Final Design Report

Alert Device for Walker (WARNS)

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Abstract

Use of assistive walking devices can lead to a loss of independence or even embarrassment. Annually, 47,000 older adults are injured from falls related to walkers and canes [1]. Current walker designs on the market are primitive, utilizing outdated safety features and lack comfort. The locking mechanisms on these walkers require a manual, pressure-based braking system similar to that of a bike, which leads to both difficulty applying enough force to brake along with a neglect to use the brakes. This becomes a major problem when used on inclines or uneven terrain that hinders the pressure the user can apply to the brakes [2]. Design of a more effective lock activation system alongside an alert system as a reminder to engage the brakes is integral for increasing the overall safety for users of walkers. This device should involve an improved locking mechanism working in conjunction with a low pitch frequency emitting device both connected to a walker. The walker should be able to be used by all regardless of age, mobility, or physical strength, and be used in any terrain without inhibiting the movement of the user. An improved system was designed to target these key areas of deficit. To evaluate the device, data was collected on each possible outcome and a pass fail test was run to determine if the device met the desired goal of success.

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I. Introduction

Walkers are a common type of walking aid used by the elderly and people who suffered injuries that inhibit their ability to walk. These walking aids can greatly increase mobility and independence. Although they have systems in place to maintain the safety of users they can fail due to various reasons. The main reason these systems fail is due to impaired cognition from the user [3]. Specifically, a common issue is users forgetting to lock the brakes on their walker. Along with this, walkers can be heavy and cumbersome making them difficult to use. These factors make traditional walkers a safety issue for certain groups of people.

This project addresses this issue by designing a walker that is more user friendly and has an improved braking system with a better mechanism to trigger the braking system. The mechanism does not require any level of dexterity or hand strength to activate. Additionally, the design includes reminders for users to activate the brakes when the walker is not in use. Together these improvements aim to improve the quality of life of people who use the walker.

There are existing designs on the market that tackle the issue of safety and usability. One specific product that offers similar functionality is a walker with electronically controlled brakes, Patent No. CA2605609C. [4] This design incorporates one or more electronically operated brakes controlled by a touch sensor. The controller is responsive to touch sensitive switches for easy operation, and is adjustable and responsive to the operator patterns. The controller may be used on sloped terrain and may be adjusted to accommodate for the weight of the user to to set limits to the speed at which it can move. This walker, although exceptional in some ways, still has limitations. The main one being how it doesn't attempt to solve the problem of users forgetting to lock the brakes. The goal in this project is to create a walker that further minimizes these limitations.

II. Background

The client Dr. Beth Martin comes from the Pharmacy Practice and Translational Research Division at the University of Wisconsin- Madison. She has a clinical practice at Oakwood Village, a senior living facility.

Some of the main design considerations include the ability to lock wheels to prevent falls and maintain safety, an alert system to remind the user to lock the brakes when needed, and be easy to use for older adults and caregivers. The design allows for accessories such as a seat, basket, handles, wheels, and locks for the brakes. It follows FDA/ADA guidelines for an assistive device. The design also falls within the budget given by the client of $300 to $500. To see the full product design specifications, see Appendix A: PDS.

After reviewing the design requirements, background information was necessary in order to execute the design properly. The first section of background research completed was regarding walkers and their users. Walker users often correlate to a lower wellbeing. Most walker users face independence and mobility issues which leads to less inclination to use the safety aspects of a walker [5].

The majority of injuries caused by walkers are falls. Falls happen because of incorrect sized walkers, poor training or direction for using the walker, and not engaging the safety aspects completely. There are a variety of walkers used by older adults. Of the walkers available, one is chosen based on the user's physical mobility. The design is applicable to a four wheeled walker with grip brakes. The brakes on a four wheeled walker are used by engaging the grip to lock them into place. The brakes are independent of each other, meaning they do not stop at the same time [6]. When creating designs, the independence of the brakes was taken into consideration.

Looking into competing designs was required to create a well rounded design. A major competing design idea was a self-locking walker concept [7]. The concept requires hand sensors that are engaged when a certain amount of pressure is applied. The brakes then trigger to lock into place. The brake system is to prevent unwanted movement on a sloped surface and unwanted movement of the walker. Another competing design was developed by Cornell biomedical researchers [8]. The design developed is an electronic braking system. The walker in the design would start in the braked setting. A button is pressed by the user to release the brakes for movement. Once the user removes their hands from the hand grips, the brakes engage again. Both ideas discovered have similar aspects to the design ideas, but differ in many ways. Both of the competing designs provided insight into the preliminary designs.

For each preliminary design, research on materials has been conducted on each. The first being button brakes. For button brakes, an adafruit fingerprint sensor would be used to trigger the fingerprint button. The adafruit sensor works with an arduino microcontroller [9]. The two would allow for tapping to lock and unlock the brakes. The second design is a noise alert for the brakes. For the noise alert system, an arduino touch sensor component and digikey speaker component would be used for execution of the design [10]. The third design is pressure sensing brakes which combines a digikey pressure sensor along with an Arduino UNO. Across all three ideas, Arduino components are essential to the execution of the project.

III. Preliminary Designs

Design 1: Button Brakes

Design one is a button braking system that utilizes a fingerprint for the locking mechanism. The design consists of two major components; the Adafruit Fingerprint sensor and the Arduino Uno Rev 3, along with smaller components such as wires, resistors, capacitors and a breadboard.

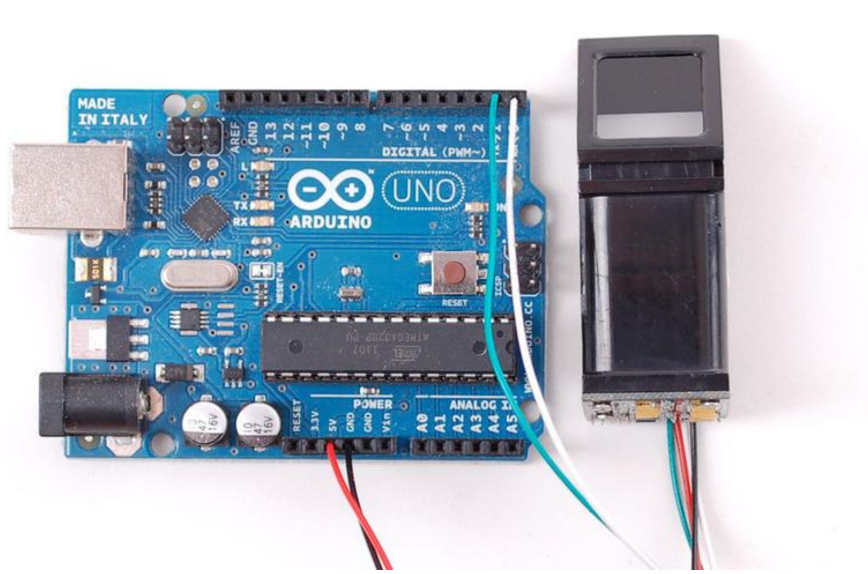


Figure 1: Arduino Uno and Adafruit sensor [11]

The design rests on the handles of a walker and controls the brakes upon the pressing of the sensor. The Adafruit sensor is a 6 pin sensor that can use basic Arduino sketches to register the differences in fingerprints. The sensor can handle between 3.6-6 V battery source and a 0.15 A current. These characteristics helped determine that the Arduino microcontroller would be a suitable device to pair with the sensor due to its similar power and digital pins. The buttons work similar to that of a light switch, toggling from on to off, or vice versa.

There are several benefits to this design consideration, the first being that the integration of a fingerprint sensor to a walker is not a feature of walkers currently and add a sense of individualism and uniqueness for the person using it. Users of walkers tend to associate their device with self worth, and so providing them with easy and personalizable technology can vastly improve interaction and use of the device [12]. This design is also feasible due to the team already having all of the materials to build the schematic apart from the adafruit sensor, which can be ordered for around $50. With the teams budget being relatively small at $300-$500, it is important to make sure that there is not overspending on any components of the design and so being able to build the most of the circuit with a fraction of the budget makes several prototyping stages possible.The design is extremely user-friendly and easy to use. If the device was placed into a hospital setting, it would require no training to integrate and give to patients making it a great option.

There are several constraints of this device. The button brake system's biggest drawback is the lack of a fail system. The purpose of the project is to create an easier alert system for patients who forget to lock the device. Despite the fact that the button would be much easier to use than squeeze brakes, if the patient forgets to lock the wheels, the walker may move without the patient anticipating and lead to injury. Another constraint is the team's coding ability. Although most of the resources were already purchased before the project, the team did not have a lot of experience coding or using Arduino. There was a large amount of time early on in the fabrication process that required learning and becoming familiar with the technology. A related constraint is also integrating the arduino and lock onto the walker. The team needed to do a significant amount of work to effectively be able to attach the locking system onto the walker to a point where it could be used both inside and outside. All these factors were taken into account when the team began to compare and evaluate the designs against each other.

Design 2: Noise Alert for Brakes

Design two is an alert system using sound. It consists of two main components. The first component is a touch sensor on both of the handles of the walker, and the second component is a sound alarm. The two components are shown below in Figures 2a and 2b respectively.

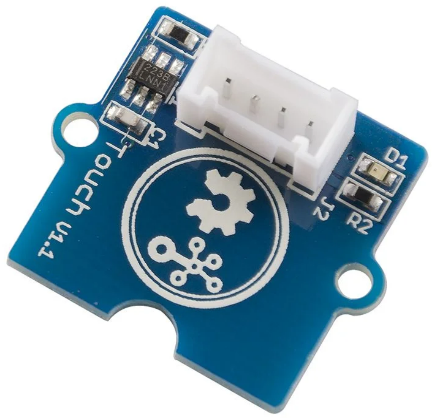


Figure 2a: Arduino Touch Sensor Component [10] Figure 2b: DigiKey Speaker Component [13]

The first component is made by Arduino. The second component is distributed by DigiKey. They are both capable of being integrated using a breadboard such as one from Arduino. Together, they sense when the brakes are not engaged and the user is not holding on to the handles for a certain amount of time, for example, 15 seconds. From there, the speaker emits a low frequency sound repeatedly until the handles are touched again or the brakes are engaged. This reminds users to engage the brakes when the walker is not in active use, such as when the user is sitting on it, or has left the walker somewhere that it could potentially roll away. After the alarm system has been successfully integrated, a light flashing alarm would also ideally be added, so users with hearing impairments could be alerted as well.

This design has many benefits and constraints to consider. The first benefit is that it effectively meets the requirement of reminding the user to lock their brakes when the walker is not in use. The second benefit is that the device is easy to use because it does not change much from the fundamentals of a walker. Nurses would not have to be specially trained in order to use this device. Another benefit is the cost effectiveness. The two components above make up the majority of the device, and only a few more would be purchased. All of the design would fit into the $300-$500 budget. The last benefit is how this design creates a habit for the user. The sound alert system continuously reminds them when they forgot to lock the brakes, and the user would develop the habit of locking it every time so they would not have to hear the alarm going off.

This design also has several constraints to consider. The first is that this design does nothing to change how the brakes themselves work. The design doesn't improve how physically easy it is to lock the brakes. It also does not lock the brakes automatically, which could be seen as desirable by users. Another constraint lies in how to determine what time interval works best for deploying the alarm. If the alarm goes off too soon after the user releases the handles, it could become frustrating for users. In such situations, the brakes would not need to be used, making the alarm unnecessary. If the alarm is delayed for too long, it would defeat the purpose of the alarm system. The last constraint is that the sound itself could be annoying to hear when the user is first learning to remember to activate the brakes. The purpose is to create a habit, but if the user is too frustrated by the sound, they could give up on the device completely.

Design 3: Pressure Sensing Brakes

Design three utilizes pressure sensors to engage and disengage the brake system on the walker. This design is composed of one pressure sensor embedded into each walker grip. The pressure sensors used in this design are shown in Figure 3a and 3b.

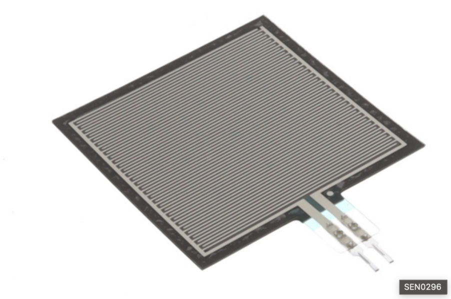


Figure 3a: DigiKey Pressure Sensor [14]

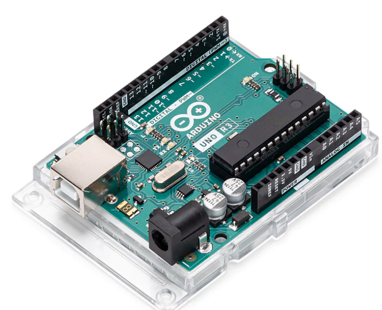


Figure 3b: Arduino UNO [15]

These pressure sensors can be integrated into the walker system by using an arduino microcontroller, shown in Figure 3b. Together, this enables the pressure sensors to communicate with the walkers brakes. When the pressure sensors are not being triggered, the brakes on the walker remain on. When a user places their hands on the walker grips, the pressure sensors are activated and the brakes are triggered to disengage. This prevents users from forgetting to engage the brakes when sitting on the walker, or when the walker is not in use.

This design creates a safer and more user friendly walker compared to traditional models, namely via improved safety features. The default condition for the braking mechanism is engaged, and as a result, the brakes are always activated when the walker is not in use. This removes the necessity for the user to manually engage the brakes when sitting on the walker or when the walker is out of use. In turn, this decreases the likelihood of users falling and injuring themselves. Along with increased safety, this design also advances ergonomics. Instead of using a squeeze-lever system that requires hand strength and dexterity to operate, this system functions without any extra actions. The user does not have to worry about engaging the brakes or disengaging the brakes. They simply place their hands on the walker grips and begin walking. When the user is finished using the walker, they remove their hands and the walker remains in place where it is left.

Although this walker offers many benefits, there are also constraints to consider. Most notably, the coding required to link the arduino, pressure sensor, and locks together is challenging. Additionally, purchasing the necessary hardware to create this design is relatively expensive compared to the other designs. Along with the monetary cost of purchasing hardware, the time necessary to integrate the pressure sensors into the walker grips would be very complex and time consuming. Lastly, this design only offers two options for breaking, fully on or fully off. There are situations in which it is necessary to apply the brakes marginally, to slow the walker down without coming to a complete stop, however this system does not allow for these situations.

IV. Preliminary Design Evaluation

Design Matrix

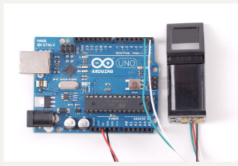
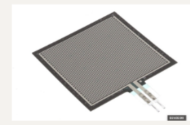
	Design 1: Button Brakes 		Design 2: Noise Alert for Brakes 		Design 3: Pressure Sensing Brakes 	
Criteria (weight)	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Feasibility (20)	3/5	12/20	4/5	16/20	2/5	8/20
Ease of Use (30)	4/5	24/30	5/5	30/30	4/5	24/30
Safety(30)	4/5	24/30	4/5	24/30	3/5	18/30
Cost (10)	4/5	8/10	5/5	10/10	3/5	6/10
Durability (10)	5/5	10/10	5/5	10/10	5/5	10/10
	Sum	78/100	**Sum**	90/100	**Sum**	66/100

Figure 4: Design Matrix for evaluating team design ideas

* Scores are out of 5

** Weighted Score = Weight * (Score / 5)

Design Criteria

Ease of Use - The ease of use of this product should be defined by how teachable and simply the steps of using the device can be translated from one person to another. This included the amount of training required to use it, any certification requirements that may exist, and how long it takes to teach the procedure. Ease of use was ranked high because it is important that all people using the device understand its functionality.

Safety - The safety of this product should be one of the most important aspects to consider because the device is made to assist those with mobility issues. The device can not be restrictive, heavy or require a large amount of physical effort in order to function properly. Safety was ranked equally as high as ease of use because it needs to help the patient complete daily activities.

Feasibility - Feasibility refers to the ease in which it is possible to make the final prototype, taking into account the materials, manufacturing tools, and technical skills required to make the final deliverables.

Cost - The budget for this project is $300-$500. All design costs made during this semester should fall around or below this value. The cost of fabrication for one device on the market should be within the budget of medical manufacturers. Overall, this was weighted the least value because we believe that the cost of designing and fabricating any of the proposed designs falls within both budgets.

Durability - Durability refers to the longevity of the device. The device should not have frail materials on the exterior and should be able to withstand the toll of constant use both inside and outside of buildings. The walker should last many years before needing to be replaced.

Design Scoring

Button Brakes:

Ease of Use - This design received a ⅘ for its ease of use. It is a very simple design that only requires tapping a sensor button in order to use, and is also easy to teach to new users, making it easy to integrate into hospitals and physical therapy. The design could have scored higher with certainty that there would not be user issues when more than one fingerprint is registered on the microcontroller.

Safety - The button brakes scored a ⅘ for its safety. This design scored high in safety due to its lack of sharp edges and inability to harm the patient upon use. The design is also small and does not hinder the handles or the frame of the design, but does not include a fail safe if the brakes are not manually locked, meaning that it did not receive full points when considering design.

Feasibility - The fingerprint design scored a ⅗ for feasibility for a few reasons. This design requires a large amount of coding, and the team does not have a large amount of experience in this area. Due to the lack of background knowledge, a large portion of the project involved learning the syntax and language that Arduino uses. The design also needed to be portable, and later into the fabrication process there was a struggle to find a power source that was portable for the device to be used outside. There are several resources in the BME department at UW Madison that the team took advantage of to try and counter the learning curve.

Cost - The cost to make the button brakes scored a ⅘ because some of the team members already own an electronics kit that can be used for a large part of the schematic. Items such as wires, resistors, Arduino, breadboards, and capacitors were not purchased for this design, as they were already available to the team. The funding from the client was allocated to purchasing the Adafruit sensor and the clamp for the wheels, staying within the budget.

Durability - The durability of this design scored the highest of all the design criteria. It was critical that the device would refrain from the need for any repair and last several years without any maintenance, including extra coding after the initial fingerprint calibration. The device could also potentially require alterations upon an injury to the finger, or if the walker tips over and sensors break. Under normal conditions and everyday use, this design should be easy to maintain.

Noise Alert for Brakes:

Ease of Use - The ease of use of the noise alert scored the highest possible. The device works similar to an alarm for seatbelts in the car and does not require any interaction with the user in order to work. With this device requiring no effort for the patient, there is no integration time for the user or training required for medical professionals. The device may be harder to use for those with poor hearing, so sound tests were also considered by the team.

Safety - The safety of the noise alert design scored a ⅘. The noise device should improve the safety of the walker by reminding users to engage the locks when not in motion, so that the users do not slip and fall when using it. The device would have scored higher, but requires research and testing to ensure that the tone is set at the appropriate pitch and volume. If the speakers are too loud, it could startle the user. If the pitch is not heard, a risk develops of the locks being disengaged when they should be enabled, potentially leading to injury.

Feasibility - The feasibility of this design scored the highest of all 3 designs due to its simplicity. The noise alert utilizes a speaker that will hook up to the Arduino. Though there were similar coding issues with the button brakes design, the addition of an audio device was much easier than coding for recognition of specific fingerprints and is why the design scored higher. Adding the noise alarm to the walker was a major challenge the team faced when making the first prototype. There were also struggles to collect quantitative data for sound and thus it was difficult to change or improve the design down the road.

Cost - The cost of the noise alert design scored the highest of the 3 designs considered in the design matrix. The cost of creating the noise alert system was extremely easy to keep within the $500 budget due to the noise emitting component being so cheap and the team owning every other part of this design. This design scored high in cost also because it would've been possible to purchase several different types of noise makers to test without exceeding the budget.

Durability - The durability of this design scored full points, tying the other two designs. The longevity of this design is extremely high because there should be no need to provide any maintenance checks nor will there be scenarios where the risk of the noise alarm breaking occurs. A consideration that the team made is when the speaker is exposed to water if it is raining when the patient is using the device outside. Water damage may break the speaker or change the sound quality and hinder its ability to perform as it should.

Pressure Sensing Brakes:

Ease of Use - The ease of use for the pressure locking design scored a 4/5 because, like the other designs, it was made to be as simple as possible for the user and medical professionals to understand. The pressure system would be easy to use but would require getting used to how much pressure must be applied to the device in order for the locks to engage. By applying pressure to the sensors located on the handles, the device should be able to lock. This requires no background training to integrate into a real world scenario where a walker is used. The walker would be locked until enough pressure is applied.

Safety - The pressure based locking design scored a 3/5 and the lowest of all designs in safety. This is largely due to the struggle that this design has when on inclined surfaces. When the user of the walker is moving down a hill the center of gravity and center of pressure of the person changes and if the person needs the walker for stability, this could cause them to accidentally lock the walker while trying to move, this could then cause injury to the patient and others in the surrounding. The other problem is an error possibility with setting the threshold of the system. If the pressure value is set too high the person using the device may not be able to successfully unlock the walker for use, defeating its purpose.

Feasibility - The feasibility of the pressure design scored a 2/5 and was also the lowest score for all 3 designs in this category. The reason this design scored so poorly is due to the difficulty of making a successful system that will lock the walker using pressure. To connect a pressure sensor to the handle of the walker would require an extremely flexible and durable material which would be hard to attain. This would also require the most advanced coding for the 3 designs that were considered.

Cost - The cost of the pressure breaks scored a 3/5 and was the lowest score across the 3 considered designs. The reason that this design scored low in cost is because it would cost the most amount of money to fabricate. The cost of sensors that can handle the weight of a person cost upwards of hundreds of dollars and this is not realistic with the specified budget of $300-$500 dollars. The team would not have enough money to purchase and fabricate an entire lock system if one component is going to be a majority of the budget and for these reasons it was given a poor score.

Durability - The durability of the pressure locks scored a 5/5 which is the same score as the other two designs. The pressure system should not see a lot of damage nor be under any extreme conditions that would cause the device to break. The biggest problem with this device is how it would handle sweat from the patient. The exposure to body fluid and other liquids could cause the pressure sensor to break and unlike the other designs, these sensors must be on the exterior of the walker in order to register the pressure the user applies to unlock it.

Final Design

The final device is a walker that includes both the button brakes design and the noise alert for brakes design. The walker has these components attached to the handles of the walker in order to make them the easiest to access for the patient. The arduino microcontroller is able to manage both the speaker and touch sensor portion of the lock system and connect down to a solenoid that was placed on the back wheels, thus engaging the brakes and restricting the movement of the walker when activated. By combining the two designs the team was better able to meet the needs of the client by making an easier to use and more effective locking system.

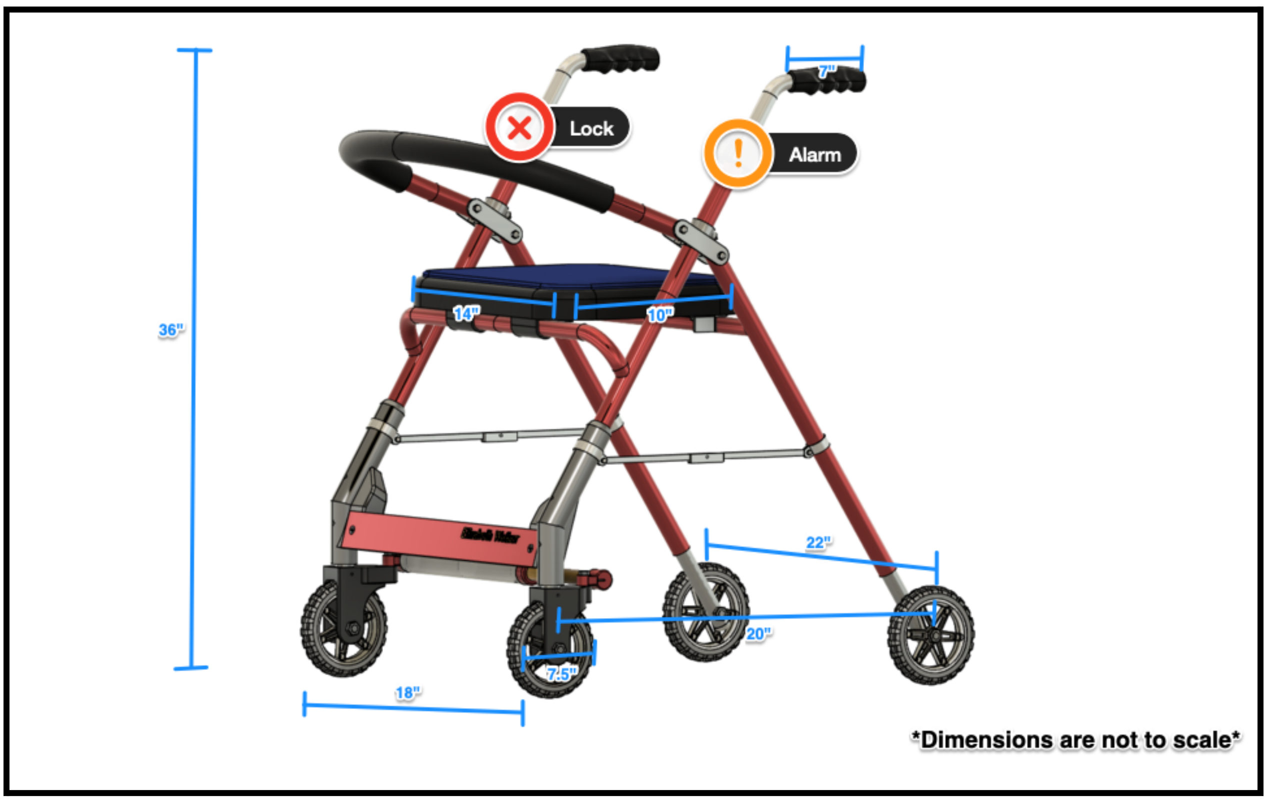


Figure 5: Initial walker system design with dimensions and location of alert/lock system (these dimensions hold true in the final prototype)

V. Fabrication/Development Process

Materials

The device will be used by both elderly and disabled people to increase safety and mobility. The materials accommodate the needs of the user by being both durable and lightweight. Using a client-provided walker, the material of the walker is guaranteed to be FDA compliant and accessible to the users. The sound component of the device uses an arduino microcontroller along with an inexpensive digikey speaker, making it easily accessible and affordable [13]. The braking component of the device utilizes another arduino microcontroller along with a small adafruit touch sensor [10]. The two systems were connected via breadboards, to be run by one single microcontroller. To attach the system to the walker, long wires were run from the circuit to the touch sensor and button up on the handles, and long wires run from the circuit down to the solenoid near the brakes. Finally, a small container to fix the electrical components and circuit to the walker was created from a low-cost plastic known as PLA [16] and recycled MDF composite.

Fabrication

The two components of the design the team pursued are the touch-sensor braking system and the noise-alerting system, both of which required arduino components and coding. The team assembled the button-braking system consisting of the touch sensor, microcontroller, solenoid and brakes. The team then assembled the noise-alerting system consisting of a speaker, microcontroller and sensor that will alert the user when the brake system needs to be engaged. The team used SOLIDWORKS for CAD designing of a components box to be 3D printed from PLA, which was attached to the walker via zip ties and electrical tape. Finally, the team used a bandsaw and a disc sander to create a lid for the component box.

Final Prototype

Figure 6: Isometric view of the final prototype, with button braking system on the near handle, touch sensor on the opposing handle, and solenoid in bottom right

Figure 7: Front view of the final prototype

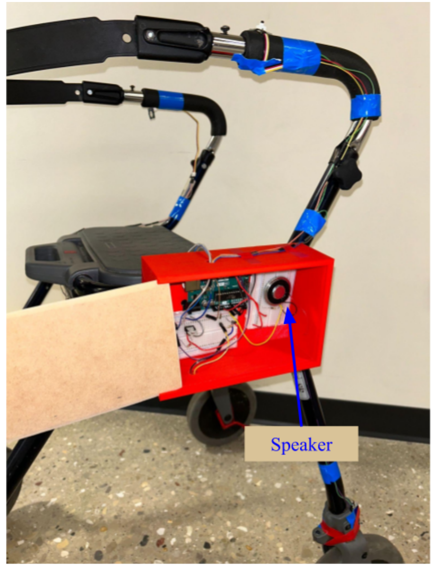


Figure 8: View of the interior of the component box, showing circuitry and speaker

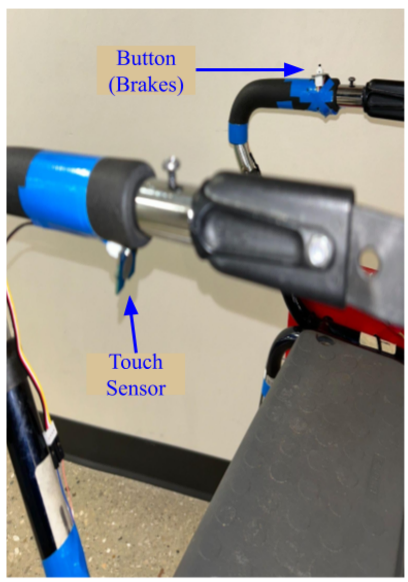


Figure 9: View of connected button and touch sensor components on handles of walker

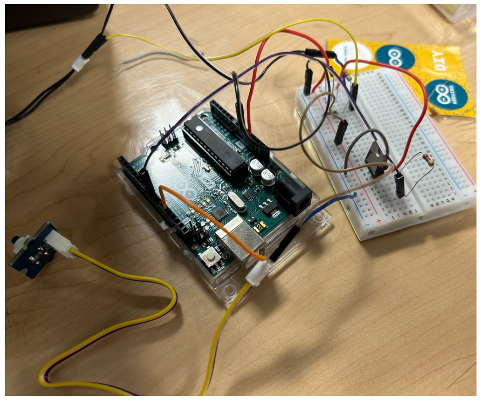


Figure 10: Circuit of solenoid and button system, connected to Arduino microcontroller

Testing

To statistically measure if the prototype created met desired expectations, the walker prototype was tested against a testing protocol. Results were then interpreted to make conclusions. The initial goal was to test the overall effectiveness of the whole braking system. Unfortunately, the constraints of time and available resources prevented the overall prototype from fully functioning. To combat this issue, each possible outcome or case was tested instead.

Data collection involved performing 10 trials for each of the four possible input cases. Condition one is when the button and touch tensor are both being pressed. Condition two is when the button is being pressed and the touch sensor is not being pressed. Condition 3 is when the button is not being pressed but the touch sensor is. Lastly, condition 4 is when neither the button nor the touch sensor are pressed. For each condition, the parameters for what is considered a success and what is considered a failure is set. These parameters are set based strictly on the observable outcome of each case. For case one a successful trial occurred if the solenoid was triggered and no sound was emitted from the speaker. This was also the terms of a successful trial in case two. For case 3, a successful trial occurred if the solenoid was not triggered and no sound was emitted. For case 4, a successful trail occurred if the solenoid was triggered and sound was emitted from the speaker. Any observation that didn't align with the set success criteria was deemed a failure. After data collection, the data prepared for statistical analysis.

The method used to test helps exemplify how the prototype meets the criteria set forth in the PDS. The PDS specifies that the device should detect when the walker is in use and when the brakes need to be engaged. The PDS additionally states that the device should engage brakes at the push of a button. Both of these device requirements are addressed in the testing via the measurement of the success of all possible conditions the walker can be in. The button and the touch sensor are both tested in the off and on positions and the results from those conditions are measured. In turn, this provides information as to how successful these components are when integrated into the walker system. The success of these components is directly related to whether or not the device conditions in the PDS are met.

The testing protocol created for our prototype addresses error and variance in the design. The test is a measure of success, which also is a measure of consistency. Consistently is critical in creating a product that can be released to the public for consumption. Especially in the case where an individual's well-being is on the line. After analysis, the data collected in this test give a conclusion as to whether or not the walker met the desired benchmark of success, 80%. This not only provides information on effectiveness but also provides information on consistency.

The expectation of the current prototype is a relatively high proportion of success. The code, circuitry, and prototype all led to this expectation. If high proportions of success are measured for each case then the walker is working as expected. If the data gives results that are low proportions of success, then there exist issues in the code, circuity, or physical prototype. Further testing would have to be done to determine where the issue is occurring.

VI. Results

The newly designed walker was tested against a desired goal of success, which was set to 80%. This value was chosen as the design is still in its infancy and can be improved in many ways. As a result, perfection was not the goal. Instead, the goal was consistent and measurable success of all components working in unison. This proportion of desired success of 0.8 was compared to each sample collected in each case. To compare these values, a binomial test was conducted for each case. The results of this test yield a p-value that can be used to make claims about the hypothesis set. The null hypothesis was set as the population proportion of success (π) was greater than or equal to 0.8. The alternative hypothesis was set as the population proportion of success (π) was less than to 0.8. A confidence level of 95% was used, creating an alpha level of 0.05. To make claims about each case, the p-value calculated from the binomial test was compared to the alpha of 0.05. P-values that exceed the 0.05 give weak evidence that the alternative hypothesis is true and, in turn, gives strong evidence in favor of the null hypothesis.

The statistical program R was used to analyze raw data and return results. The function binom.test was used to yield the p-values. The respective p-values obtained for cases one, two, three, and four were 0.6242, 1, 0.8926, and 0.8926. Each p-value observed was substantially greater than 0.05, thus the conclusion for all cases is that there is strong evidence in favor of the null hypothesis. In other words, the tests did not lead to statistically significant results, so the population proportion of successes for each case are all likely greater than 0.8. For these results, implementing multiple comparison corrections is not needed, as the cases are not being compared to one another. Rather, each case is compared to the predetermined success factor of 80%.

Results of analysis can be seen visually in the graphs below. The blue shaded region represents the p-value calculated from each binomial distribution. The region was shaded at and below the measured number of successes. For example, in the first case there were 8 observed successful trials and two observed failures. To determine the p-value, the sum of the individual probabilities from 0 to 8 was calculated. Yielding a value of 0.6242, which can be seen in the blue shaded region. The same process is repeated for the remaining cases.

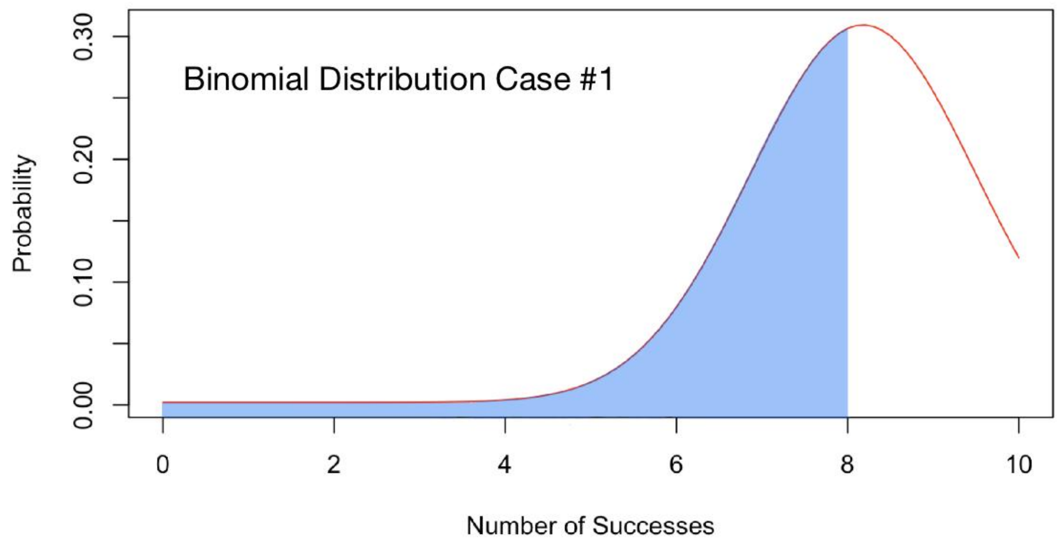


Figure 11: Binomial distribution graph of case one with the shaded region representing the calculated p-value for the collected data.

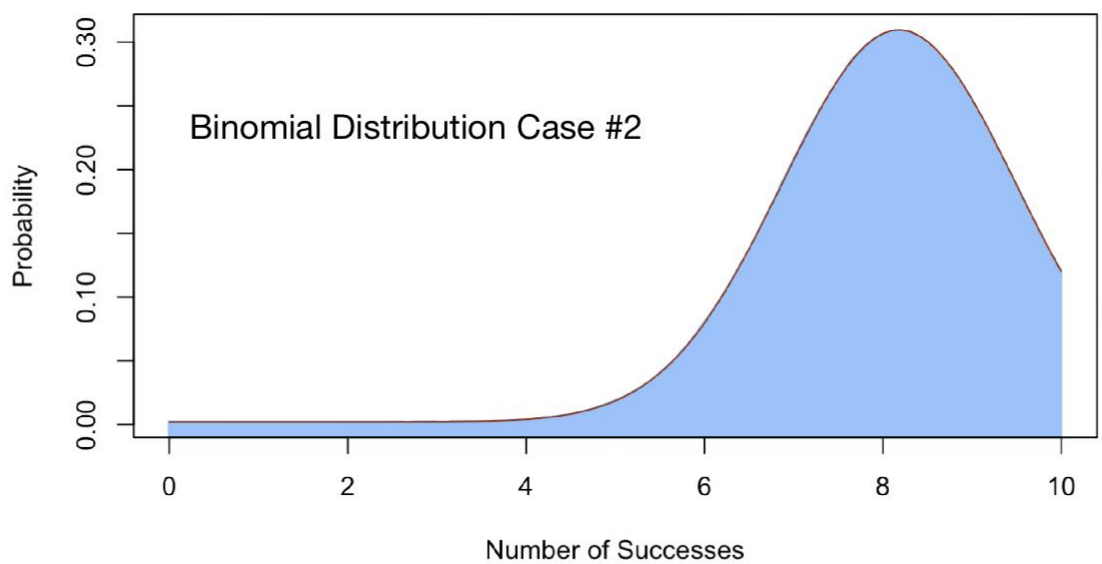


Figure 12: Binomial distribution graph of case two with the shaded region representing the calculated p-value for the collected data.

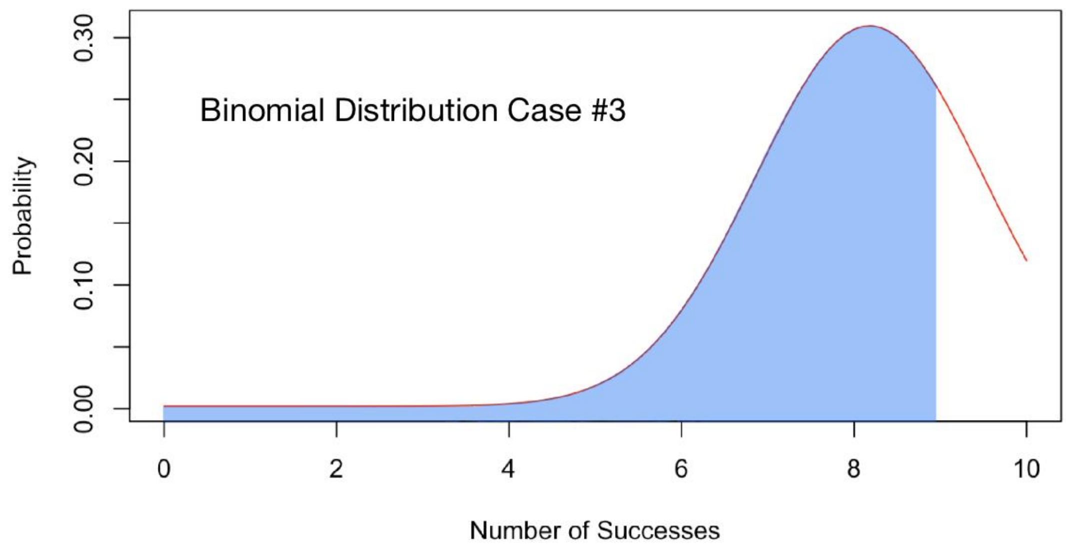


Figure 13: Binomial distribution graph of case three with the shaded region representing the calculated p-value for the collected data.

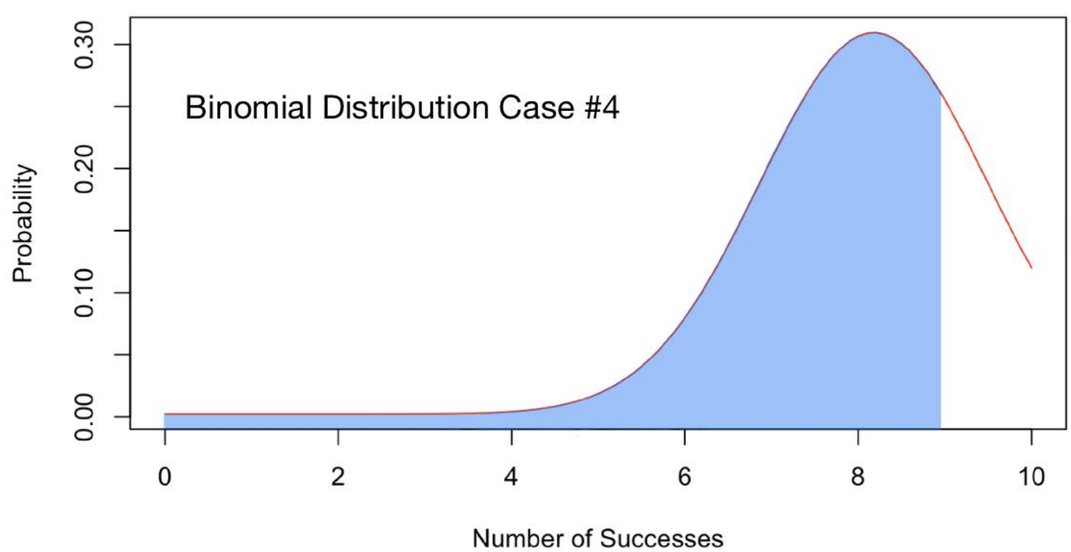


Figure 14: Binomial distribution graph of case four with the shaded region representing the calculated p-value for the collected data.

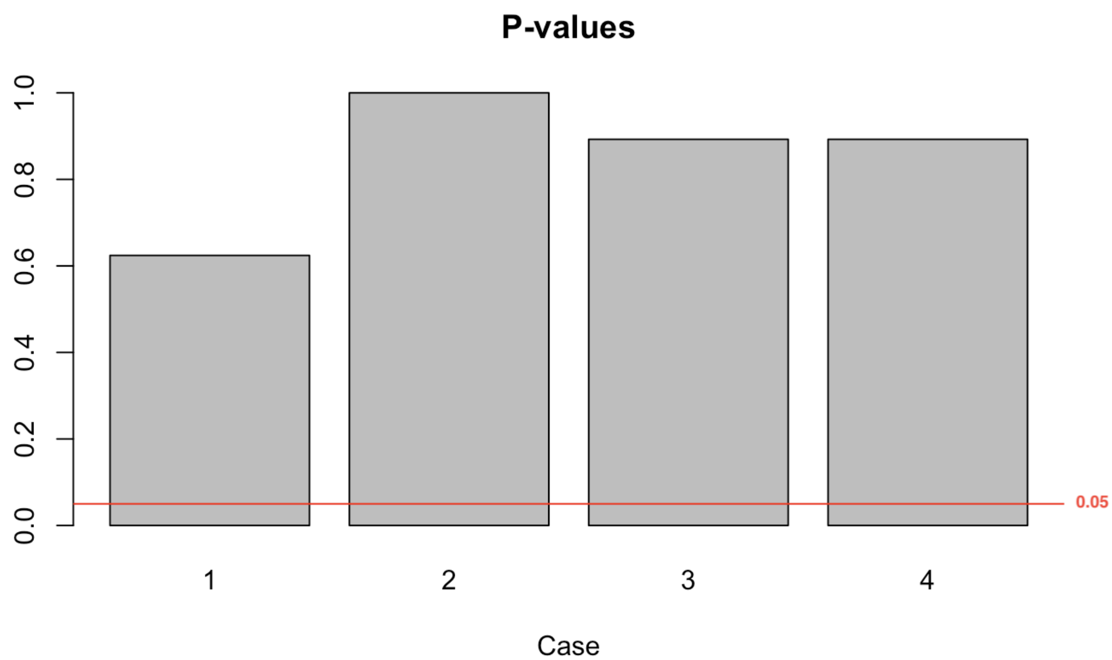


Figure 13: Bar graph displays the p-values from each case compared to the alpha level of 0.05. All cases exceed 0.05 substantially, leading to the conclusion determined above.

Overall, the results yielded provide insight as to the degree to which the walker prototype created is successful. The results led to the claim that the current prototype met the desired success rate. As a result, it is reasonable to conclude that this design has potential to turn into a successful working product.

VII. Discussion

Results from testing were important when considering the functionality of the alert device and comparing it to other devices on the market. Despite the results of testing which concluded that the alert system meets the target efficiency range, the prototype is still not to the standard of similar walkers that are currently on the market. The results do however show that with continued work the prototype could be available as a marketable product in the future, due to the fact that there are several relevant design components.

The team fabricated a walker and alert system within the given $300, ending with a total of less than half of the budget provided by the client. With the prototype being fabricated at such a low cost and comparable to the average price range of market available products, the design is affordable for patients of varying socioeconomic backgrounds. The prototype also had the alert system added to it in a way that did not hinder the use of the product for patients and could be deemed appropriate to be used in a professional environment. This concluded that the design is appropriate for patients of all ages and the target demographic of patients between 74-85+ [5]. This as well as suitable walking space between the wheels and large handles also means that the product is suitable for people of varying backgrounds, as there is sufficient space for people of differing heights and weights. Additionally, the design's alert system is fundamentally basic and would require minimal to no training for nurses, assistants, and users to learn. Due to the several ethical considerations in the team’s design and testing of the walker, the alert system involves inclusivity for different body types, affordability for several socioeconomic backgrounds, ease of use, suitability for both professional and public use, and a strong emphasis on safety and control.

Based on the evaluation of the prototype through results and ethics, there are still changes that will need to be made to the design. The design included a 5 V solenoid that is not sufficient in strength to cause braking for the walker on its own. Thus further research will need to be conducted in order to find a suitable replacement that could consistently handle the force required to stop the walker from moving. Additionally, the brake will also need to be implemented to all wheels to improve the stopping mechanism. There will also need to be changes made to the timer and speaker which currently emit noise instantly when neither the sensor nor button is pressed when there should be a 15 second delay before this occurs. The team will need to consult other opinions on coding for this scenario to occur and potentially consider finding another noise emitting component.

Sources of error for this project can be concentrated in the testing of the device. Though testing yielded results greater than expected, the braking mechanism did not test if the walker would be stopped when in motion, rather that the brake is triggered. This would lead to skewed results as if the same tests were performed on the walker while moving, results of the findings may look significantly different than what was analyzed. Another potential error is the inconsistent time between trials. The team did not account for the time in between trials to be a factor in their results, however, insufficient amounts of time between trials resulted in large amounts of current moving through the solenoid and leading it to heat up significantly. This could have been a cause of failed trials and would also skew the results of testing for every case.

VIII. Conclusion

Many older adults struggle with remaining independent on account of many challenges that come with age. Those who choose to use walker devices tend to feel confined or do not want to admit when they need assistance. An alert system associated with their walker would help them feel more independent while simultaneously improving their safety and mobility. The team addressed this problem by creating an alert device for a walker. The device was designed to help older adults retain their independence, which could both improve the widely used braking system as well as implement an alerting system to remind the user to engage their brakes. After extensive background research, the team decided on a final design that would best incorporate both of these features onto a provided walker. The major components to the design included a solenoid, DigiKey speaker, Arduino touch sensor, Arduino button, and a microcontroller. Together, the components worked together to create an alert device prototype.

The fabricated product was then put through a number of tests to test its efficiency. The tested design was observed under a number of criteria. Through testing, the design seemed efficient in proof of concept. The design exceeded the predicted 80% success rate. However, the design had constraints along with the successes. The first constraint being the size of the solenoid in the final product. The size and force of the solenoid on the design is too small to stop the full force of the wheels of a walker. Along with the solenoid, the microcontroller has a maximum of 5V. The team was limited to a certain number of available components on the market that could work within the 5V range. Additionally, the coding for integrating each component together has errors.

The team used multiple resources, but could not create code that would utilize the 15 second interval correctly. In the future, work is needed to improve the design.

Due to the constraints of the 5V maximum, more research was conducted in terms of replacing the solenoid. To improve the force of the solenoid, moving from a solenoid to a linear actuator would provide for a more efficient braking system with greater force and therefore greater friction against the wheels. Additionally, the box holding the microcontrollers for the components can be fabricated smaller. The larger box allows for less security of the components held within. Creating a smaller box would allow the client to move more easily with less issues from the components themselves. The box can also be attached more effectively. Currently, the box is attached via zip ties. Researching and compiling new methods of attachment are important for the future. Besides the box, it is essential to research and implement a portable battery for a power source. Once the preliminary constraints are addressed, a focus group can be conducted to see if potential users think the device would be useful. Overall, the team fabricated a prototype design that was able to effectively alert the user that their brakes will engage after the sound. The team observed that for this semester, each condition exceeded the goal success rate of 80%, therefore it was deemed that the design has potential for a continuation at a later date.

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X. Appendix

A. Preliminary Design Specifications

Previously Revised: 12/06/2023

Title: Alert Device for Walker (WARNS)
Client: Dr. Beth Martin
Team: Matt Hudson, Meghan Kaminski, Colin Bailey, Sara Sagues, Daniel Pies

Function:

The device will provide walking assistance along with an integrated safety system that will produce a low pitch frequency as a reminder for the user that the brakes will engage when the walker is not in use. The low pitch frequency will emit when contact is not detected on the walker grips for more than 15 seconds and the brakes are not engaged. After this duration, the walker will emit a low frequency tone and automatically engage the brakes. While the walker is in use, the brakes can be engaged or disengaged at the press of a button.

Client requirements:

- Device should be similar in height to similar walkers on the market assisting people from 5'3ft to 5'11ft
- Device should have wheels at the base of the device that can easily lock and unlock upon patients decision
- Device should detect when the walker is in use and when the brakes need to be engaged
- Device should have an alert system that emits low frequency noise at a range older patients would be able to hear
- Device should include the following accessories; seat, basket, handles, wheels, and lock for wheels
- Device should follow FDA and ADA regulations
- Budget between $300 and $500.

Design Requirements

1. Physical and Operational Characteristics

a. *Performance requirements*:
   i. Device should focus on emphasizing the safety features of the walker
   ii. Device should be able to alert the user if the brakes are left unengaged using a a low frequency alert system
   iii. Device should engage brakes at the push of a button
   iv. Device should detect if patient has their hands on the walker grips
b. *Safety*:
   i. The device must allow the user comfortable use of their walker
   ii. The device must be easy to learn how to use for users and nursing assistants
   iii. The device must help the user to lock their walker brakes
   iv. The volume of the alert system will be a lower frequency so users with hearing impairments can still hear the noise
   v. The product will provide additional alert for the user to use their brake system
   vi. The device must not hinder the mobility of the patient using it
c. *Accuracy and Reliability*:
   i. Due to the time constraints and new nature of the project, a prototype is requested
   ii. The product should be testable
   iii. The product should follow a list of precautionary tests for safety
   iv. The product should follow a list of accuracy tests in terms of the technology and details to the prototype
d. *Life in Service*:
   i. The device should last throughout the entire years in use, up to twenty years
   ii. The device should have replaceable parts so it continues to be usable after repair
   iii. The device can be used everyday for up to 10 hours per day
   iv. The device will not be used for long periods of time over long distances, but over short periods of time over short distances

e. *Shelf Life*:
    i. The device should remain undamaged throughout time in storage
    ii. The Arduino microcontroller should last up to 20-30 years in storage [21]
f. *Operating Environment*:
    i. Older adults aged 74-85+ will use this product [5]
    ii. The walker should support a weight of the average adult in independent living up to the higher threshold of weights
    iii. The walker will be used indoors on hardwood, tile, and carpet
    iv. The walker will also be used outdoors on concrete, grass, and gravel
g. *Ergonomics*:
    i. The device will be easy for patients and medical staff to use
    ii. The device will not further hinder the mobility of the patient
    iii. The device will not be loud enough to disturb others patients, staff, or people in the vicinity
    iv. The device will be easily attachable to the frame of the walker
h. *Weight*:
    i. The device produced must be light and compact as to minimally increase the weight of the walker. The total weight should be similar to a traditional non-altered walker as to avoid causing injuries to patients while using our walker
    ii. Walkers range from 5-12 pounds depending on the type of walker [20]
i. *Materials*:
    i. All materials used to fabricate the device must comply to FDA guidelines
    ii. Materials used must be easily accessible nationwide and affordable
j. *Aesthetics, Appearance, and Finish*:
    i. The overall size of our smart-walker must be able to accommodate the standard walker and be adjustable for different walker sizes
    ii. The device must be minimally intrusive and blend in seamlessly with the walker
    iii. Appearance must be appropriate for use in elderly care facilities
    iv. Appearance must safely and efficiently hide all digital components

2. Production Characteristics
    a. *Quantity*:
        i. The client wants use to create one working prototype in the given timeframe
        ii. Long term goal is to mass produce the device such that several could be in hospitals, retirement homes, and recovery clinics
    b. *Target Product Cost*:
        i. The client has provided a budget of $300-$500
        ii. The cost of production should be feasible for medical facilities nationwide
3. Miscellaneous
    a. *Standards and Specifications*:
        i. Must comply with Sec. 890.3825 of the FDA within Title 21 [18]
        ii. The device must comply with the ADA's restrictions for manually powered devices [17]
    b. *Customer*:
        i. The customer highlighted that the design should focus on safety, specifically focused on brakes to prevent the device from slipping out from under the user
        ii. The customer would prefer that the device be light-weight
        iii. The customer wants the device to be modular, to adapt to a variety of needs
    c. *Patient-related concerns*:
        i. Device should allow patients to minimize pain while moving
        ii. Device should enable patients to access any and all areas around their homes and in their daily lives
        iii. Device should not have any sharp object or open wires that could cause harm to the patient
        iv. Device should provide an alert system that reminds the user to engage their brakes

d. *Competition*: This section covers other devices and patents on the market related to alert devices for walkers

    i. [19] Collapsible Upright Wheeled Walker Apparatus (Patent No. US10322056B2) - This is a patent for a walker device with adjustable armrests to support sufficient user upper-body weight to facilitate a natural and upright gate for a wide range of mobility-impaired individuals

    ii. [18] Electronically Controlled Brakes For Walkers (Patent No. CA2605609C) - This is a patent for an improved electronic braking system for walkers that incorporates one or more electronically operated brakes. The controller is responsive to touch sensitive switches for easy operation, and is adjustable and responsive to the operator patterns. The controller may be used on sloped terrain and may be adjusted to accommodate for the weight of the user to to set limits to the speed at which it can move

B. Expense Sheet

ORDER 1

Item	Description	Justification for Purchase	Manufacturer	Mft Pt#	Vendor	Vendor Cat#	Date	QTY	Cost Each	Total	Link	True Cost (S&H + Tax)	Receipts Reported & Notes
Amazon													
Arduino	Microcontroller for open-source hardware	Group needs a microcontroller to run programming through for electronics of prototype, majority of group experience is through Arduino	Arduino	A000066	Amazon	B008GRTSV6	10/22/2023	1	$27.98	$27.98	https://www.a	$29.42	Yes
Electrical Tape	1/2 inch wide x 20 feet long	Tape for securing wires/other components to frame of the walker	Marinco Electrica	339066	Amazon	N/A	10/22/2023	1	$2.99	$2.99	https://www.a	$3.15	Yes
Solenoid	Mini Push-Pull 5V Solenoid	This will serve as the brake by applying friction to the wheel	Adafruit	2776	Amazon	B0722JK1L1	10/22/2023	1	$12.30	$12.30	amazon.com/	$12.98	Yes
Resistors	Resistor kit - 25 of 20 different resistors.	Used for circuitry	Sparkfun	COM-10969	Sparkfun	N/A	10/22/2023	1	$13.43	$13.43	https://www.a	$14.17	Yes
DigiKey													
Breadboards	Solderless Breadboard Terminal Strip (No Frame) 3.23" x 2.17"	Used for circuitry	UNIVERSAL-SOLD	3647-Solderle	Digikey	N/A	10/22/2023	3	$2.87	$8.61	https://www.d	$19.58	Yes
Speaker	8 Ohms General Purpose Speaker 1 W 300 Hz ~ 5 kHz Top Round	Used to emit noise for the alert component of the design	Soberton Inc	433-1150-ND	Digikey	N/A	10/22/2023	1	$2.90	$2.90	https://www.d	$10.74	Yes
Arduino													
Touch Sensor	Detects change in capacitance when a finger is nearby	Used for circuitry	Arduino	C000182	Arduino	101020037	10/22/2023	1	$4.30	$4.30	https://store-u	$7.40	Yes
Button	Arduino-compatible button	Used for circuitry	Arduino	C000142	Arduino	11020000	10/22/2023	1	$1.50	$1.50	https://store-u		
									TOTAL:	**$74.01**		**TRUE TOTAL** **$86.70**	

ORDER 2

Item	Description	Justification For Purpose	Manufacturer	Mft Pt#	Vendor	Vendor Cat#	Date	QTY	Cost Each	Total	Link	True Cost (S&H + Tax)	Receipts Reported & Notes
Amazon													
Transistors 3 Pack	Pack of transistors, used for circuitry for solenoid	Used for circuitry	BOJACK	TIP120	Amazon	B08BFYYK7D	11/1/2023	1	$8.99	$8.99	BOJACK TIP12	$15.80	Yes
Diode Pack	Pack of diodes, used for circuitry for solenoid	Used for circuitry	BOJACK	1N4001	Amazon	B07Q3HBM6	11/1/2023	1	$5.99	$5.99	BOJACK 1N40		
									TOTAL:	**$14.98**		**TRUE TOTAL** **$15.80**	

ORDER 3

Item	Description	Justification for Purchase	Manufacturer	Mft Pt#	Vendor	Vendor Cat#	Date	QTY	Cost Each	Total	Link	True Cost (S&H + Tax)	Receipts Reported & Notes
3D Print													
Component Box	PLA Ultimaker printed box to house components of the design	A safe place is needed to store components, as well as a way to attch them to prototype	UW Makerspace	N/A	UW Makersp	N/A	11/17/23	1	$14.16	$14.16	N/A	$14.16	Yes
									TOTAL:	**$14.16**		**TRUE TOTAL** **$14.16**	

C. Arduino Code

```
int SOLENOID = 7;
int button = 12;
int buttonRead = 0;
int lastState = LOW;  // the previous state from the input pin
int currentState;     // the current reading from the input pin
//int newState;         // the new reading after 15 sec
int sensor = 8;
const int SENSOR_PIN = 13;

#include "Timemark.h"
Timemark myclock(15000);
```

```
void setup() {
  // initialize serial communication at 9600 bits per second:
  Serial.begin(9600);
  // initialize the Arduino's pin as aninput
  pinMode(SENSOR_PIN, INPUT);
  pinMode(button, INPUT);
  pinMode(SOLENOID, OUTPUT);
  digitalWrite(SOLENOID, LOW);
  myclock.start();
}

void loop() {
  buttonRead = digitalRead(button);
  currentState = digitalRead(SENSOR_PIN);
  if (buttonRead == HIGH && lastState == HIGH && currentState == HIGH) {
    digitalWrite(SOLENOID, HIGH);
    myclock.start();
    noTone(sensor);
  }
  else if (buttonRead == HIGH && lastState == LOW && currentState == LOW) {
    digitalWrite(SOLENOID, HIGH);
    myclock.start();
    noTone(sensor);
  }
  else if (buttonRead == LOW && lastState == HIGH && currentState == HIGH) {
    digitalWrite(SOLENOID, LOW);
    myclock.start();
    noTone(sensor);
  }
  if (myclock.expired());
  myclock.stop();
  Serial.println("now beep");
  tone(sensor, 1000, 5000);
  digitalWrite(SOLENOID, HIGH);
  lastState = currentState;
}
```

D. Raw Data

Case 1

Success - Solenoid is on and there is no sound

S	F	F	S	S
S	S	S	S	S

Phat - 8/10

Case 2

Success - solenoid is on and no sound

S	S	S	S	S
S	S	S	S	S

Phat - 10/10

Case 3

Success - No solenoid and no sound

S	S	F	S	S
S	S	S	S	S

Phat - 9/10

Case 4

Success - Solenoid on and sound emit

S	S	S	S	S
S	S	S	S	F

Phat - 9/10

E. Statistical Analysis

```r
binom.test(8,10,0.8, alternative = "less")

binom.test(10,10,0.8, alternative = "less")

binom.test(9,10,0.8, alternative = "less")

binom.test(9,10,0.8, alternative = "less")
```

The image above shows the code used to conduct each binomial test, yielding the p-values for each case.