as one giant piece, but because of the dimension of 3d printer, it was sectioned and divided into four parts. The hoop was constructed to have symmetrical geometry, in which quadrant 1 and 4 are symmetric to 2 and 3 shown on figure1. Quadrant 1 and 2 were meant to positioned on the back of the subject, and 3 and 4 were extended with handles. Connection between 1 and 2 was
constructed with simply insertion and screw. Quadrant 3 and 4 were connected to 1 and 2 correspondingly using hinge method shown on figure 3. Using hinge method, quadrant 3 and 4 were manageable to be opened and closed when the subject put on the device.

Figure 1. Captured image of “hoop” from the top view. Left image is when the frontal handle parts are positioned to be closed, and right image is when handles are open.

Use of bungee cords between the vest and the hoop, where the 6 bungee cords were inserted into semi-circular cross-sectional holes located on the inner region of the hoop shown on figure 2, would bring close connection between the vest and the device for sensation while absorbing impacts like a safety seat belt on a car. These bungee cords are connected tightly as much as possible to reduce possible loss of translated sensation.
Figure 2. Four aligned parts marked with relatively quadrant I, II, III, and IV. Quadrant I and II were built for back part, and III and IV were built for opening and closing handles.

Figure 3. Cross-sectional area of the “hoop” with 6 semi-circular regions for bungee cord attachment. Frontal parts for the handles are positioned to be open.
The ultimate goal of this device was for toddlers to be able to put the device on and off by themselves without help from their guardian or parents in their daily life.

**Version II. Function allowing to roll over obstacles with certain height**

Based on the result from trial I, it was obvious that additional mechanism was required to push device forward and eliminate hesitation caused by getting stuck at cracks on the road. Since the radius of round cane tip was too small to automatically run over the cracks, additional material that allows the device to roll over certain heighted obstacles was used. First of all, typical cracks that can be found on the road were estimated as 25 millimeters, however, we would need to avoid device to run over obstacles that are too big and high so that toddlers are eligible for tripping easily by obstacles that are higher than level of toddlers’ feet when they walk. Therefore, wheel type material that would automatically allow the device to easily go over 25millimeter, but not above. Moreover, one of the functions we wanted to accomplish in
the new design was to make device to move in side directions when toddler tends to move to side way. Use of wheel would allow this function as typical office chairs can move in 360° direction with only little force applied. Thus, whenever toddlers change their direction to left or right, this 360° rotating wheel would allow changing in direction. Therefore, we decided to adopt wheels that are used for office chairs into the device to see if it resolves the problem. As shown in figure 5, officer chair type wheel has larger diameter compared to ball type cane tips which it allows to roll over obstacles with height around 25millimeter, and leads ball type cane tips to roll over as well.

Figure 5. Drawing showing sizes of obstacle(25.4), wheel(76), and ball type cane tip(50). All units are in millimeters.

To incorporate wheel into the design, the whole design for version I had to be adjusted and modified. Because the wheel needs to rotate not only in direction of x-axis for rolling over obstacles but also around y-axis for directional changes, straight bar on the bottom that was connecting both sides with cane tips and used as a bumper could no longer be used. Instead, to adopt 360° rotating wheel, we decided to make frontal bumper as an arc shape. Nonetheless,
vertically fixed original cane tips were found out to be causing too much friction with the ground when the tiles on the road were not equally levelled out. Therefore, the original cane tips were positioned to be parallel to the ground so that their ability to rotate 360° in horizontal direction would allow smooth rolling when the device is pushed forward.

Additionally, we wanted to add visual element into the device, so that the device can be approached and felt more friendly by users and their fellows. Considering the users’ ages, the friendly looking toy-like design would be able to attract and get users’ attention more easily. Therefore, along with keeping the core functions of the device, we decided to create an exterior surface that covers the cane tips and connections while having friendly appearance. Therefore, we decided to mimic those typical toys that are known to attract toddlers and children which are mostly in shapes of animals or commercialized cartoon characters shown in figure 6. The dimension of new design was 300x150x130 which did not fit in 3d printer, so it was necessary to divide it into two pieces. Dividing into symmetrical left and right parts was not an issue, but the method to connect two parts was a new problem. Therefore, two locations on cross-sectional surfaces were chosen to create socket-joint by one part having two ‘plugs’, one on nose region and one on bumper region and other part having two ‘sockets’ exactly on same location shown on figure 7.
Figure 6. Toy cars for children in the market labelled in A, and Design constructed in Version II labelled in B.

Figure 7. Two locations of plugs created on one side of divided parts. A and B are relatively at nose and bumper region.
Also, there was a slight change on connection between harness and cane poles. The hoop created in previous version was one of the parts that took most of time for designing and constructing, however, it was removed due to its lack of user-friendly easiness. Instead, more simple and direct connection between harness and cane poles was designed. Since the hoop was removed, bungee cord connection method was also removed despite its durability and stability. Still, 3d printed parts to insert the end of pole were needed, so we came up with idea of using neodymium magnets between harness and pole-connected 3d parts. Handles were designed to be attached with 3d part connected to pole as whole one piece, and circular shaped neodymium magnet was attached onto the inner side of pole connector piece using super glue. However, the remaining problem was the method to put another neodymium magnet on the harness.

If the magnet was directly attached on the surface of the harness using super glue, the following problem would be that magnet would eventually fall off from wearing occasionally. Also by this way, magnet would be fixed at that specific location and not be able to be adjusted when it needs to be located relatively on the sides of the waist of user in respond to tightening on the harness. When the harness is tightened to cater for the user, the circumference of the waist band of harness would be also changed. If the magnets are in fixed position, the position would move towards front part of body if the harness is tightened. To avoid direct attachment on the surface, adequately sized pockets were made on both sides of the harness temporarily shown on figure8. By this way, harness could be attached to handle part by attaching to magnet inserted inside of handle shown on figure9. This method allowed 360° rotation of harness when attached to handle as well as detachment.
Figure 8. Images of harness taken from front and side. Circular shape on middle of harness is temporarily sewn-in magnet.

Figure 9. Images of harness attached with handle part. Right image shows the magnet connection between harness and handle.
**Version III. Reduced overall weight and increased portability**

Originally the wheeling mechanism was tested using regular wheel that is used for office chairs in version II, but was replaced with wheel type cane tip in version III because the weight was too heavy. Therefore, wheel type cane tip from Ambutech was chosen to be used as additional material based on the its adequate size of radius and overall dimension. Three cane tips, two ball types and one wheel type, were designed to be aligned at their centers so that larger middle wheel type cane tip touches the obstacles or cracks on the road first. The underlying mechanism for this aligned center is to make wheel type cane tip to have first touch with the obstacle to lead other two side cane tips to roll over.

Moreover, based on version II we noticed that the weight of assembled 3d printed device was too heavy to be portable and too big to be printed massively with 3d printer. Because expected functions we wanted to achieve in version II were observed, we decided to reduce all the unnecessary materials and keep the main frame, because printing time required for 3d printing was enormous because of the overall mass and size of version II design. Therefore, the thickness of wall of 3d printed parts were reduced to 3mm, based on impact testing with different size of thicknesses. Thickness between 3mm and 4mm was estimated to maintain constant stability without observable cracks on the wall resulting from force exerted from either connection with pole or collision with external obstacles or wall. Also, unnecessary outer surface created in version II was removed and main frames required to hold cane tips were only remained. Main frame thus consisted of parts to hold three cane tips with small bumper on the front. Parts were connected using light weighted carbon fibered bar.

Dimension of main frame was kept consistent with version II, such as distance between two ball tips and distance from bar to bumper. In order to reduce weight, visual factor was excluded to stick with and focus on functionality of the device, in which the resulting design is
shown in figure 10.

Figure 10. Images of frame of version III taken from front and top views. Only parts for 3d print are shown.

Two side parts were designed only to hold ball type cane tips, connect poles and insert another piece for connection with harness. On these parts, two smaller hollow tube-like pieces were extruded to insert poles to connect with other parts. Larger tube piece with hexagonal
shaped cut inside was design to insert additional part that was designed to have 360° rotation with connection to pole which is shown in figure10. The small quarter circle arc part on the bottom of top view was constructed to connect two poles attached to side parts and serve as a bumper bar to only allow obstacles with height lower than 1 inch which is also shown in figure11.

![Figure 11. Frame constructed for version III with dimensions labeled.](image)

The giant hollow tube on the top of the design was constructed to connect ball bearing part designed to create pivotal rotation of wheel type cane tip. The part on the bottom of three parts on figure13 connects to wheel type cane tip. This part is design to create pivotal effect for wheel type cane tip to smoothly pivot on the center of the giant hollow tube.
Figure 12. Ball bearing for pivotal rotation of wheel type cane tip.

Figure 13. Schematic image of aligned parts for assembly.

On the side parts, circular tube shapes were then extruded out to make connection with shafts.
These parts were then extruded out at angle of approximately 60° from the ground, which made shaft to have 30° from perpendicular to the ground as complementary angles. 30° angle was reasonable that elbow flexion required when using cane was approximately 20° to 30°. However this angle might need to be changed, so 360° rotatable adjustable pieces were created to be placed between the side parts and shafts shown on figure 14 and 15.

Figure 14. Image of 360° rotating adjustable piece on the right side composed of individual pieces presented in orders for assembly on the left side.
Figure 15. Version III design with all parts assembled together.

Figure 16. Image of version III design from side view showing blocking bar 1 inch above the ground.
**Version IV. Angle adjustment and harness-handle connection**

Use of harness for the connection of the device and the user’s body was found to be hard to manage. Though the harness could be made larger for users who are relatively older than those who are just learning to walk, alternative design that could replace the use of harness was discovered. Originally the purpose of this alternative design shown in figure17 was to provide more stable connection between harness and handle, but it was found to be useful without harness in trial II. The height of this clip-on piece was made to fit the width of side of harness, and incorporated circular extruded part where the magnet would be attached on had slightly smaller size so that it could be inserted into handle part. This additional extruded part would allow more stable attachment of handle part in comparison to previous design that handle and harness were attached only through magnetic pull force.

![Figure 17. Image of clip-on piece made to clip onto harness while connected to handle. Image on the right side shows relative locations where extruded part would be inserted into handle part.](image-url)
Moreover, angle adjustment part was found to be inconvenient and hard to manage, so new type was discovered in this new design. The angle, once fixed for specific value, would not need to be changed unless the size of user changes, but need to be accurately managed in the first place. Therefore, the part consisted of 24 wedges in 360° in which there was 15° difference between two consecutive wedges was built to be attached to both side parts and handle parts to even out the angle differences. Two identical parts were supposedly fit into wedges of each other to keep the angle firmly by screwing both parts as shown in figure 18 and 19.

Figure 18. Image of angle adjustment parts fit onto each other on left side. Front view of the part is shown on right side.

Figure 19. Image of angle adjustment part inserted into one of the side parts.
Calculations

Shafts connecting between the device and harness-attached handle needed to be tailored to fit participants with different sizes. In order to prepare shafts, sizes of waist width, distance from waist to the ground were required and measured.

Variables and constants

$\alpha =$ Angle required to be adjusted depending on waist width of user.

$a =$ 55mm (length between two connected angle adjustment pieces.)

c = 23mm (thickness of clip and handle inserted together.)

$h =$ 59.47mm (height of device measured from ground to center of angle adjustment pieces.)

$s =$ length of shaft.

t = 290mm (width of device measured between centers of inserted angle adjustment pieces.)

w = width of waist measured straight from left to right side.

y = distance from waist to ground.

Given the width of waist, angle to be adjusted has to be calculated first to find appropriate length of shaft. Since there are two identical angle adjustment pieces on both sides of the device, it needs to be divided into 2 to find angle to be adjusted on one side. If the width of waist is equal to the width of device, angle adjustment pieces are straightened with no angles. Angle changes are made starting from y-axis, arcsin of distance in x-direction needs to be calculated in order to find right angle. Thus, to find length difference between width of waist and width of device is calculated below. Length required to be adjusted $x = t-w-2c$, because there are two clips and handles. Since there are two angle adjustment pieces, $x/2$ is the length has to be made from adjusting angle, where $x = \sin(\alpha) \times a$ shown in figure20.
Thus, $\alpha = \arcsin((x/2)/a) = \arcsin((244-w)/110)$

Once the angle required to be adjusted, length of shaft to be prepared can also be calculated. $s = y-h-(27.5+15.5+35.13)-a*cos(\alpha)+(10+15)$, where 27.5 is distance of one angle adjustment piece measure from end to the center of circle described on figure 20. 15.5 comes from distance of angle adjustment piece inserted into side parts where the insertion hole on side parts is 12mm. Also, depth of the hole located on different parts, which 10mm and 15mm are the depth of the hole on angle adjustment and handle part respectively. Because when angle is adjusted, only variable that changes is the distance between attached two angle adjustment pieces, because the distance varies depending on how much the part is adjusted either inward
or outward. Thus, \( s = y - 112.6 - a \cos(\alpha) \), where \( a \cos(\alpha) \) represents the changed length depending on angle adjustment. All measurements are in millimeters.

**Materials**

For the cane tips, two “rolling ball 8mm threaded tips” from Ambutech were used in trial I, and one “rover free wheeling hook tip” from Ambutech shown in figure 21 was used additionally in trial II. Rolling ball tips had diameter of 50mm, and rover tip had diameter of 76mm. Designs were constructed using design software, Solidworks Educational Edition 2013, and all the designed parts were printed using two different types of 3d printers, one supported by CUNY HUB and the other, Zortrax M200.

![Figure 21. Image of two types of cane tips used in research. Rolling ball 8mm threaded tip shown on left and rover free wheeling hook tip shown on right](image)

Light weighted carbon fiber shafts were used for connection between 3d printed parts. And also, 30mm diameter neodymium magnets were first used for connection between two symmetric parts in version II and then used for connection between handle and harness in version III.
CHAPTER IV
RESULTS

Trial I

A 2.5 years old participant, who is partially almost blind white girl, was tested with the version I device. Prior to testing with device, she performed walking without any support or assistive device and showed defensive posture and seemed to be afraid of having footsteps. She could not identify or recognize the location of obstacle until she touches the trashcan with her feet. She was constantly having defensive posture, meaning her two arms were held up frontwards to either locate any reachable obstacles to avoid or walls to depend on. While she was having defensive posture, it was observed that upper half of her body was maintained forth with her lower half was balanced towards back. For participant’s safety, the only obstacles used in this trial were nonstationary 2.5 inch height trashcan and stationary wall.

After she put the device on and kept on for few minutes walking with it, surprisingly she started to walk faster than when she walked without the device. Her defensive posture was corrected and the subject was being able to realize the location of trashcan and to push it forward. Also, when she was stopped by the wall, she was in capable of changing her direction to the opposite direction meaning that she could sense which side of two cane tips were touching the wall.

Interestingly, her behavior was observed to be changed a little as well. After when she finished walking without the device, she was constantly looking for her parents to hold her up which is presumably because she wanted to feel safe and get away from the situation of standing still by herself. However, when she tried the device on, she was keep walking with the device for another 20 minutes after the test was done, which seemed she gained a
confidence walking with the device.

Figure 22. The participant with device tried on is walking on the road after trial I.

After few weeks letting participant’s family for using the version I device daily, feedback was provided for implementation for next step. First of all, the device was usable without any difficulty in the house, however, when she was unable to move forward when two cane tips were stuck at the road blocks or cracks. Secondly, she was not able to reach or get closer to objects when she wanted. Because the connections between the cane poles and the hoop were fixed in position which did not allow separated movement of user. This problem could also be found using in the house, when the subject tries to reach objects on the table or get something from refrigerator. Therefore, solution to these constraints was challenged in next step.
**Trial II**

Trial II was tested on 2.5-year-old boy with vision in prior to test the device on his sister who is blind. The purpose of this trial was to see if version III functions perfectly. Because the measurements of his body sizes were not obtained in prior to testing, shafts were cut into right size at the testing location. Originally, the angle adjustment pieces connecting shafts were planned to be adjusted at the right angle in response to the size of participant by adding glue around the pieces. In the first attempt, angle was fixed at approximately 60° from the ground. However, it seemed the device fixed at 60° was a little too close to the participant that participant’s feet almost touched the device. The angle had to be adjusted, but already glued pieces were hard to be readjusted. Thus, other method to change angle of shafts needed to be determined.

Furthermore, the harness which was made based on sizes of first participant did not fit new participant. However, the trial was still carried out by using new connecting method we made for temporary. This method incorporated clip-on method which was preliminary designed to be clipped on both sides of harness, but was clipped onto participant’s pants for the trial. Though the height of clipped on parts was lower than it needed, the functions of device were observed to be working finely. Changing direction and rolling over the cracks were easily carried out by participant, however, attaching and detaching handles were not tested because we ran out of time. So, methods to connect device to participant and to adjust the angle corresponding to participant’s size were the new challenge for next step.
CHAPTER V
CONCLUSION

In this research, series of different versions of assistive device were designed and modified after trials as a trial-and-error implementation and based on the results, the newer designs after each modification showed better performances and approached towards anticipated goal of the study made prior to the beginning, and further improvements. The result of the study suggested that this novel design device improved walking of toddlers and enhanced their confidence, which improved walking and behavior may encourage faster development of gross motor skills.

There were several constraints that our team faced during the development of the designs, which were mostly technical issues. First of all, due to limited source for 3d printing at stage of version I construction, the design modifications took longer than expected as a result. The design construction was solely made through steps of construction, modification, production, and assembly, whereas production process took much longer than needed in which version III at the end consisted of only important frames so that we could print parts faster, realize the needs of modification, and reprint with adjustment. Also, due to limited access to find adequately qualifying participants, number of trials that was needed to gather sufficient amounts of data was not fully met. However, based on two trials and testing by ourselves, it was evident that the final design showed its efficacy on guiding and supporting toddlers while they are walking.

In comparison to regular white canes, this novel device currently has heavier total weight resulting from using plastic in 3d printing, however, this issue may possibly be resolved once the device undergoes proper manufacturing stage where 3d printed parts are replaced with
better, light weighted materials. Still, the overall weight of the device is light enough to be portable by children and toddlers.

There are some restrictions and conditions for using this novel device. One of the function that we wanted to accomplish on this device was allowing users to reach object or target that they want to approach, but this was managed indirectly. When blind people with cane try to approach to the target, they would move the posture of their arm and hand to move cane close to their body so that there is no object blocking between the users and the target. In this novel design, when user tries to approach to the target when the device is reached the target and does not move further, rotation of clip-on part attached in between harness and handle allows the harness to move up on user’s body and thus the user is able to touch the target. In case when this method is not translated perfectly, secondary option may play role in which detachment of magnets between the harness and the handle would allow users to be freed from the device and reach the target, though, this method incorporates the use of hands to detach the device from harness in which hands-free mechanism does not apply in this case. Moreover, hands-free mechanism would not be applied when toddlers walk up and down the stairs. The theoretical idea that could make this possibly hands-free as well was also found during transition from version II to version III, but it requires additional supplementation on the device that would make the device to become massive. Furthermore, provision of instruction for users must be required to properly use the device. For instance, toddlers might get upset and frustrated when device is stopped by a stationary object which was observed after trial I and prior instruction and explanation on situations are needed for toddlers about the circumstance in which it may be obvious to people with fully developed recognition but it is not for toddlers.

The greatest thing about this novel device is that it has a lot of potentials to be further improved. Studies related to visual impairments have been widely carried out, but there were
not much focused on new design of cane itself, but most of them were focused on add-on to already existing white cane, such as GPS guided, environment sensing and smart phone related applications. Visual element that was removed after version II could be included back into the device during the manufacturing stage once the material selections are done. Since the major targets of this device are toddlers and children, it is as much as important to be shown as an attractive device to others who would see toddlers and children using it. Also, other factors can be further improved such as connection methods between harness and handle to make it easier for toddlers to attach and detach the device when needed. Moreover, depending on whether the device is going to be manufactured as custom made for individuals for clinical trials or ready made for industry, design could be also adjusted for the purpose. Because the layout design was created on computer software, specific dimensions could be easily altered. Currently the angle adjustment compartments are not fixed at certain angle in order to be adjusted in accordance with user’s size and age, but once the optimal angle for users are determined on following trials, the angle compartment could be fixedly created on the side parts before manufacturing.

Though, the preliminary purpose of development of this device was not to replace the usage of ordinary white cane by people with visual impairment, it would be grateful if they are induced to use this novel device. Moreover, because this device needs to be tested to be ensured for its safety and further adjustment, we are temporarily more focused on making toddlers to have natural transition from using this device as a learning tool to walk to using white cane once they grow up, and that is reason for the handles created additionally on the device so that toddlers may acquire awareness of using handle once they move on to using regular white cane. Further studies on improvement of this device could make optimized walking mobility device that may be not only useful for toddlers, but also for all people with visual impairments.
Because so much new ideas come from already existing designs by realizing what factors are lacking in them, this research was harder than any other research considering there is not much working products or ideas on a new device for blind toddlers possibly because the market focused on blind children is relatively small. Therefore, further studies are required to reach optimization of the device as well as we need more social attentions towards blindness and people suffering from it to help people with visual impairments.
REFERENCES


Published 2017.


Published July 2016.


9. Michael Brambring. Divergent development of gross motor skills in children who are blind
or sighted. Journal of visual impairment and blindness. 2006;100(10):620-634


15. Sylvain Cardin, Daniel Thalmann, Frederic Vexo. A wearable system for mobility improvement of visually impaired people. The visual computer. 2007;23(2):109-118


18. R.L Pogrund. The preschool blind child can be a cane user. Journal of visual impairment and blindness. 1989;83(9):431-439

