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Alert System and Cadence Walker

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Abstract

Older adults who are dependent upon walking aids may harm themselves from falling when they forget to use their aid. In order to achieve fall prevention through increased walking aid usage, the team created a device to be attached on a two-wheeled walker with the ability to alert users when they move an unsafe distance away from the walker. The device is also capable of recording information about the user regarding time usage, distance traveled, and cadence. This data will be reported to care providers for clinical observations and evaluations. The key components to achieve these features include using a coupled proximity transmitter and receiver, a microcontroller, and a speedometer, in addition to a relevant circuit board, power source, and storage device. The prototype was tested for accuracy in recording speed and distance. Lastly, human test subjects used the walker and device over a two-day period to determine that the alarm system increased usage of the walking aid. In the future, this device will need IRB approval to test on elderly adults. It will also need to be patented and slightly modified for mass production and commercial use.

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Background:

Falls are the leading cause of injury and death among older adults. In fact, falls are five times more likely to bring elderly people to the hospital than any other condition. These falls can occur in a number of ways, but one of the leading causes is when an older adult who requires a walking aid, forgets his or her aid when walking. These falls can cause serious injury to the elderly. One out of three adults over 65 years old experiences a fall annually, with 25% of the incidents resulting in moderate to severe injuries. The risk of a fall due to forgetting walking aids increases in elderly who also suffer from some form of dementia, which affects more than 60% of the elderly population over the age of 85 [1]. Economic impact of these falls is estimated at $237 million annually in Wisconsin, and near $20 billion annually in the United States [2].

Motivated by these facts Dr. Jane Mahoney, one client for this project, coordinates a 7 week community based workshop called "Stepping On" which develops specific knowledge and skills to prevent falls. Adults who participate in the Stepping On program experience a 31% reduction in falls [3]. This project also works with the University of Wisconsin Center for Health Enhancement Systems Studies (CHESS). The mission of the center is "To lead in research and development of innovative health systems, in order to optimize individuals' health behaviors, quality of life, and access to services." Their research focuses on integrating cutting edge informative technologies with healthcare systems to better understand patient concerns and deliver custom care treatment strategies. CHESS works on issues such as substance addiction, improving communication between oncologists and patients and enhancing quality of life for the elderly. One of the project clients is Dr. David Gustafson who is member of the CHESS research team and has worked projects in all areas of the program center.

Problem Statement:

Older adults who require the use of assistive walking devices for daily motility can harm themselves due to falling when forgetting to use their aid. This issue is further complicated in adults diagnosed with any type of dementia, who are more likely to forget their walking devices. The goal of this project is to design a system to be mounted on a two-wheel walker that notifies the user when they begin to walk away without their walker. In addition to the alert mechanism the walker should provide usage feedback such as time usage, distance traveled, and cadence. This data should then be transferrable to care providers on a daily basis to help evaluate the health and habits of the patient and improve patient care. The technology would ideally be transferable to use with other assistive walking devices such as canes and four-wheel walkers.

Design Criteria:

This device must meet a number of expectations and criteria in order to adequately improve the safety of walker use and prevent falls. The most important aspect of the design is to alert the user when they begin to get up and walk away without their walker. This feature is the main way to help prevent falls resultant from the user walking without the necessary walking aid. In order for this alarm to prevent falls, it must alert the user before they begin to walk away without the walker by sounding an alarm when the user is more than one meter away from their walking aid. The alarm sound should be gentle so as to not startle the user and subsequently cause them potential harm. Ideally, a voice recording capability would be best for the alarm sound.

The design should be able to record and report daily usage of the cane such as total time used, total distance covered, and cadence. These values can be displayed on a screen attached to the walker for simple reference by the user. These data should be able to electronically transfer daily to the care provider. This information will help the care provider evaluate the health of the user.

Lastly, this device will be designed for the use of elderly, particularly those that exhibit cognitive impairment. The user interface should be simply navigable for those who are not familiar or comfortable with technology. There should be no small buttons or features that are difficult to manipulate. The alarm should also have an adjustable volume so that those with hearing impairments will still be able to use it effectively. The alarm system and screen based device should not add a weight over two pounds and should not hinder normal use of the walking aid.

Competition:

The idea of a talking wheeled walker that measures cadence is a relatively novel idea. There is one close competitor that may be discussed, which is the TrekCane adjustable walking cane from Sky Med [Figure 1]. This cane allows for the measurement of cadence giving the user data on steps, time walked, and estimated calories burned [4]. The price for a device such as this costs around $35 based on a google shopping search. What this assisted walking device does not have and what this project aims to implement is a alert system for when the user forgets their walker when getting up to move. It also does not have the ability to easily send this data to the care provider for patient health analysis.

Figure 1: Sky Med TrekCane that counts steps taken and estimates distance. From http://www.soymedical.com/coms1602.html#.UH9Y2W_MjQQ

Ethical Considerations:

Ethics behind the two-wheel walker include balancing cost and function. As mentioned earlier this device will act as an assistive medical device, which requires a certain level of accuracy. Accurate data collection for clinical observation and analysis are highly important to help improve in home patient care as well as help prevent injury due to falls. As a result when selecting proper components for the device, performance should be considered a relative priority over cost. The device should find a medium that allows very accurate function and data collection with a minimally expensive cost.

Further ethical concerns are when this device is complete, human subjects will be needed to test its performance. Procedures required for testing on elderly human subjects include each project member's completion of the Collaborative Institutional Training Initiative (CITI) training for Institutional Review Board (IRB) approval. Any additional applications and legal documents will be prepared and submitted to the IRB before this kind of testing can begin.

Design Alternatives:

In order to effectively design a device for the client, the design was split into two pieces, the alert system and cadence. Each category has several design alternatives discussed below and a matrix of the options that helped the team choose the most effective design.

Alert System:

The first set of designs considered deal with the walker sensing when it is being forgotten. These alternatives are sensors that in some way can detect the distance between the user and the walker once they have been integrated.

Bluetooth Sensor:

The Bluetooth sensor can be found in a multitude of electronic devices including computers, cell phones, and headsets. Information is exchanged wirelessly between two devices by transmission of a radio signal on a 2.45 GHz band [5]. To avoid interference with other signals the Bluetooth device frequency hops 79 channels that are spaced 1 MHz apart [6].

To incorporate the Bluetooth sensor [Figure 2] into our device we wish to attach a lightweight Bluetooth transmitter on the wrist of the user and the receiver on the walker. The receiver would be constantly receiving signals until the transmitter was out of range and the receiver stopped receiving signals, at which point the alarm sequence would be triggered. Bluetooth signals come out of range at 10 meters, but may carry up to 40 meters in open spaces [7].

Figure 2: Circuitry of a typical Bluetooth sensor. From http://electronicsbus.com/bluetooth-wireless-sensor-network-system

Infrared Sensor:

The infrared sensor is often seen in many areas daily for motion sensing of light or in gaming systems such as the Wii. This sensor operates by using a photosensor detects elements of thermal variation emitted as infrared light [8]. This would allow the device to

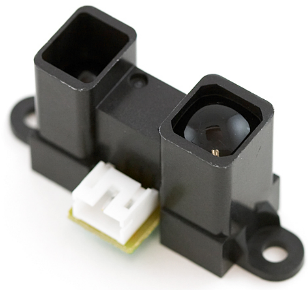

Figure 3: Infrared sensor that exemplifies its limited directionality. From http://www.sparkfun.com/products/8958

sense motion of a user around the device. In this design, the infrared sensor would be placed on the walker and constantly track the movements of the user. If the user started to move too far from the walker, the alarm would then be triggered. Infrared sensors are vulnerable to interference from other infrared sources, such as candle light and fluorescent light. This may give a false reading and cause the alarm to sound when it should not, or fail to sound when it should. These sensors are also one directional and the device would require several of them to get full 360° coverage of motion around the walker [Figure 3].

Proximity Sensor:

This alternative was added after the first semester of the design process. The reason for this change is discussed in the Final Design section later. There are several devices known as proximity sensors commercially available that can detect how far away a user is from a specific device. This is done through a Bluetooth based transmitter and receiver. The receiver is worn or carried by the user and detects the signal output of the transmitter which is attached to the device in question. When the user has gone out of range of the transmitter signal, which is usually adjustable for desired distance, the receiver will beep to inform the user they are out of range [Figure 4]. This type of proximity sensor would need minimal adaption, if any, to be integrated into the walker. Depending on the devices available, the transmitter may have to be altered to be wearable around the wrist or ankle [15].

Figure 4: Proximity sensor design to alert user when they have walked unsafe distance from their laptop. From http://www.remoteplay.com/support_laptop.asp

FM Transmitter:

The final alternative for sensing the distance between the user and the walker is the use of an FM transmitter. Common uses of FM transmission include long range radio station transmitters all the way down to low power transmitters which may connect an .mp3 player with a car radio. FM radio transmitters work by emitting a sinusoidal carrier signal of a given frequency, which is modulated, by higher frequency data signals [9]. The carrier signal amplitude decays as distance between transmitter and receiver increases. Cutoff amplitude can be then processed to estimate distance between transmitter and receiver [Figure 5]. With this device, the user will carry a small FM transmitter, and the receiver will be mounted on the walker. A microcontroller will process the signal strength and trigger the alarm when the amplitude falls below threshold.

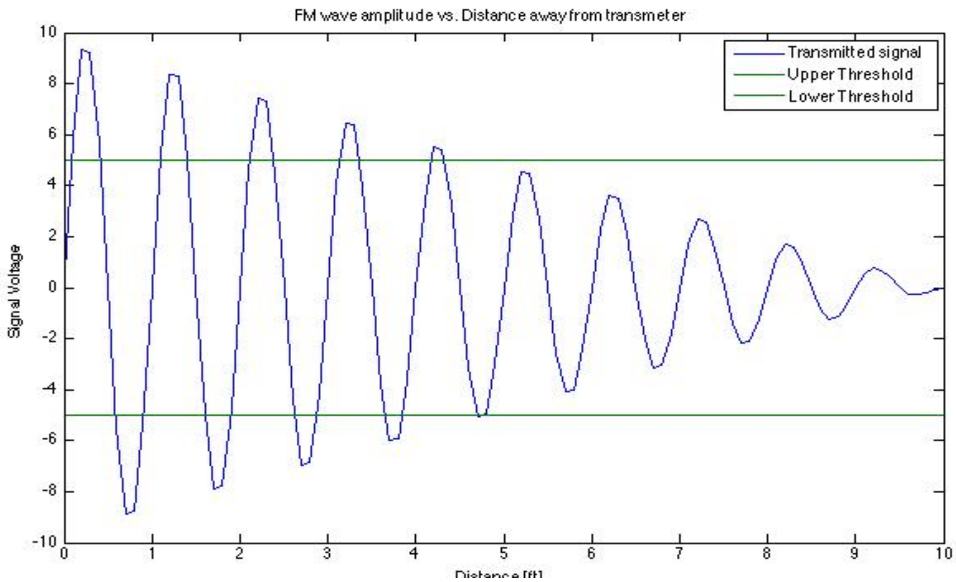

Figure 5: This graph shows the FM wave amplitude vs. distance away from the transmitter. As distance increases so does the decay in the amplitude of the sinusoid, triggering an alarm once it falls below threshold.

Proximity Sensor Design Matrix:

A design matrix was created to evaluate our four alternatives to choose which one will continue into our prototyping phase. Criteria include accuracy, interference, feasibility, size/weight and cost. Accuracy and interference were the most important criteria and were weighted as such.

Table 1: Alarm sensor design matrix with three alternative designs scored against a set of weighted criteria.

Alarm Sensor					
Criteria	Weight	FM Transmitter	Bluetooth Sensor	Infrared Sensor	Proximity Sensor
Accuracy	35%	4	1	2	5
Interference	25%	3	1	2	4
Feasibility	15%	4	3	2	4
Size/Weight	15%	3	4	3	3
Cost	10%	4	2	4	2
Total	5	3.60	1.85	2.35	4.00

Accuracy is the ability to appropriately measure a distance of 1 meter as defined in the design requirements. With this in mind the FM transmitter scored the highest because of its ability to tune distance measurement by altering the transmission signal strength. Bluetooth scored low because its cutoff range is at least 10 meters, which is too far for the design needs. Interference is defined as the ability of the data input to the receiver to be free of artifacts, which may skew the accuracy measurement. Both Bluetooth and FM transmitters rate high here as a clear transmitter-receiver connection is needed. FM transmitters score a little lower because of the possible errors it could run into with other various radio waves. Infrared scored the least because of misreads when under candle light and fluorescent light. Feasibility is the ability to incorporate the sensor with the governing microcontroller. Here FM transmitter and Bluetooth scored the highest because the transmission and receiving components already have established literature, and signal processing is minimal. Infrared got low marks due to extensive signal processing and programing needed for distance calculations. With the given weights and scores determined, the matrix helped to conclude that the FM transmitter was the best way to incorporate proximity sensing into the device.

The proximity sensor was an alternative that was added after the FM transmitter, the previous design with the highest score on the matrix, was proven to be too problematic for the team to use (discussed in Final Design). The addition of this alternative in the matrix resulted in it being the best option overall for the alarm system portion of the design. It scored top marks in accuracy due to its ability to directly alarm based on distance between the walker and the user with minimal or no changes by the team. Many of these proximity sensors are designed for use in areas with a high population, and therefore a high tolerance for potential electronic interferences. This makes it unlikely to be susceptible to any kind of electronic interference in normal settings and gives it a high score in that category. While the feasibility category previously referred to the ability to integrate with the microcontroller, the proximity sensor would not have to be integrated unless voice modifications were made later on. In this respect it scored high in feasibility as well. The size and weight of the device depends on the specific one purchased but should be reasonable small and light, putting it at an average score for that category. Finally some proximity sensors can range near $70 for the setup, making it one of the pricier options on the matrix. However its excellent scores in the higher weighted categories makes it the best way to proceed with in the final design.

Cadence Measurement

Cadence is another area of the design that deserved consideration of alternative designs. Because there is no direct way to measure cadence on a walker, the team considered alternatives that could be incorporated into a microcontroller to convert the data collected into the cadence data desired by the client.

Pedometer:

A pedometer is a small, inexpensive, electromechanical device that tracks the user's steps by detecting hip motion. This is accomplished by counting the oscillations of lead ball or a pendulum within the device. Pedometers, which use these systems are vulnerable to false positives caused by uneven terrain or an unsteady gait. Most often a pedometer is calibrated by the user for step distance to provide an estimate of distance [10]. A pedometer could be incorporated into the device to count the lifts of the non-wheeled legs of the walker, counting it as two steps. There are screen-based pedometers that also track time and allow the user to connect them to a computer via USB to track their daily usage [Figure 6]. This feature would allow an elderly user to easily send their caregiver daily updates on their walker usage. However, this measurement would be near to impossible for those individuals who put tennis balls on the non-wheeled legs to prevent them from having to lift the device at all.

Figure 6: Screen-based pedometer that allows connection to a computer for daily tracking. From http://www.dimensionengineering.com/images/products/DE-ACCM3Dbig.jpg

Accelerometer:

An accelerometer implements 3-axis MEMS inertial sensors to detect local accelerations [Figure 7]. This raw data is then processed with software designed to filter out false positives and detect true steps. Accelerometer based step detection is often found in smart phones and similar devices. When the step counter is in a smart phone distance measurements can be taken from existing connections to the GPS, otherwise total distance is estimated from the users calibrated individual step distance [11]. This technology could be implemented into the walker device to count the steps of the use. This kind of cadence counting would be significantly more complicated however and require a lot more circuitry, data processing, and programming.

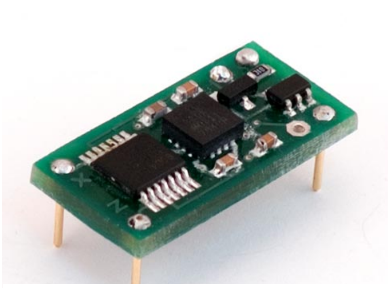

Figure 7: The typical circuitry of chip embedded accelerometer. From http://gatorade2008.republika.pl/itrip2/itrip-both.jpg

Figure 8: Bike speedometer with the equipment to count revolutions of a wheel. From http://image.made-in-china.com/2f0j00FeOEKtJhrRpj/Bicycle-Cycle-Computer.jpg

Speedometer:

Simple and inexpensive speedometers designed for bicycles calculate speed by tracking wheel rotation [Figure 8]. By mounting a magnet to the spokes of the wheel and an electric sensor mounted on the forks tracks wheel revolutions by the magnetic induction as it passes by the current [12]. By calibrating the device for the radius of the wheel, distance and speed can easily be calculated from the pulse rate count. A device such as this could easily be modified to work with the wheel of a two-wheeled walker. Bike speedometer are also able to record the relevant data needed for this design such as time used and distance traveled in addition to counting wheel revolutions, which with some simple programming of the microcontroller could give cadence data. Like the pedometer, some more expensive speedometers have the ability to connect via USB to the computer. This would eliminate modifications to the device in order to send usage data to the care provider.

Cadence Design Matrix:

A design matrix was constructed to evaluate the three designs and choose which design will continue on to prototyping. Evaluation categories include accuracy, attachment, feasibility, and cost.

Table 2: Cadence measurement design matrix with three alternative designs scored against a set of weighted criteria.

Cadence				
Criteria	Weight	Accelerometer	Speedometer	Pedometer
Accuracy	45%	3	4	2
Attachment	25%	3	4	1
Feasibility	20%	1	5	3
Cost	10%	3	3	5
Total	5	2.6	4.1	2.25

These categories were then given a weight based on importance. The highest weight was given to accuracy because the cadence information will be sent to the care provider for analysis on patient health and care. The other substantial category was attachment because the device has to attach in a manner that will not impede normal use of the walker. The speedometer scored well in both categories, because of the simplicity of the sensing wheel revolutions of the walker. The pedometer and accelerometer received poor marks in these categories because they must be kept on the user's person, and ideally the device should be centralized to the walker. The accelerometer also scored poor marks in feasibility because of the complex software analysis needed compared to the low program requirements of the speedometer and pedometer.

Final Design:

Based on the results of the two matrices, the key components on the two-wheel walker in terms of the sensor and cadence measurements will be the proximity sensor and the speedometer. An Arduino microcontroller will serve as a central hub which will power the device and store the output data gathered by the speedometer unit. Data can be accessed on the controller via an SD card that will be added. A circuit must be designed to allow communication between the controller, speedometer, storage device, and output display. A block diagram has been made to illustrate these connections [Figure 9].

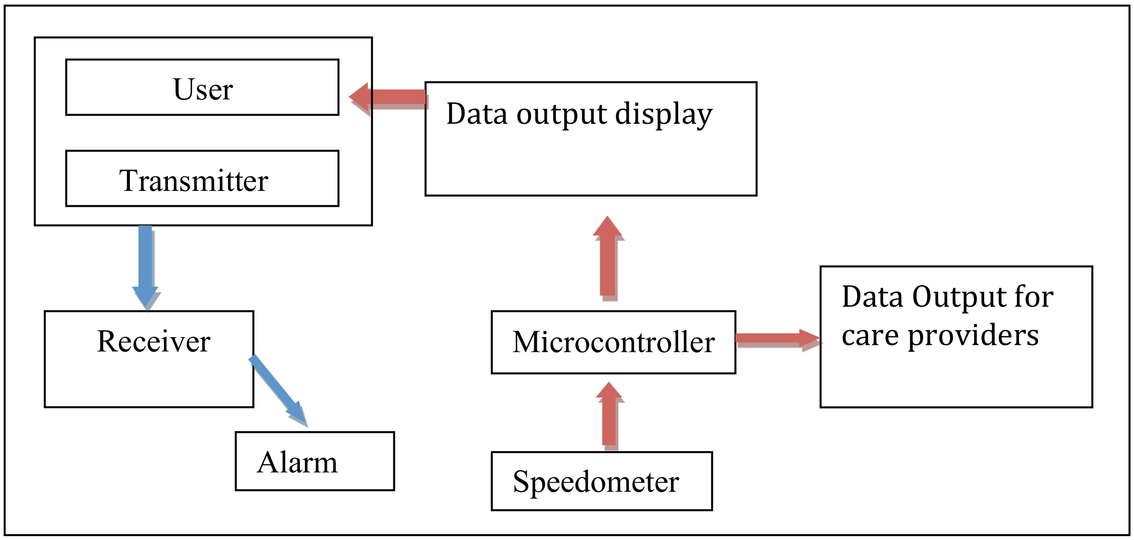

Figure 9: Block diagram of the alarm and cadence process on the two-wheel walker. A microcontroller will process and store data and output data to display or as a data file for use by care provider.

Originally, the alert system was created with the FM transmitter and receiver through implementation with the microcontroller. A circuit was connected to connect a simple receiver with an Arduino microcontroller and the decibel signal attenuated around one foot from the transmitter, ideal for the distance the clients wanted. While the distance testing data, seen in Appendix C, seemed promising for this setup, there was a lot of signal interference when the device was removed from a controlled lab setting. The signal would frequently be lost entirely or diminish to allow only a couple inches distance between the transmitter and receiver. This prompted the change to the proximity sensor for measuring patient distance from the walker.

Distance will be monitored by a transmitter mounted on the walker and a small, low power, lightweight proximity receiver to be kept on the user's person. The receiver will have to be designed into a wearable device such as a bracelet or anklet. When the distance between the receiver and the transmitter exceeds a meter, an alarm on the receiver will sound.

As for cadence measurement, a modified bike speedometer will be placed on the walker to measure wheel revolutions per unit time. This digital data will pass through the same microcontroller mentioned previously for further processing, such as time usage and velocity. The microcontroller will also be programmed so that the data collected can be stored in other databases, which in this case, an SD card, for care provider's analysis.

Prototype:

Speedometer Circuitry:

To augment the functionality of the alarm system we have included a method of recording some information about how the walker is used. Data such as walking speed and distance are potentially important metrics for a study of an elderly patient's behavior, and our client has expressed interest in adding this functionality. The design uses hardware components from a bicycle speedometer to sense the wheel revolutions and the Arduino microcontroller to interpret the data as seen in Figure 10. The sensor hardware consists of five magnets attached to a spoke of the wheel and a reed switch attached to the frame. A reed switch is a circuit component, which is normally open but closes in the presence of a magnetic field. As the wheel rotates the magnet passes by the reed switch, completing the circuit and outputting a pulse of current into the analog input of the microcontroller. To integrate the pulse data into distance and speed, code was added to a template available online (13).

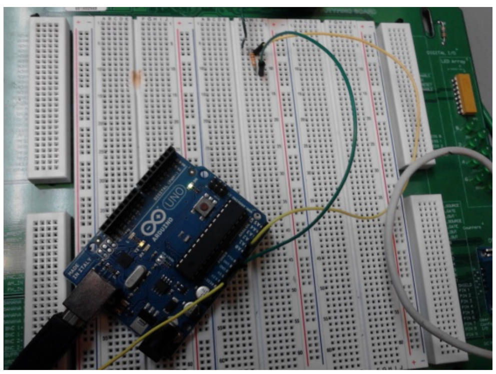

Figure 10: Speedometer hardware connected to Arduino microcontroller through a simple circuit.

The first bit of code tells the computer to run each loop at a rate of 1000 Hz. At the beginning of the loop the computer detects if the reed switch is open or closed. Once the switch is found to be closed a series of tasks are executed. First a 300 ms counter is started to prevent duplicate readings of a single switch close. Next the time elapsed between pulses is stored and summed to provide the total time the walker was in use. Given the time between pulses and the constant wheel circumference (equivalent to the distance traveled in one revolution) an instantaneous speed is calculated. This speed can then be sent to a display in a future model of the device. If more than four seconds has elapsed after a pulse detection the walker is assumed to have stopped. Once the walker has stopped the total distance and average speed are calculated and stored in an SD card inserted in the microcontroller. This data in an excel file could be output to a care provider by taking the SD card out of the controller and put it on any computers. The simplified flowchart of how the above codes work is shown in figure 11.

The whole cadence measurement system, including the speedometer circuitry, microcontroller, SD card, on/off switch, and a 9-volts –battery pact, are put together in a black case that is attached on the side of the walker with velcro. This allows ease of relocation of the device to different walker in the future.

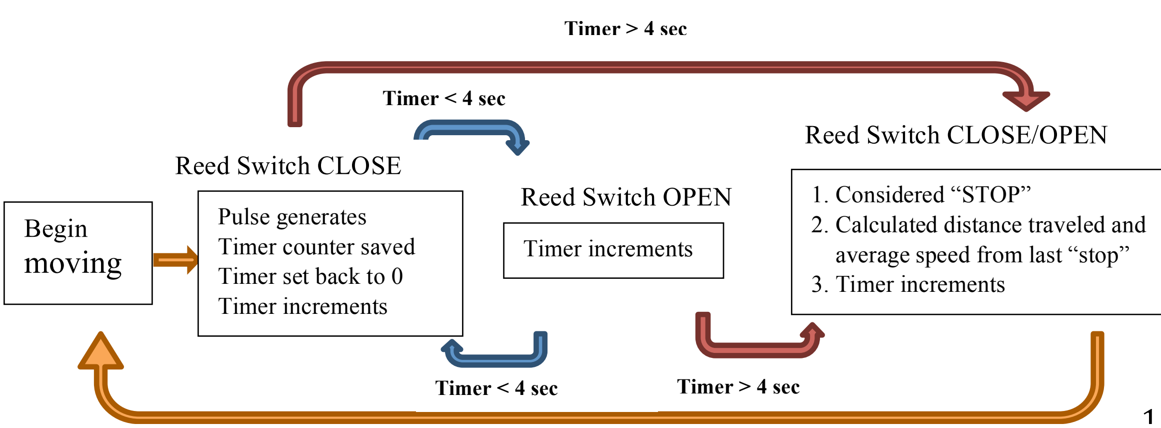

Figure 11: Arduino Flowchart of the Speedometer. Timer counter increments constantly and only is set up to be zero the moment the reed switch closes. When Timer exceeds 4 seconds before detecting any new pulse, the microcontroller considers that as the stop sign, outputting corresponding cadence measurement before the stop.

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parent when their child has wandered an unsafe distance in busy and highly populated areas. The signal transmitter is inside the panda bracelet, which is normally worn by the child [Figure 12]. The parent then holds, pockets, or clips on the receiver. The side of the receiver has an adjustable dial that controls the distance of alarm, which is a loud beeping. Both pieces operate through battery power [16].

Figure 12. Proximity sensor that alarms when the panda bracelet is too far from the receiver. Taken from http://www.specialtyalarms.com/site/1313932/product/30-210

For the walker the transmitter is strapped onto the lower bar of the walker and the receiver is clipped onto the user. The exact inner working of the transmitter and receiver are currently unknown, but the team believes that they run off Bluetooth sensors similar to other proximity sensors that were considered.

Accuracy Testing:

Testing began by determining that the device recorded information that was accurate within 5% of the daily total, as specified in Appendix A. This is to ensure that the device is both reliable for the walker user and that the data being sent to the care provider is representative of user usage.

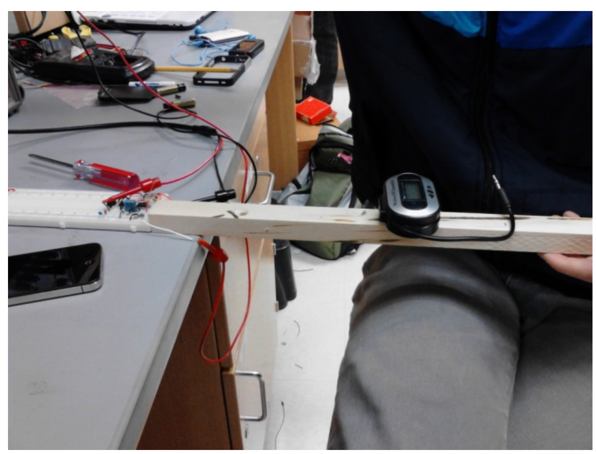

Figure 13. Distance testing of the transmitter signal as it moved away from the antenna in 3 in. increments.

The team replicated the FM transmitter test plan for testing the alarm distance for the new proximity sensor [Figure 13]. The panda transmitter was attached to the lower bar of the walker at 19.81 in. above the floor. The receiver was then incrementally moved away until the alarm sounded and this horizontal distance was recorded. To measure for some sense of reliability, this process was repeated for a total of ten trials [Table 3]. Simple geometry and Pythagoreans theorem were then used to find the total (taking into account both horizontal and vertical components) alarm distance between the transmitter and receiver.

Trial	Plastic Alarm Distance (in)	Metal Alarm Distance (in)
1	51.96	34.71
2	48.96	33.69
3	63.48	59.87
4	43.44	34.92
5	59.52	34.00
6	47.04	34.20
7	56.52	59.64
8	51.00	34.40
9	51.00	34.40
10	54.96	34.92
Average	52.79	39.47
Standard deviation	5.97	10.70

Table 3. Recoded alarm distance measurements as the receiver was moved away from the transmitter while attached to the walker on plastic and metal.

Trials 3 and 7 when the transmitter was attached to metal gave significantly higher alarm distances than the other eight trials. This directly resulted in the high standard deviation for the data set. However, when the transmitter was moved to a plastic part of the walker for attachment, the average increased to just over 52 in. but the standard deviation of the data set was less than 6 in. Based on the difference between these data set, it appears that the when the transmitter is attached to the metal of thee walker it acts like an antenna and will randomly amplify the signal transmitted.

The accuracy of the speedometer was also tested. The magnets were attached to one of the walker wheels at approximately equal distances from the center. The magnetic sensor was taped to the walker leg to create a similar set up to the one seen in Figure 14. The time and distance data was recorded on the computer using the microcontroller and corresponding computer program. Manual recording of the revolutions and time were recorded by the team members and then compared to the data from the speedometer. The difference between the two values is shown in Figures 15 and 16 and the raw data is in Appendix C. The average difference between distance was 2.2 in. with a standard deviation of less than an inch. Since the manual distance was 10 ft for each trial, this value is well within the 5% (6 in.) specified in Appendix A. The average difference in speed was 0.156 ft/s but the 5 percent specification should make this average difference be 0.07 ft/s or less. The standard deviation for the data is 0.13 ft/s which is also a large value. If human error is considered however, it is more likely that this large average difference and standard deviation are due to human reaction time lags when starting or stopping the time. Because of this, it is reasonable to assume that because of the excellent accuracy in distance the more inaccurate speed data is actually due to errors in the team's time recording rather than in the speedometer recording. Therefore, the speed recorded by the walker is likely within the 5% accuracy specified in Appendix A.

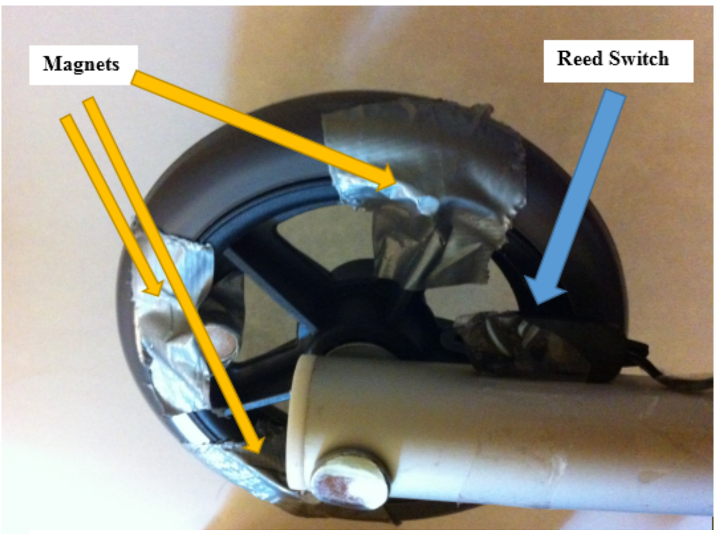

Figure 14. Setup of accuracy testing for the time and cadence recording of the speedometer equipment and program.

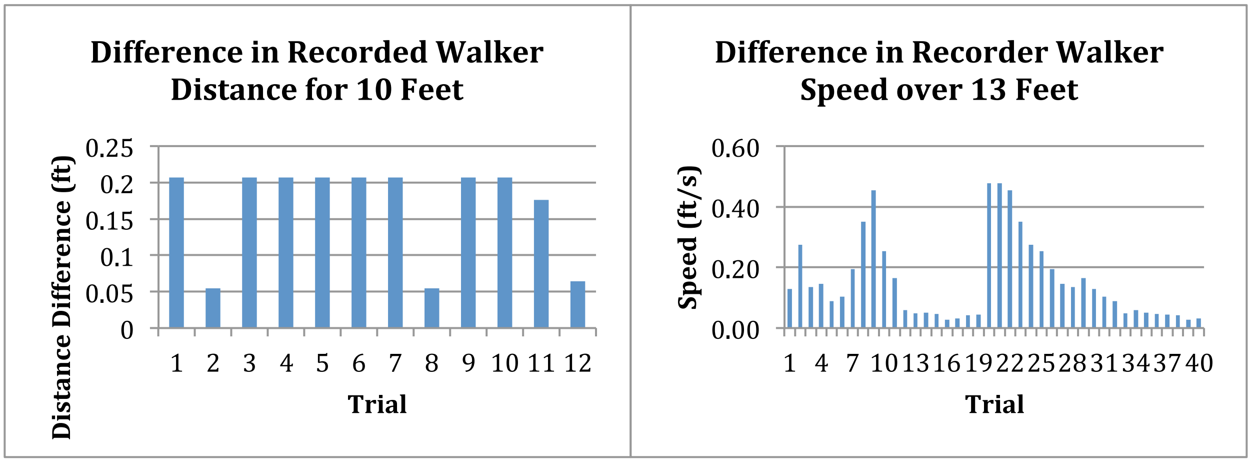

Figure 15 & 16. Difference in distance (left) and speed (right) between data recorded by the speedometer and physical recordings by the team.

Human Subject Testing:

The device was tested by three different human subjects in order to verify that the alarm increased the use of the walker as compared to walker use without the alarm. In order to do this, each test subject used the walker for two nonconsecutive days in order to prevent getting used to using the walker. The test subjects were individuals who did not require the use of a walker, since people who do not need to use the device are most likely to forget it. On the first day each subject used the speedometer portion of the device without the alarm. On the second day the alarm was attached and activated during the time of use. The difference in usage between these two days for each individual subject is seen in Figure 17 and the raw data is included in Appendix D. A student's t-test comparing the alarm system data to that of the baseline collected on the first day was conducted to see if the displayed difference was significant in time usage and distance. For these tests the degree of freedom for the t-test was four. The resulting t value was 1.32 and 1.27 for distance and time respectively. Both of these values exceed the 0.15 alpha value, indicating a 0.15 probability that the significance between the two trials is due to chance, which is 1.19. Because these testing subjects are not actually walker users, this level of significance is promising for the device and will likely improve when the device is tested on elderly walker users.

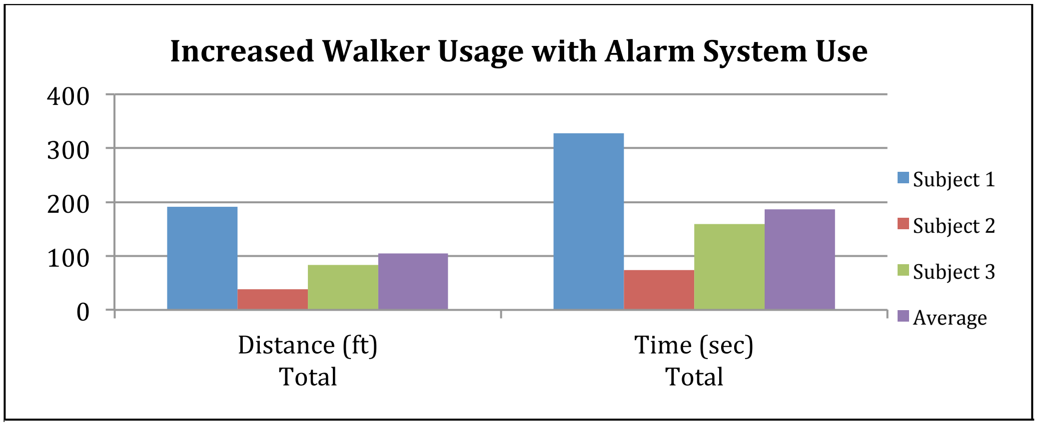

Figure 17. Difference between day one (baseline) and day two (alarm system) total usage in time and distance. Each subject saw an increase in both usages with the alarm system.

Assisted Living Facility:

The final prototype and the testing results were presented to seven faculty members at a local cognitive impairment assisted living facility. These faculty members ranged from physical therapists, executive directors, nursing staff and marketing staff. The device was shown to them in full with a brief explanation on the inner workings and the opportunity to lift and move the walker. After viewing this demonstration, the staff was asked to fill out a brief survey, seen in Appendix E, about the device. Their response to the device and its benefits were overwhelmingly positive. Their opinions are shown below in Figure 18. These help to show that while some changes still need to be made in the future of this project, there is both a market and a desire for this device with minimal risk of falls or aggravation. It will not only act as a preventative care tool but it will also help care providers and staff evaluate their patients' needs and give the necessary adjustments in care.

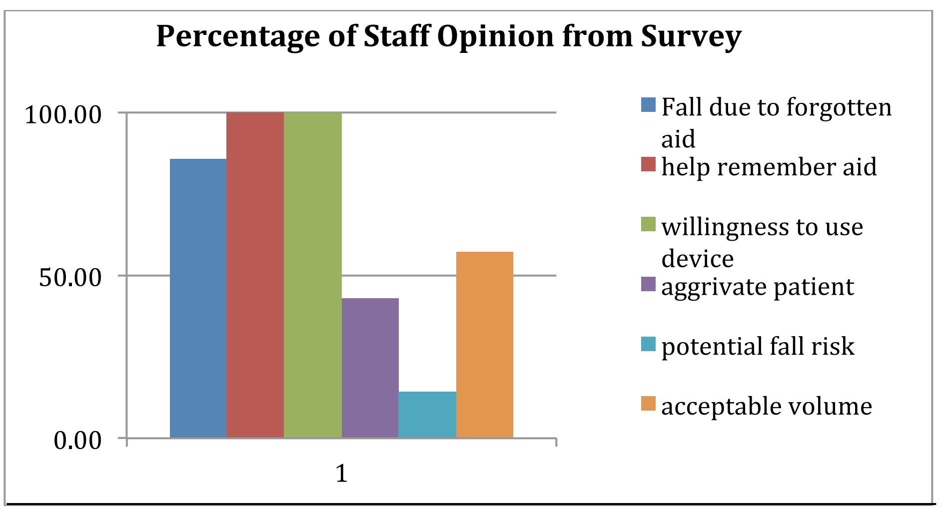

Figure 18. Percentage of employee survey takers that agreed to each statement. Results showed device would have overall positive impact.

Cost:

Throughout the year the team bought a variety of parts to build circuits, a speedometer kit, and several transmitters and receivers while the prototype developed and changed. The total cost for the year so far is listed below in Table 4. With these costs, the team estimates that an individual device will cost approximately $70. This price should come down with creation of individual proximity sensor rather than one purchased off the market as well as decreases from buying certain products in bulk.

Table 4: Total costs for the project over the course of the year. Prices for individual purchases and pieces included.

Item Purchased	Cost
RD100 Speedometer Parts Kit	$20.05
Arduino Microcontroller	$32.00
Receiver/Transmitter Kit	$54.97
FM Receiver	$9.88
FM Transmitter	$10.31
Diodes	$56.22
Proximity Sensor	$27.98
Arduino additions	$20.01
SD Card	$8.00
Batteries	$15.22
Mounting Box	$4.73
Velcro	$4.00
Total	**$263.37**

Future Work:

Moving forward, should this project be picked by another team, there is still work to be done modifying the device to better fit the client needs. Ideally, the proximity sensor would be hand-made by the team rather than purchased commercially. This will allow the alarm to sound at a range of signals from as close to one foot to five or six feet away. The adjustable distance will allow the device to be customizable to patients who are more or less reliant on their walker or who are at greater risk of suffering a fall. The client would like to keep the alarm separate and incorporate several different cases besides the panda outfit to make the device personalized and recognizable to an individual patient in order to help condition them to their walker. Additionally the alarm should change from a beeping, which is very common in an assisted living facility, to a personal voice that would say the owners name when reminding them to get their walker.

As for the speedometer device, this could be produced by an outside company on a much smaller scale to help reduce the size of the device. The client would also like a slightly more secure device attachment to prevent the device from falling off if hit while turning. This would include other options such as clips or zip ties. Additionally an LCD display and interface navigation buttons will be added to display relevant data and make any adjustments, such as adapting the device to walkers with varied wheel diameters. Finally, a simple pamphlet with mounting, battery, and data instructions will be constructed, including any possible warnings that are later deemed necessary.

Conclusion:

The created prototype has proven to increase walker use through the alarm system and will provide useful patient usage data to care givers to determine health and falls risk. Once the proximity has been made adjustable in both alarm distance and volume, it will be ready to be tested on elderly walker users. Similar and more substantial results are expected with these changes. After this the device will be able to be patented and processed for mass production. The use of this device for individuals living independently or in any type of assisted or cared facility will improve patient safety and prevent many users from experiencing falls due to forgetting their walker. They will also experience better health care through the evaluation of their average daily usage by care providers and staff.

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Appendix A:

Project Design Specifications
October 20, 2012
Rachel O'Connell, Jared Ness, Alpha Liu, Billy Zuleger

Problem Statement:
Older adults that require the use of a walker for daily motility can cause serious harm to themselves by forgetting to use their walker. The goal of this project is to design a walker that can notify the user when the user begins to walk away without it. In addition, the walker should provide useful feedback about the walker usage such as time, total steps taken and cadence. The technology would ideally be transferable to use with a walker.

Client Requirements:

- Walker must have a sensor that notifies the user when they walk away without it
- Walker needs to be able to measure time used, steps taken, and cadence
- Data from the walker must be transferable to care provider

Design Restraints:

1. **Physical and Operational Requirements**
    a. *Performance requirements:* The walker should be able to support user weight and should not inhibit normal mobility.
    b. *Safety:* The alarm on the walker should not startle the user causing unsafe behavior.
    c. *Accuracy and Reliability:* The walker should notify the user when they are approximately one-three feet away from the walker. Step count, cadence and time of use data should be accurate within 5% of the total steps taken and the total time used.
    d. *Life in Service:* The device should last for lifetime of the patient with appropriate power supply.
    e. *Shelf life:* Shelf life is not an applicable restraint for the device.
    f. *Operating Environment:* The device will be used in a clinical study by a clinical research assistant. The device should be able to function in the home as well as outside.
    g. *Ergonomics:* The device should be comfortable for the user and not inhibit their normal. The device should be easy to read for low vision

users, should have no small buttons, and should be easy to use for users with limited technological knowledge.

h. *Weight:* The device weight should not add more than 2 lbs to the functional walker weight.

i. *Materials:* The walker should be made out of standard materials such as aluminum, that can incorporate the appropriate electronic equipment.

j. *Aesthetics, Appearance, and Finish:* The user sensor should be small and attachable to clothing or wrist. The incorporated electronics should be neatly packaged.

2. Product Characteristics

a. *Quantity:* The client requires one working prototype to be tested by human subjects.

b. *Target Product Cost:* $20-500, could be increased with client approval

3. Miscellaneous

a. *Standards and Specifications:* The device should hold patient weight and be user friendly.

b. *Customer:* The device will be tested on human subjects

c. *Patient concerns:* The device should be user friendly for those with audio, visual, and precise movement impairments. The alarm should not cause additional agitation or unhealthy patient behavior.

d. *Competition:* There are no walkers that are able to sense when the user walks away or that are able to quantify usage.

Appendix B:

Speedometer Code (C++)

```
//calculations
//tire radius ~ 2.5 inches
//circumference = pi*2*r =~15.708 inches
#define reed A0//pin connected to read switch
//storage variables
int reedVal;
long timer;// time between one full rotation (in ms)
float fps; //feet per second
float radius = 2.5;// tire radius (in inches)
float circumference;
int maxReedCounter = 100;//Time after first detection of switch
closed (in ms)
int count = 0; // counter for data storage array.
int reedCounter; // decrements by one every 1/1000s
float totDistance = 0;
float newDistance = 0;
float totTime = 0;
float totTimeUsage = 0;
```

```
float totTimeSecond = 0;
float avgSpeed = 0;
float storageAr [3] [100];
int i = 0; //after 10 secs without pulse response, output 0
avgSpeed.
int n = 0; // make sure avg is only calculated once everytime
timer > 2000
String dist = " Feet";
String rate = " Feet per Second";
String time = " Second";
void setup(){
  reedCounter = maxReedCounter;
  circumference = 2*3.14*radius;
  pinMode(reed, INPUT);
  // TIMER SETUP- the timer interrupt allows precise timed
measurements of the reed switch
  cli();//stop interrupts
  //set timer1 interrupt at 1kHz
  TCCR1A = 0;// set entire TCCR1A register to 0
  TCCR1B = 0;// same for TCCR1B
  TCNT1 = 0;
  // set timer count for 1khz increments
  OCR1A = 1999;// = (1/1000) / ((1/(16*10^6))*8) - 1
  // turn on CTC mode
  TCCR1B |= (1 << WGM12);
  // Set CS11 bit for 8 prescaler
  TCCR1B |= (1 << CS11);
  // enable timer compare interrupt
  TIMSK1 |= (1 << OCIE1A);
  sei();//allow interrupts
  //END TIMER SETUP
  Serial.begin(9600);
}
ISR(TIMER1_COMPA_vect) {//Interrupt at freq of 1kHz to measure
reed switch
  reedVal = digitalRead(reed);//get val of A0
  if (reedVal){//if reed switch is closed
    if (reedCounter == 0){//min time between pulses has passed
      i = 0;
      n=0;
      fps =
((56.8*float(circumference/3))/float(timer))*5280/3600;
//calculate feet per second
      newDistance = fps * float(timer)/1000;
      totDistance = totDistance + newDistance;
      totTime = totTime + timer;
      timer = 0;//reset timer
      reedCounter = maxReedCounter;//reset reedCounter
    }
    //else{
    //if (reedCounter > 0){//don't let reedCounter go negative
    //reedCounter -= 1;//decrement reedCounter
```

```
    //}
    //}
  }
  else{//if reed switch is open
    if (reedCounter > 0){//don't let reedCounter go negative
      //k = 0;
      reedCounter -= 1;//decrement reedCounter
    }
  }
  // walker is stopped. average speed calculated. total distance
and average speed stored in array. array count updated, mph
reset.
  if (timer > 2000){
    i +=1;
    if (i > 10000 && n ==1){
      avgSpeed = 0;
      storageAr [0] [count] = totDistance;
      storageAr [1] [count] = avgSpeed;
      storageAr [2] [count] = totTimeSecond;
      displayFPS();
      i = 0;
      n = 2;
    }
    if( n ==0){
      if (totDistance != 0){
        avgSpeed = ((totDistance )/ (float) totTime)* 1000 ;
//feet / sec
      }
      else {
        avgSpeed = 0;
      }
      n =1;
      totTimeUsage = totTimeUsage + totTime;
      totTimeSecond =totTimeUsage /1000;
      storageAr [0] [count] = totDistance;
      storageAr [1] [count] = avgSpeed;
      storageAr [2] [count] = totTimeSecond;
      displayFPS();
      count +=1;
    }
    fps = 0;//if no new pulses from reed switch- tire is still,
set mph to 0
      totDistance = 0;
    totTime = 0;
  }
  else{
    timer += 1;//increment timer
  }
}
void displayFPS(){

  //Serial.print(storageAr [0][count]);
```

```
  //Serial.println(dist);
  //Serial.print(storageAr [1][count]);
  //Serial.println(rate);
  Serial.print(totDistance);
  Serial.println(dist);
  Serial.print(avgSpeed);
  Serial.println(rate);
  Serial.print(totTimeSecond);
  Serial.println(time);
}
void loop(){
}
```

Appendix C:

FM Transmitter Testing Data

Distance (ft)	Trial 1 (dB)	Trial 2 (dB)	Trial 3 (dB)	ave (dB)	stdev (dB)
0.25	-39.156	-39.62	-39.7	-39.49	0.29
0.50	-44.14	-45.39	-46.3	-45.28	1.08
0.75	-46.8	-49.5	-53.6	-49.97	3.42
1.00	-49.608	-53.9	-57.7	-53.74	4.05
1.25	-56.62	-58.8	-59.4	-58.27	1.46
1.50	-57.252	-59.4	-59.4	-58.68	1.24
1.75	-58.188	-59.7	-60.3	-59.40	1.09
2.00	-58.188	-60.8	-60.6	-59.86	1.45
2.25	-58.188	-60.8	-60.6	-59.86	1.45

Distance Difference Testing Data

Trial	Distance (ft)	Distance Difference (ft)
1	10.2069	0.2069
2	9.9452	0.0548
3	10.2069	0.2069
4	10.2069	0.2069
5	10.2069	0.2069
6	10.2069	0.2069
7	10.2069	0.2069
8	9.9452	0.0548
9	10.2069	0.2069
10	10.2069	0.2069
ave	10.1546	0.1765
stdev	0.1103	0.0641

Speed Difference Testing Data

Time (s)	Manual Speed (ft/s)	Computed Speed (ft/s)	Difference (ft/s)
9.1	1.44	1.31	0.13
6.7	1.95	1.68	0.27
8.7	1.50	1.37	0.13
8.1	1.62	1.47	0.15
9.7	1.35	1.26	0.09
9.2	1.42	1.32	0.10
7.5	1.75	1.55	0.20
5.5	2.38	2.03	0.35
5.4	2.42	1.97	0.45
7.1	1.84	1.59	0.25
9	1.45	1.29	0.16
11.6	1.13	1.07	0.06
11.5	1.14	1.09	0.05
11.9	1.10	1.05	0.05
12.5	1.05	1.00	0.05
13.8	0.95	0.92	0.03
15	0.87	0.84	0.03
13.2	0.99	0.95	0.04
12.9	1.01	0.97	0.04
5	2.62	2.14	0.48
5	2.62	2.14	0.48
5.4	2.42	1.97	0.45
5.5	2.38	2.03	0.35
6.7	1.95	1.68	0.27
7.1	1.84	1.59	0.25
7.5	1.75	1.55	0.20
8.1	1.62	1.47	0.15
8.7	1.50	1.37	0.13
9	1.45	1.29	0.16
9.1	1.44	1.31	0.13
9.2	1.42	1.32	0.10
9.7	1.35	1.26	0.09
11.5	1.14	1.09	0.05
11.6	1.13	1.07	0.06
11.9	1.10	1.05	0.05
12.5	1.05	1.00	0.05
12.9	1.01	0.97	0.04
13.2	0.99	0.95	0.04
13.8	0.95	0.92	0.03
15	0.87	0.84	0.03
ave	1.50	**ave**	0.16
		stdev	0.14

Appendix D:

Day 1 - **Subject 1**

Distance (ft)	Average Speed (ft/s)	Time Usage (s)
0	0	0
1.5703	0.2288	6.86
3.9257	0.5299	14.27
0	0	14.27
15.7029	0.5931	40.75
11.5155	0.5789	60.64
0	0	60.64
9.6835	0.723	74.03
0	0	74.03
8.6366	0.5116	90.91
0	0	90.91
11.2538	0.6238	108.96
0	0	108.96
2.8789	0.4673	115.12
19.3669	0.7732	140.17
26.1715	0.7936	173.15
7.0663	0.6636	183.8
0	0	183.8
6.5429	0.7708	192.28
0	0	192.29
19.1052	0.6547	221.47
0	0	221.47
6.8046	0.4846	235.51
3.664	0.4483	243.69
0	0	243.69
8.1132	0.6854	255.53
0	0	255.53
10.2069	0.7428	269.27
0	0	269.27
12.5623	0.7937	285.09
Total Distance (ft)	**Average Speed**	**Total Time used**
184.771	0.6148	285.09

Day 2 - **Subject 1**

Distance (ft)	Average Speed (ft/s)	Time Usage (s)
0	0	0
21.9841	0.916	24
16.7498	0.7087	47.64
4.7109	0.5023	57.02
0.2617	0.0654	61.02
9.4218	0.6615	75.26
10.992	0.7919	89.14
7.5897	0.3957	108.32
2.0937	0.2997	115.31
2.8789	0.2772	125.7
11.5155	0.6058	144.71
16.4881	0.7123	167.85
9.4218	0.739	180.6
10.7303	0.6925	196.1
11.7772	0.553	217.39
13.8709	0.535	243.32
17.0115	0.72	266.95
4.7109	0.6668	274.02
15.7029	0.704	296.32
4.4492	0.5709	304.11
0.2617	0.0654	308.11
10.4686	0.541	327.47
13.8709	0.6007	350.56
11.2538	0.7767	365.05
15.1795	0.6267	389.27
20.6755	0.7416	417.15
13.3475	0.8269	433.29
0.2617	0.0654	437.29
7.328	0.7677	446.84
10.2069	0.666	462.16
12.824	0.6587	481.63
2.3554	0.2975	489.55
2.3554	0.3067	497.23
7.0663	0.5493	510.09
15.9646	0.6594	534.3

8.8983	0.6865	547.27
2.0937	0.3687	552.95
2.8789	0.3657	560.82
2.8789	0.4973	566.61
4.4492	0.5592	574.56
9.4218	0.5272	592.44
1.832	0.3321	597.95
5.7577	0.6121	607.36
2.6172	0.4565	613.09
Total Distance (ft)	**Average Speed**	**Total Time used**
376.6084	0.5505	613.09

Day 1- **Subject 2**

Distance (ft)	**Average Speed (ft/s)**	**Time Usage (s)**
0	0	0
0	0	0
12.0389	0.8162	14.75
0	0	14.75
17.0115	0.8681	34.35
0	0	34.35
10.4686	0.8261	47.02
0	0	47.02
5.496	0.7022	54.85
0	0	54.85
13.6092	0.9612	69
0	0	69
9.16	0.9247	78.91
0	0	78.91
3.9257	0.5223	86.43
0	0	86.43
9.9452	0.7956	98.93
0	0	98.93
14.6561	0.8334	116.51
3.664	0.5255	123.49
10.4686	0.7853	136.82
0	0	136.82
0.2617	0.0654	140.82

Day 2 - **Subject 2**

Distance (ft)	**Average Speed (ft/s)**	**Time Usage (s)**
0	0	0
5.496	0.5078	10.82
0	0	10.82
18.8435	0.931	31.06
0	0	31.06
19.6286	0.9529	51.66
0	0	51.66
9.6835	0.7693	64.25
0	0	64.25
12.0389	0.6395	83.07
9.4218	0.8053	94.77
0	0	94.77
12.3006	0.8866	108.65
0	0	108.65
9.6835	0.7584	121.41
0	0	121.41
8.8983	0.6344	135.44
0	0	135.44
10.4686	0.7871	148.74
12.3006	0.7203	165.82
0	0	165.82
13.3475	0.6464	186.47
0	0	186.47

0	0	140.82
9.9452	0.848	152.55
0	0	152.55
12.5623	0.8195	167.88
0	0	167.88
13.3475	0.8686	183.24
18.8435	0.6561	211.96
0	0	211.96
Total Distance (ft)	**Average Speed**	**Total Time used**
165.404	0.7335	211.96

5.2343	0.4954	197.04
12.3006	0.6971	214.68
0	0	214.68
13.8709	0.8683	230.66
0	0	230.66
6.0195	0.7078	239.16
0	0	239.16
7.328	0.5934	251.51
0	0	251.51
2.8789	0.3836	259.01
3.9257	0.5723	265.87
0	0	265.87
6.0195	0.7089	274.36
0	0	274.36
3.664	0.3285	285.52
Total Distance (ft)	**Average Speed**	**Total Time used**
203.3528	0.6854	285.52

Day 1- **Subject 3**

Distance (ft)	**Average Speed (ft/s)**	**Time Usage (s)**
0	0	0
0	0	0
2.0937	0.3889	5.38
0	0	5.38
14.3943	0.8252	22.83
0	0	22.83
7.328	0.7524	32.57
0	0	32.57
15.1795	0.952	48.51
0	0	48.51
17.7966	0.936	67.52
0	0	67.52
5.7577	0.6957	75.8
0	0	75.8
6.2812	0.7023	84.74
0	0	84.74
10.2069	0.7949	97.58

Day 2 - **Subject 3**

Distance (ft)	**Average Speed (ft/s)**	**Time Usage (s)**
0	0	0
0.2617	0.0654	4
17.7966	0.8199	25.71
0	0	25.71
4.4492	0.5689	33.53
9.6835	0.5375	51.54
13.3475	0.6424	72.32
9.4218	0.5565	89.25
0	0	89.25
8.3749	0.5617	104.16
19.1052	0.7942	128.22
0	0	128.22
0.2617	0.0654	132.22
0	0	132.22
10.7303	0.7269	146.98
1.0469	0.2094	151.98
0	0	151.98

0	0	97.58
6.2812	0.6891	106.7
0	0	106.7
4.7109	0.6957	113.47
0	0	113.47
9.4218	0.863	124.39
0	0	124.39
17.7966	0.6415	152.13
0	0	152.13
12.0389	0.9439	164.88
0	0	164.88
18.3201	0.7928	187.99
0	0	187.99
0.2617	0.0654	192
0	0	192
10.7303	0.5771	210.59
20.6755	0.625	243.67
0	0	243.67
5.2343	0.6259	252.03
0	0	252.03
0.2617	0.0654	256.03
11.7772	0.8985	269.14
0	0	269.14
15.7029	0.9839	285.1
7.8515	0.5956	298.28
0	0	298.28
Total Distance (ft)	**Average Speed**	**Total Time used**
220.1025	0.6868	298.28

10.4686	0.8204	164.74
0	0	164.74
10.992	0.6871	180.74
3.664	0.2377	196.16
0	0	196.16
10.992	0.6484	213.11
12.5623	0.625	233.21
0	0	233.21
8.3749	0.5306	248.99
0.2617	0.0654	252.99
0	0	252.99
12.824	0.6824	271.79
22.2458	0.718	302.77
0	0	302.77
17.7966	0.7371	326.91
0	0	326.91
0.2617	0.0654	330.91
0	0	330.91
2.3554	0.4287	336.41
3.9257	0.5661	343.34
11.2538	0.7183	359.01
0	0	359.01
8.3749	0.6133	372.67
0	0	372.67
18.3201	0.9071	392.86
0	0	392.86
37.4253	0.7768	441.04
0	0	441.04
16.4881	0.9652	458.12
0	0	458.12
Total Distance (ft)	**Average Speed**	**Total Time used**
303.0662	0.5635	458.12

Appendix E:

Facility Staff Survey

1. How often (if ever) do most users forget their walking aid?

   once a day 2-4 time a week once a week once a month rarely

2. How often do users have a fall because of forgetting their walking aid?

   no yes if yes: how often?______________________

3. Do you think a device like this would help users remember their walker?

   no yes if no: why?______________________________

4. Do you think users would be willing to use a device like this?

   no yes if no: why?______________________________

5. Do you think that the alarm would aggravate the patients or you?

   no yes if yes: why?______________________________

6. Would you or patients like the alarm more if it was a voice reminding them to take their walker?

   no yes

7. Do you think the alarm would startle patients, potentially causing a fall?

   no yes if yes: why?______________________________

8. Is the alarm volume acceptable?

   no yes

9. Did you find the device cumbersome in any way? (weight, position)

   no yes if yes: why?______________________________

10. Do you have any other concerns with the device?

   no yes if yes: what?______________________________