Six-Minute-Walk Test iPhone Application

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1.0 Abstract

The Six-Minute Walk Test (6MWT) application utilizes the iPhone's accelerometer, audio, internet access, and data storage capabilities to create a useful test for determining functional exercise capacity at home. This test compliments regular exercise and routine rehabilitation for those suffering from poor cardiopulmonary health by allowing the user to track his/her condition. This application provides the user with an easily-navigated program that displays clear results. The test is simple and includes both clear visual and verbal instruction. A personal pedometer is programmed into the application as well as a data logger and emailing system that allows the user to freely track his/her progress. It also comes with a pretest that calculates the step distance for the user in case he/she does not know it. We preformed testing on the accuracy measurements of the pedometer and decided that no single setting will work for every user and therefore we added in a sensitivity adjuster so that the user can tailor it to his/her settings.

2.0 Introduction

2.1 Background

The 6-Minute Walk Test (6MWT) is a walk test performed in a period of 6 minutes by patients with cardiopulmonary illnesses. The primary measurement is the distance (6MWD) the patient is able to walk, as quickly as possible, on a flat, hard surface. Currently the test is monitored in a clinical setting by a doctor and takes place in a one-hundred foot long hallway (ATS, 2002). The 6MWD of each performance can be compared and analyzed with the previous data in order to indicate the health condition of the patient both before and after surgery.

The 6MWT began as a 12-Minute Walk Test (12MWT) in the 1960's. The 12MWT was altered to a period of 6 minutes because the results of a 6-minute walk test remained accurate but the shorter period lowered the intensity of the course. Moreover, the 6MWT is now easier to administer and better reflects activities of daily living than other walk tests (Enright, 2003). In preparation for the test, the patient should not eat food within an hour of beginning the test, should be well rested preceding the test, and should wear comfortable, breathable attire. During the test, the physicians must have easy access to any emergency equipment such as an automated external defibrillator or inhaler in case of an emergency (ATS, 2002). Unlike other walk tests, the patients, while performing the 6MWT, can pace themselves under their own tolerance of intensity, but the pause times should be recorded and taken into consideration after the test (Enright, 2003). Another important feature is the verbal encouragements which are a set of standard phrasing of encouragements that the physicians will use at specific time intervals during the test to motivate the patients in their performance. Besides the measurement of 6MWD, patient's heart rate, dyspnea, fatigue, and SpO_2 (Pulse Oximeter Oxygen Saturation) will be looked at before and after the test to investigate the cardiopulmonary condition of the patient (ATS, 2002). In short, the results of the 6MWT allow both the patient and doctor to asses the patient's current condition and monitor any improvements after medical intervention.

2.2 iPhone Functionality

Using the features and benefits from the 6MWT, our objective is to create a similar test using an iPhone application that will generate 6MWT data in a home setting. This data will be useful in assessing patient improvement by testing the patient before and after medical intervention. The standard iPhone has robust functionality to make this possible. Our application will utilize the multi-touch screen, accelerometer, Wi-Fi, audio playback, data storage, and exportation to create a useful home test for measuring functional exercise capacity.

2.2.1 Multi-Touch Screen

With the 3.5-inch (diagonal) widescreen multi-touch display, the users can softly touch the screen with his/her fingers rather than pushing a button. This technology enhances the ease of use when generating with the 6MWT since the patients can start or stop the test more readily by tapping the screen rather than hitting a small button on another mobile measuring device.

2.2.2 Accelerometer

The iPhone responds to motion using a built-in accelerometer. When rotating an iPhone from portrait to landscape, the accelerometer detects the movement and changes the orientation of the image on the screen accordingly. Thousands of existing applications have taken the advantages of the accelerometer in the iPhone and programmed it as a pedometer, video playback device, and gaming system. The accelerometer feature in the iPhone will be used in calculating the patient’s walking distance. This is possible because of the change in orientation of the device while walking will create an acceleration that can be picked up by the accelerometer. The acceleration will be turned into a vector quantity, and therefore a step can be detected by imposing a certain threshold for the accelerometer to exceed (preliminary acceleration graphs can be seen in appendix 10.3).

2.2.3 Wi-Fi

Wi-Fi technology gives the iPhone users quick access to the Internet while they are in a Wi-Fi hotspot. This network will be required for the exportation of the data after performing the 6MWT. It will also be used to access to any other relevant information and alow the user to contact the doctor via email.

2.2.4 Audio Playback

The headphone jack and speaker can also be taken into account to the design. The verbal instructions of the test and the encouragements can be delivered through the headphone jack or speaker to the patients.

2.2.5 Power Efficiency

According to the technology specification published by the Apple, the built-in rechargeable lithium-ion battery performs at high power efficiency. The standby time has been up to 300 hours. While using the 3G network, it is up to 5-hour of usage. With the length of the 6MWT being short compared to these values, the power provided by iPhone is sufficient for our application.

2.3 Motivation

Despite the fact that this is an extremely powerful and research-proven test, it still has several aspects that ultimately led to the creation of our final solution. Firstly, the test requires a technician or doctor to be present while it is being performed. This led to its steep cost of up to two-hundred dollars (David Van Sickle, 2010). Although this was insurance reimbursable, it presents a significant financial burden for those without insurance who would greatly benefit from routine tracking.

Secondly, the test was time consuming for both the hospital and the patient. Appointments had to be made in advance, there were long traffic times both ways, and the waiting times for when the patient reached the hospital added up to many times the amount of the actual test which just took six minutes.

These two factors made it logical to redesign the six-minute-walk-test (6MWT) to take advantage of the current available technology so that its benefits can be more widespread. Combining the test with the iPhone or iTouch allowed three crucial benefits to arise. Firstly, if the application was available on the iTunes store along with a short description, which would generate greater awareness for the test and the major diseases of its main users chronic obstructive pulmonary disease (COPD). Secondly, a significant portion of the “middle-man” time would be cut out as the patient could perform the test on his/her own schedule. Finally, because the application is on the highly-trafficked iTunes store, it would be available to millions of people regardless of their condition. As long as they accurately track their data, this test can provide meaningful information for users of all conditions.

3.0 Design Specifications

Our client, David Van Sickle, suggested some important requirements for this project. He noted that it was necessary to record and organize the data from the test so that patients can see their progress over time. This would allow patterns to be observed and could provide opportunities for preemptive action. Also, the original 6MWT contained periodic encouragements so this feature will be included in the application as well.

In addition to our client’s recommendations, it was necessary to set up some specifications ourselves as well. First, the program must not be resource intensive. The accelerometer measurements have to be precise enough so that steps are accurately recorded without consuming too much battery. From initial testing, a frequency of 7.1Hz appears to accurately catalog the steps while being power-friendly at the same time.

A few safety concerns arose including the idea of distracting visuals on the screen while the test is in progress. Because the primary audience for the test is older individuals, having distracting visuals on the test screen can easily lead to distraction and possible injuries. If an emergency were to occur, it would be extremely helpful to have some method to contact others for assistance. This is why a button to call the patient's emergency contact was implemented on our test screen, so that assistance for injury or other problems can be quickly addressed. Unfortunately, we could not test this feature because the iPhone provided to us did not have a SIM card.

For the test itself, it required measurement accuracy to within 5% of the patients total distance walked. This is because the distance measured is the primary statistic that is looked at when analyzing the 6MWT data. So, a large variability in the pedometer can lead to misleading results.
Finally, one of the most important aspects of the 6MWT is that the program must be easy to use for the patient. With an older and less technology-savvy audience in mind, the interface m intuitive page flow as well as large, easily accessible buttons. Both Fitts' and Hick's laws were applied to our three designs and influenced the final decision of pursuing the "hybrid design".

3.1 Fitts' and Hick's Law

In order to help decide between the three different interfaces, two tests were conducted to look at the ergonomics of these interfaces. The first of these tests was Fitts' Law, which was created in 1954, by Paul Fitts. This law models the ease of movement in human-computer interactions and assigns a number to the index of difficulty of a task. The equation of Fitts' Law is T = a + b(ID) but for our purposes we only used the index of difficulty (ID) portion of the law. The equation for the index of difficulty $ID = \log_2\left(\frac{D}{W} + 1\right)$ is with ID being the index of difficulty, D the distance from the starting position to the button, and W the width of the button on the axis of movement (Beggs et al., 1972). To make the test as accurate and realistic as possible, the starting position was on the right side half way up the phone and remained constant for every screen on all three interfaces.

The other test performed was Hick's Law, which was created in 1952, by William Hick. This law was used to quantify the time it would take the average person to make a decision between the buttons on the screen. The equation for Hick's Law is $T = \log_2(n+1)$ where T is the decision or reaction time and n is the number of buttons on the screen (Kirkby, 1974).

4.0 Design Options

The three design ideas portray differences in the user interface (UI). Because the design must accurately measure the 6MWD and send data to a physician, these aspects must be consistent across all design proposals. Furthermore, focusing on the usability of the user interface is important for prototype success because most 6MWT patients have little to no experience with a smart phone. The three designs of our UI are wizard, branched, and hybrid. All of these designs contain the functional components, such as taking the test, viewing previous data, etc.

4.1 Design 1: Wizard

This design is similar to the wizard program that helps user's install software on their computers. This design is straightforward to use, and it is the most intuitive design. The user proceeds through the options in a predetermined order on a linear path, without the option to jump to other screens without going through several intermediates.

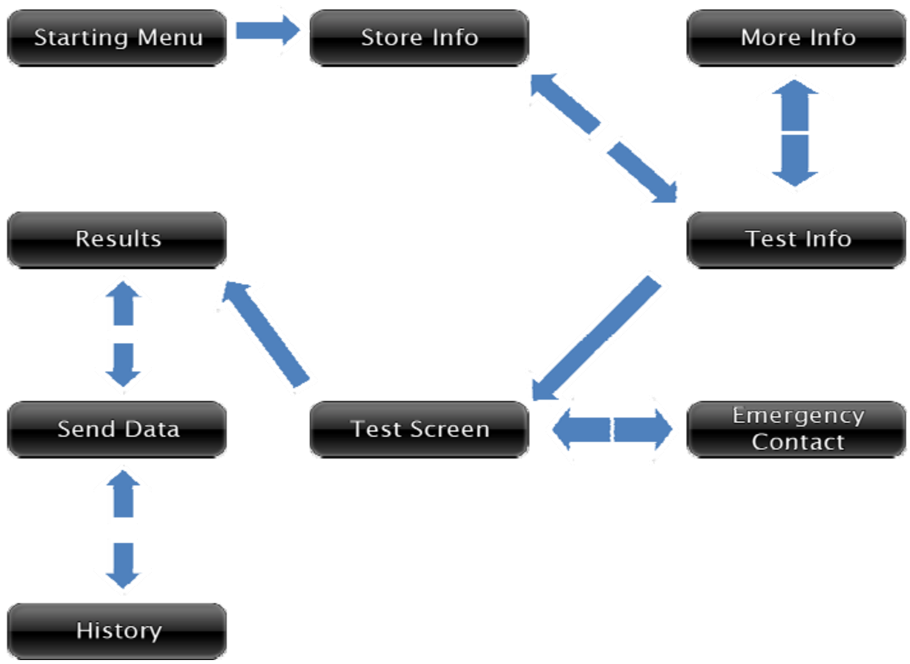

Figure 1: The Wizard Design

As you can see in figure 1, the wizard design also lets the user go back to change any information they may later determine to be incorrect. The "more info" and "emergency contact" options are the only options do not adhere to the linearity principle. In all designs, these two options cannot be part of the standard walk test. The "emergency contact" option should only be executed in the event of an emergency. While the user should already have an understanding of the 6MWT, the "more info" option is accessible for precautionary reasons.

This design received the highest speed rating from all of our sample users. The application of Fitt's and Hick's law also favored this design. Hick's Law is upheld because the number of choices on any given screen is low. Because there were few buttons, we were able to make the buttons larger, allowing a more favorable Fitt's Law value. On the other hand, the questionnaire filled out by the sample users showed little support for this option. User comments indicated this is because they often had to go through too many screens to get to the one they wanted.

4.2 Design 2: Branched

Our second design increases the usability of the user interface. This is accomplished by adding a menu option to the UI. The menu will allow the user more freedom to move around, making options easier, and in some cases faster, to execute. This design has little linearity in its structure. The degree of connectivity is large, and this allows the user to access other options while going through the absolute minimum of intermediate screens.

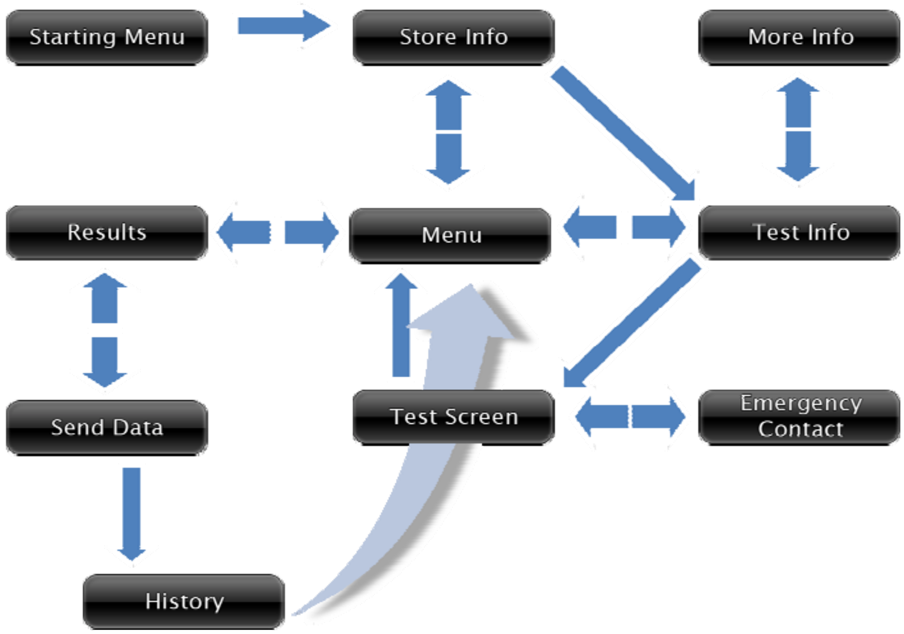

Figure 2: The Branched Design

The user is directed towards the “store info” options only with their initial use of the application. Subsequent uses will initialize directly at the menu screen. Five of the main options will be allowed to send the user back to the menu. The menu will allow the user to access three of the main options. The “more info” and “emergency contact” options have remained the same as in the wizard design. The only screens that must be viewed in sequence are the “test info” and “test screen” options. This is to re-emphasize the preparatory procedures the patient must perform for the test.

This design warranted the lowest score in the speed test among the sample users. This is likely because with so many options at each screen, the user had to take a longer time to decide which button to press to get to the indicated screen. Similarly, this large amount of choices led a lower Hick’s Law value than the wizard. These added options also mean less room to expand buttons, which makes them smaller and more difficult to press. This is represented in a low Fitt’s Law value. The branched design earned a mediocre score from the user questionnaire. User comments indicated that this design seemed similar to user interfaces they were used to, but had too many options to work smoothly.

4.3 Design 3: Hybrid

Our third design is a combination of the first two. The best design is one that would incorporate some of the user freedom of the branched option, while still guiding the user to their most likely desired screen. For the average user, an experience would resemble opening the app, taking the test, viewing results compared to previous attempts, and possibly sending this data to their physician.

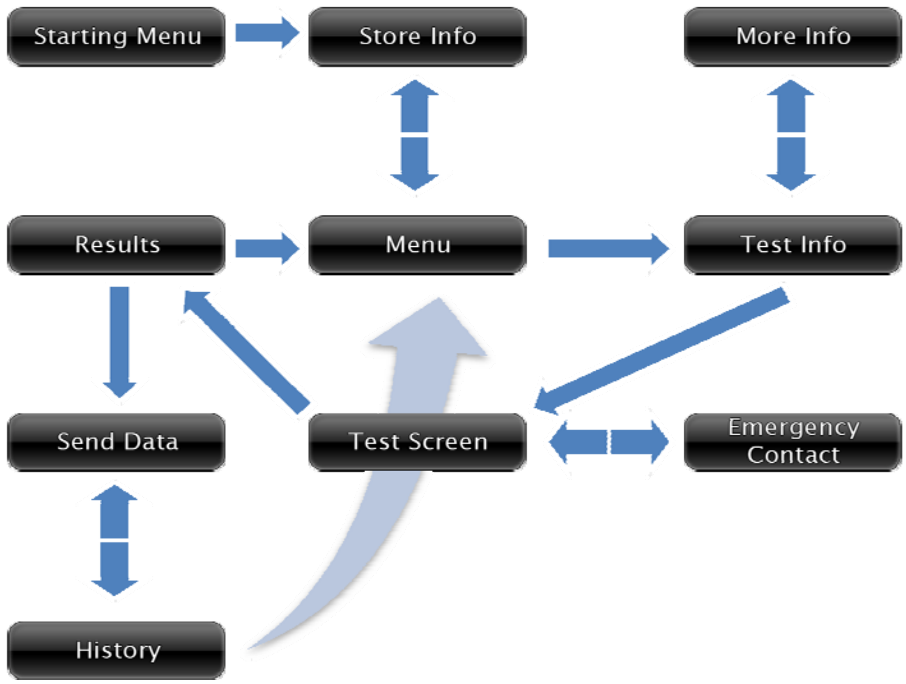

Figure 3: The Hybrid Design

Similarly to the first two designs, the user is asked to store their personal information upon initial use of the application. The menu option from the branched design was kept. This provides a “home base” where the user will be sent upon completion of the most common components of the application. Much of the user choice has been removed. This helps remove clutter from screens that had too many choices. This also helps direct the user to their most likely destination (the test screen).

Removal of user option warranted a much higher speed score than the branched design. The users found their way to the desired screen much more quickly and efficiently. As a consequence, the limited amount of buttons per screen achieved a higher Fitt’s Law values than the branched design. This design was the overwhelming favorite among our sample users. User comments indicated that this is because it is was similar to what they are familiar with, either in other iPhone apps, or other software user interfaces in general.

5.0 Design Matrix

Our design matrix focused on four main categories: Navigation Speed, User Rating, and Ease of Use which incorporates both Fitts' and Hick's Laws.

Table 1: Design Matrix

Category	Wizard	Branched	Hybrid
Navigation Speed (40)	35	15	30
User Rating (40)	16	24	35
Ease of Use (20) - Fitts' Law - Hick's Law	20	13	13
Total (100)	71	52	78

5.1 Interface/Usability Testing

In-order to test our three designs we tested a variety of subjects and had them perform tasks they would need to complete when actually using the application. We had them enter the program and enter their personal information. They then were asked to complete a 6MWT and send that data using the export function. Next, they were asked to look at a specific set of history, and then change their emergency contact information. Each of these five tasks was timed individually as well as the total time it took compete the five tasks. Once they were finished testing each of the three interfaces they were asked to rate each interfaces ease of use on a scale of 1 to 10 and comment on each.

5.1.1 Navigation Speed

Our sample users directly determined the navigation speed categories values by measuring the time each user spent on each page. The test users were given a list of five of the most important aspects of the designs and asked to get to that option in the user interface. The users were then timed for each option. The average of all times for all users was then correlated to a value out of forty and inserted into the matrix.

5.1.2 User Rating

The sample users also determined the user rating category values. After they were done sampling the user interfaces, they were given a questionnaire. The questionnaire asked for a rating (1 – 10) of each user interface and to indicate a reason for the rating you gave. This rating was then adjusted to be out of forty and inserted into the matrix.

5.2 Ease of Use

To calculate the ease of use of each of the three interfaces we used both Fitts' and Hick's Laws. Fitts' Law models the ease of movement and assigns these movements an index of difficulty while Hick's Law quantifies the decision time of a user to choose from a set of buttons on each screen.

Both of these tests resulted in numerical values with the smaller numbers meaning the screen and interface were quicker and less confusing to use. In order to use these values in our design matrix, we needed to make the smaller values worth more. This was done by looking at the numbers relative to each other and then assigning each a value of one to ten.

Fitts' Law assigned the Wizard interface a value of 2.128, the Branched interface a 2.184 and the Hybrid interface a 2.173 (see appendix 10.2). These values resulted in the Wizard getting a 10, the Branched a 5, and the Hybrid a 6 in our design matrix. Hick's Law assigned the Wizard interface a value of 1.416, the Branched interface a 1.618, and the Hybrid a 1.737 (see appendix 10.2). These values resulted in the Wizard getting a 10, Branched an 8, and the Hybrid a 7. These values for the each law were added together and put in the design matrix as the ease of use for each interface.

5.3 Category Weights

Because the first two categories involved user input, they are rated significantly higher than the Hick's and Fitts' Law categories. The "Navigation Speed" and "User Rating" categories were each given a weight of 40%, while the "Ease of Use" category that included values from Hick's and Fitts' Law calculations was given a total weight of 20%. The difference is so drastic because in the end we want to make this program as quick and intuitive as possible for the user. This is much more accurately determined through the use of experimentation than through analytical equations.

6.0 Final Design

The final design incorporates the automation of the ‘wizard’ and the choices of the ‘branched’ desgins. Testing provided substantial feedbacks that lead the team to the final design. The sequence of screens of the final user interface is shown in figure 4 there is also a larger version in appendix 10.7:

Figure 4: Above is final flow design chosen based on results of usability testing. Program is entered from the left-top corner and the yellow highlighted page is the main menu. The blue, green, and purple arrows represent offshoots from the main menu and represent the information storage, testing, and history pages of the application respectively.

6.1 First use and main menu

Upon first opening of the application, the user has the option to watch either an introduction video or continue to the main menu. Once at the main menu the user must enter his/her personal information to in-order to obtain accurate results from the test. After saving his/her personal information, the user will be taken to a menu page with options to take the test, change their information, or view his/her history. Since this is the users first time using the program the history will not yet be populated. This menu (shown in figure 4 as highlighted menu screen) will be the default page upon opening the application after the initial splash screen.

6.2 ‘Information’ button – blue section

The blue button on the menu page allows the user to change and save their personal information at any time. This button takes you to a personal information page that includes name, weight, height, sensitivity of the pedometer, and step distance. This screen is also includes a tab view with multiple tabs which lead to pages which allow users to change his/her doctor information and export his/her data to them. These tabs also allow the user to change his/her emergency contact information and take a small pretest to calculate stride distance. This small test prompts the user to take ten steps and then measure and enter the distance he/she walked. Next, the application then calculates the patient’s stride distance automatically.

6.3 ‘Take Test’ button – green section

Once the user presses the ‘Take Test’ button, they are taken to the important preparation information page and are given the option to see more detailed instructions if needed. Following the ‘Proceed’ button, the user will be prompted to attach their iPhone to their belt and then touch the “Begin Test” button to begin the test. During the test the user will be given audio encouragement at minute intervals and will be warned 15 seconds before the end of the test (see appendix 10.4 for audio). When the test ends, the phone will vibrate and say, “STOP.” When the user is finished with the test, he/she will be taken to a results page and have an option to proceed to the main menu.

6.4 ‘History’ button – purple (data) and red (export) section

Upon pressing the purple “History” button the user will see a chart that will indicate if the users progress has improved or weakened compared with his/her previous tests. This chart also displays the users step count and total distance walked for all of his/her previous tests.

7.0 Testing

(Stride Distance) * (Number of Steps) = Distance Walked

The major measurement calculated by the Six Minute Walk Test is the absolute distance traveled by the user. The most accurate method that the current application utilizes is to calculate this absolute distance traveled by multiplying the products of two individual variables: the stride distance of the user and the number of steps walked by the user in a specific test.

7.1 Stride Distance Calculation

To calculate the stride distance of the user, the program uses a multiplier based on gender and the user’s height that was entered in their personal information section. This multiplier is 0.415 for males and 0.413 for females (Hellie, 2010). We obtained this multiplier online and tested it for accuracy.

The user will also able to generate a more customized and accurate stride distance by taking a quick test available on the personal information section tab of the application. This test will have the user walk ten steps and then measure the distance they walked in inches. The user then inputs their distance walked into the application and it automatically finds the user’s precise stride distance.

To test the multiplier we tested five males and five females. We had each of the individuals walk exactly ten steps and then measured their distance traveled. We then divided this number by ten to acquire their actual stride distance. This number was then compared to the theoretical stride distance attained from the multiplier and the subjects’ height.

From these tests we found that the multiplier we found online was very accurate. In males we found that the average difference in stride distance was .13 +/- .64 inches and -.09 +/- .65 inches in females. This means that even if the user does not take the test available in the personal information section they can still obtain accurate results from the application. The results of the stride distance accuracy testing can be found in appendix section 10.6

7.2 Pedometer

The iPhone's accelerometer measures the acceleration in three directions (x,y,z) and displays these readings as a constant. This constant can be positive or negative depending on the direction that the iPhone is swayed. The iPhone will be secured on the individual through a belt such that only one direction will experience significant changes in its acceleration readings. This direction, x, is measured at a 10 Hz frequency and a step is registered when the accelerometer reading in the x direction surpasses a certain threshold.

To test our pedometer we tested it on four men and three women. Each individual was tested at a range of threshold values. The program was then carefully calibrated until the steps read by the pedometer matched the actual number of steps taken by the user. This threshold value was then correlated to the height-weight ratio of the individual. The results of pedometer testing accuracy can be found in appendix 10.5.

8.0 Future work

Although the design is fully functional at present, there are still some improvements that can be made. The client has suggested several added features that may be useful if work on this project is to continue. The team has also thought up some improvements for the 6 minute walk test iPhone app.

The iPhone currently uses the integrated iPhone accelerometer to conduct its distance measurement. The client has suggested perhaps implementing the integrated GPS function of the iPhone to yield similar data. Preliminary research indicates that the iPhone GPS is accurate enough to conduct the 6 minute walk test. This semester, the team chose to avoid the GPS option because of the simple limitation that it cannot be used indoors. Given the demographic of the 6MWT and the brisk Wisconsin climate, this restriction was simply too limiting to pursue. This feature could be added as an option, however. Data from both the accelerometer and GPS (if outdoors) could be cross referenced to assure greater accuracy.

Another way of calculating step distance is via WiFi networks. The iPhone SDK contains the necessary APIs to interact with a large number of WiFi routers. Inclusive in the interaction is the ability for the iPhone to "ask where it is" relative to the networking router. For this to be used to accurately measure a distance over a time, at least two routers must be present. This limits the use of this option to public, free WiFi areas. This option could potential be used as an additional check to assure 6MWD accuracy.

The client requested that the 6MWT app have the ability to call for help, in case of an emergency during the test (i.e. a fall). The current app does not yet contain the code to do this. Apple's current iPhone development kit does not contain the necessary code to make a phone call while operating an app. However, Apple has promised the necessary code in an upcoming version of the SDK. Once this is released, the 6MWT will have this feature available.

The 6MWT data that a user creates can currently only be read in a table form. In the future, this table should provide selectable options. Specific information about the particular test will be shown, such as date and time, will be given. In addition, a graphical representation of their performance over time should be given somewhere in the history section.

The client also requested a personal health information centralization service, such as Google Health. Connecting the 6MWT app and an online database would vastly improve the response to the user. The user's scores could be compared to the scores of other, like individuals. The user could also view their results in a variety of forms (graphs, tables, etc) from anywhere with internet access, not just their iPhone. Research must be conducted to parse out the best online medical database option. Additionally, the interactions of this website and the iPhone must be studied.

The current iPhone app sends an e-mail to the user's physician upon request. Although helpful, this function currently only delivers the 5 most recent test scores. The HTML coding within the iPhone app will need to be studied more to yield more results that can also be attached in tabular and graphical forms. Additionally, the e-mail function of the app does not notify the user if it is unable to send the e-mail (lack of 3g, WiFi). This warning should be added to reduce user confusion.

Addition of a fatigue voice analysis feature would help the 6MWT evaluate the state of the individual after the test is taken. There is has already been research into what certain breathing patterns indicate after a prolonged period of exercise. Implementation of this research on the iPhone in the 6MWT app would help evaluate the general health of the user. Additionally, the sound file recorded could be sent to the user's physician and uploaded to their health account database for further examination or insertion into official medical records.

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10.0 Appendix

10.1 Select testing evaluation forms

The following sheet is a sample evaluation used during usability/interface testing.

Design Interface Simulation Evaluation
Test Subject: Lindsey Meyer

Enter time at which task was completed

	1 (original)	2 (H/S combo)	3 (wizard)
Save Personal Information		.05	20
Run Test		.50	all in
Send Data		.05	one
See Specific Trial History		.05	
Change Emergency Contact		.10	
Total Time	.30	.41	1:39

Enter 1 (hard) – 10 (easy)

Ease of Use	6.3	8.5	5

no option to remove here

Design Interface Simulation Evaluation
Test Subject: Grace Pitera

need more options after test

not clear that use history to end

Enter time at which task was completed

	1 (original)	2 (H/S combo)	3 (wizard)
Save Personal Information	.04	clear	
Run Test			
Send Data	.04		
See Specific Trial History	.13	.09	
Change Emergency Contact	.03		
Total Time	1.02	.29	.40

Enter 1 (hard) – 10 (easy)

Ease of Use	5.5	7	4

very confusing

back to prep better confusing

Design Interface Simulation Evaluation
Test Subject: Lauren Hallstedt

hated

ok

no control

Enter time at which task was completed

	1 (original)	2 (H/S combo)	3 (wizard)
Save Personal Information			
Run Test			
Send Data			
See Specific Trial History			
Change Emergency Contact			
Total Time	.40	.34	.31

Enter 1 (hard) – 10 (easy)

Ease of Use	4	6	6

10.2 Fitt's and Hick's Law analysis

Below are the full analysis of each of the three designs using Hick's and Fitts' Laws. The averages for each of the designs are highlighted in yellow.

Hick's Law										
Hybrid				Wizard				Options		
Slide #	n	T		Slide #	n	T		Slide #	n	T
2	1	1		3	1	1		3	1	1
3	2	1.584963		4	7	3		4	1	1
4	3	2		5	2	1.584963		5	2	1.584963
5	8	3.169925		6	4	2.321928		6	4	2.321928
6	9	3.321928		7	3	2		7	7	3
8	3	2		8	2	1.584963		8	8	3.169925
9	5	2.584963		9	2	1.584963		9	2	1.584963
10	3	2		10	2	1.584963		10	5	2.584963
14	3	2		11	1	1		11	3	2
15	2	1.584963		12	1	1		12	7	3
16	2	1.584963		13	1	1		13	3	2
17	1	1		14	1	1		14	2	1.584963
18	1	1		15	1	1		15	1	1
19	4	2.321928		16	1	1		16	3	2
20	5	2.584963		17	1	1		17	3	2
21	1	1		18	1	1		18	1	1
22	1	1				1.416361		19	1	1
23	1	1						20	1	1
24	1	1						21	1	1
25	1	1						22	1	1
		1.73693						23	1	1
								24	1	1
								25	1	1
								26	1	1
										1.617988

Fitts Law	From side position					
		d	w	ID		
Hybrid						
2	Let's Walk	4.3	1.4	2.025535		Slide
				2.025535		Average
3	change info	3.9	1.6	1.78136		**2.173405**
	Take test	3.8	1.5	1.82103		
				1.801195		
4	change info	3.9	1.6	1.78136		
	history	3.1	4	0.827819		
	take test	3.8	1.5	1.82103		
				1.476736		
5	save	4.8	1	2.536053		
	bday	2.5	0.9	1.917538		
	weight	2.2	1.1	1.584963		
	height	2	2	1		
	condition	2.1	2	1.035624		
	sex male	3.3	0.5	2.925999		
	sex female	2.4	0.4	2.807355		
	ec	3.3	0.7	2.514573		
				2.040263		
6	menu	5.6	1	2.722466		
	save	4.3	0.9	2.530515		
	bday	2.5	0.9	1.917538		
	weight	2.2	1.1	1.584963		
	height	2	2	1		
	condison	2.1	2	1.035624		
	sex male	3.3	0.5	2.925999		
	sex female	2.4	0.4	2.807355		
	EC	3.3	0.7	2.514573		
				2.115448		
7	menu	5.6	1	2.722466		
	save	4.3	0.9	2.530515		
	bday	2.5	0.9	1.917538		
	weight	2.2	1.1	1.584963		
	height	2	2	1		
	condison	2.1	2	1.035624		
	sex male	3.3	0.5	2.925999		
	sex female	2.4	0.4	2.807355		
	EC	3.3	0.7	2.514573		
				2.115448		
8	Individual	3.5	1.2	1.969626		
	Send	3.9	1	2.292782		
	Menue	3.5	1.1	2.06413		
				2.108846		
9	trial 1	3.4	1.7	1.584963		
	trial 2	3.2	2	1.378512		
	trial 3	3	4	0.807355		
	menu	5.4	1.2	2.459432		
	History	4	0.9	2.444785		
				1.735009		
10	dot 1	8	0.5	4.087463		
	dot 2	7.2	0.5	3.944858		
	dot 3	4.3	0.5	3.263034		
				3.765119		
11	dot 1	8	0.5	4.087463		
	dot 2	7.2	0.5	3.944858		
	dot 3	4.3	0.5	3.263034		
				3.765119		
12	dot 1	8	0.5	4.087463		
	dot 2	7.2	0.5	3.944858		
	dot 3	4.3	0.5	3.263034		
				3.765119		
13	dot 1	8	0.5	4.087463		
	dot 2	7.2	0.5	3.944858		
	dot 3	4.3	0.5	3.263034		
				3.765119		
14	More info	4.2	1.1	2.268489		
	menu	5.6	1.2	2.5025		
	start	4	1	2.321928		
				2.364306		
15	back	4.8	1.1	2.423211		
	begin	2.5	5	0.584963		
				1.504087		
16	Restart	2.7	2.7	1		
	Call EC	2.1	2.5	0.879706		
				0.939853		
17	Done Recording	4.6	1	2.485427		
				2.485427		
18	menu	4.8	1.1	2.423211		
				2.423211		
19	edit	3.8	0.9	2.384664		
	send	4.2	1	2.378512		
	menu	5.7	1.1	2.628031		
	history	3.9	0.9	2.415037		
				2.451561		
20	back	4.8	1.1	2.423211		
				2.423211		
21	menu	4.8	1.1	2.423211		
				2.423211		
22	back	4.8	1.1	2.423211		
				2.423211		
23	back	4.8	1.1	2.423211		
				2.423211		
24	back	4.8	1.1	2.423211		
				2.423211		

		d	w	ID		
Branched						
3	Let's Walk	4.3	1.4	2.025535		Slide
				2.025535		Average
4	Store Info	4.1	1.5	1.900464		**2.183802**
				1.900464		
5	Change Info	4.1	1.5	1.900464		
	Take Test	4.4	1.3	2.13245		
				2.016457		
6	Change info	4.1	1.5	1.900464		
	History	3.1	2.9	1.04891		
	Send	3.4	2.8	1.146841		
	Take Test	4.4	1.3	2.13245		
				1.557166		
7	Birthdate	2.5	0.9	1.917538		
	weight	2.2	1.1	1.584963		
	height	2	2	1		
	condition	2.1	2	1.035624		
	Stride	2.5	1.2	1.624491		
	Econtact	3.3	0.7	2.514573		
	Save	4.8	1.1	2.423211		
				1.728629		
8	Birthdate	2.5	0.9	1.917538		
	weight	2.2	1.1	1.584963		
	height	2	2	1		
	condition	2.1	2	1.035624		
	Stride	2.5	1.2	1.624491		
	Econtact	3.3	0.7	2.514573		
	Save	4.2	0.9	2.5025		
	menu	5.9	1.1	2.669851		
				1.856193		
9	Individual Trials	3.5	1.2	1.969626		
	menu	4.8	1.1	2.423211		
				2.196419		
10	trial 1	3.4	1.7	1.584963		
	trial 2	3.2	2	1.378512		
	trial 3	3	4	0.807355		
	menu	5.4	1.2	2.459432		
	back	4	0.9	2.444785		
				1.735009		
11	dot 1	8	0.5	4.087463		
	dot 2	7.2	0.5	3.944858		
	dot 3	4.3	0.5	3.263034		
				3.765119		
12	menu	5.6	1.2	2.5025		
	start	4	1	2.321928		
	i1	2.6	0.8	2.087463		
	i2	1.4	0.8	1.459432		
	i3	0.4	0.8	0.584963		
	i4	1.7	0.8	1.643856		
	i5	2.5	0.8	2.044394		
				1.806362		
13	menu	5.7	1.1	2.628031		
	back	3.9	0.9	2.415037		
	start	2.5	5	0.584963		
				1.87601		
14	restart	2.7	2.7	1		
	call contact	2.1	2.5	0.879706		
				0.939853		
15	done record	4.6	1	2.485427		
				2.485427		
16	send	4	1.3	2.027481		
	menu	5.7	1.1	2.628031		
	history	3.9	0.9	2.415037		
				2.35685		
17	send	4	1.3	2.027481		
	menu	5.7	1.1	2.628031		
	history	3.9	0.9	2.415037		
				2.35685		
18	menu	4.8	1.1	2.423211		
				2.423211		
19	back	4.8	1.1	2.423211		
				2.423211		
20	back	4.8	1.1	2.423211		
				2.423211		
21	back	4.8	1.1	2.423211		
				2.423211		
22	back	4.8	1.1	2.423211		
				2.423211		
23	back	4.8	1.1	2.423211		
				2.423211		
24	back	4.8	1.1	2.423211		
				2.423211		
25	back	4.8	1.1	2.423211		
				2.423211		
26	back	4.8	1.1	2.423211		
				2.423211		

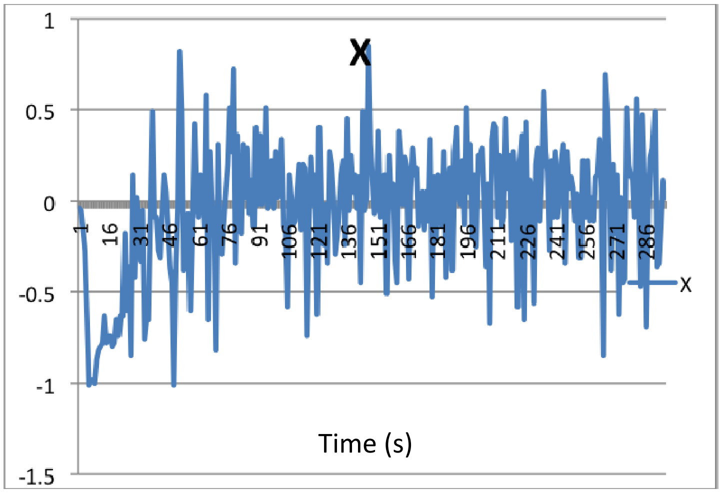
		d	w	ID		
Wizard						
3	Let's Walk	4.3	1.4	2.025535		Slide
				2.025535		Average
4	Save	4.1	1.5	1.900464		**2.127739**
				1.900464		
5	Individual Trial	3.7	1.3	1.943416		
	Send	4.6	0.9	2.611435		
				2.277426		
6	trail 1	3.4	1.7	1.584963		
	trial 2	3.2	2	1.378512		
	trial 3	3	4	0.807355		
	back	4.8	1.1	2.423211		
				1.54851		
7	dot 1	8	0.5	4.087463		
	dot 2	7.2	0.5	3.944858		
	dot 3	4.3	0.5	3.263034		
				3.765119		
8	More info	4.4	1	2.432959		
	Start	4.8	1.1	2.423211		
				2.428085		
9	back	4.8	1.1	2.423211		
	begin	2.5	5	0.584963		
				1.504087		
10	restart	2.7	2.7	1		
	call ec	2.1	2.5	0.879706		
				0.939853		
11	done recording	3	4.5	0.736966		
				0.736966		
12	history	4.8	1.1	2.423211		
				2.423211		
13	send	4.2	1	2.378512		
				2.378512		
14	exit	4.8	1.1	2.423211		
				2.423211		
15	back	4.8	1.1	2.423211		
				2.423211		
16	back	4.8	1.1	2.423211		
				2.423211		
17	back	4.8	1.1	2.423211		
				2.423211		
18	back	4.8	1.1	2.423211		
				2.423211		

10.3 Initial Accelerometer Data

The iPhone's accelerometer measures the acceleration in three directions (x, y, and z) and displays these readings as a constant. The following data test these readings in each of the three directions with a quick walk test to pick up acceleration values for a step.

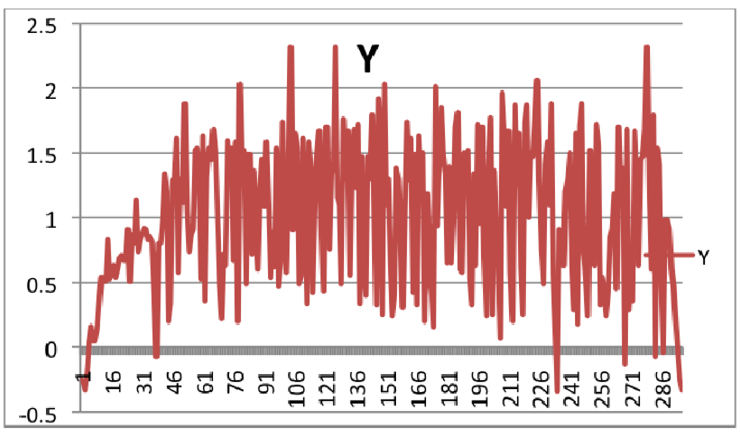
Threshold

Value (#)



Threshold

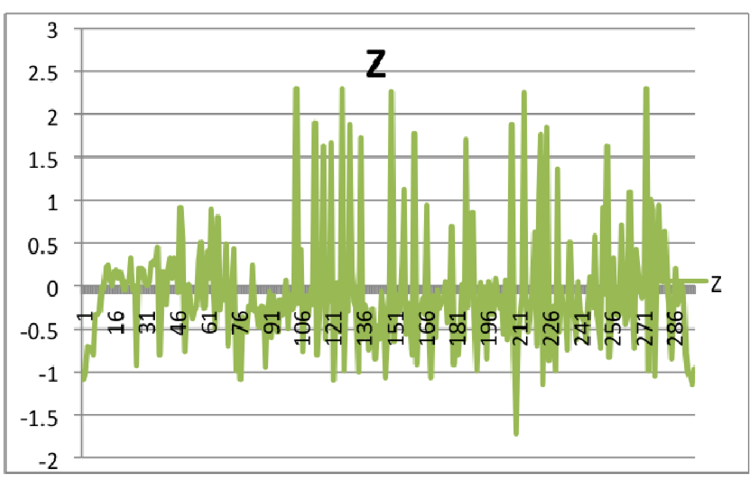
Value (#)



Time (s)

Threshold

Value (#)



Time (s)

10.4 Audio Recordings

These are the ATS guide line audio encouragements that are spoken to the patient at specific intervals throughout the test.

1 minute – “You are doing well. You have 5 minutes to go.”

2 minutes – “Keep up the good work. You have 4 minutes to go.”

3 minutes – “You are doing well. You are halfway done.”

4 minutes – “Keep up the good work. You have only 2 minutes left.”

5 minutes – “You are doing well. You only have 1 minute left.”

5:45 minutes – “In a moment I’m going to tell you to stop. When I do, just stop right there and I will ask you a question. Press the finish recording button when you have fully answered.

10.5 Step Count Testing

10.5.1 Hard Data

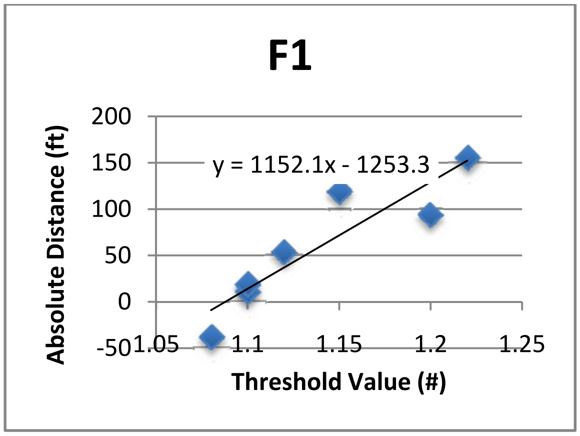
Data from step count accuracy testing taken from four males and three females.

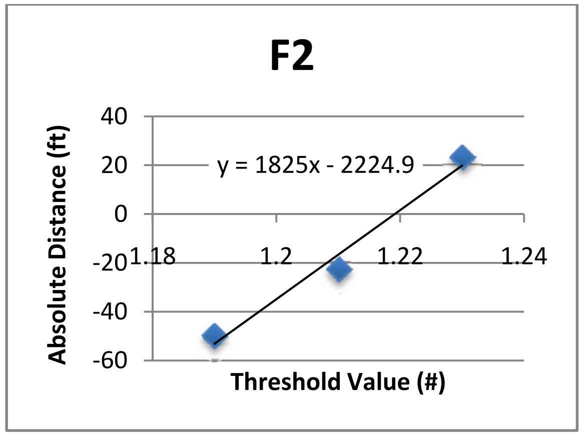
	Pedo	Thresh	Difference	Abs. Difference	% Difference	iPhone
Male 1	355	1.15	-95	95	26.76%	450
	329	1.17	-45	45	13.68%	374
	360	1.17	-59	59	16.39%	419
	350	1.19	-79	79	22.57%	429
	334	1.2	-16	16	4.79%	350
	325	1.2	-30	30	9.23%	355
	329	1.2	-49	49	14.89%	378
	354	1.2	-40	40	11.30%	394
	373	1.22	-17	17	4.56%	390
	373	1.22	-12	12	3.22%	385
	315	1.24	50	50	15.87%	265
Female 1	355	1.08	-39	39	10.99%	394
	334	1.1	10	10	2.99%	324
	335	1.1	18	18	5.37%	317
	360	1.12	53	53	14.72%	307
	375	1.15	119	119	31.73%	256
	365	1.2	93	93	25.48%	272
	359	1.22	155	155	43.18%	204

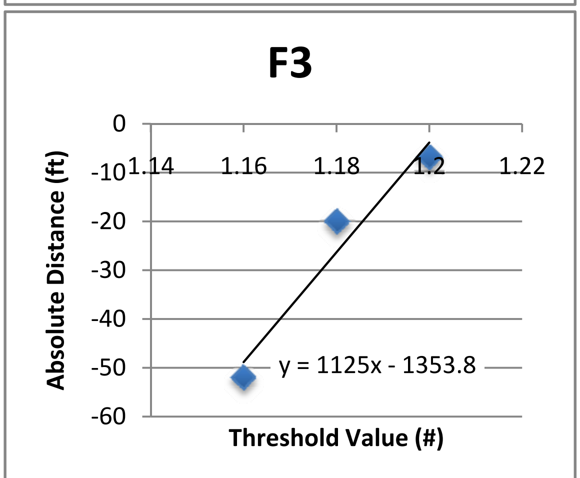
Male 2	336	1.1	-30	30	8.93%	366
	341	1.12	2	2	0.59%	339
	364	1.22	95	95	26.10%	269
	357	1.12	-37	37	10.36%	394
	354	1.12	-47	47	13.28%	401
Male 3	400	1.12	-192	192	48.00%	592
	400	1.16	-86	86	21.50%	486
	400	1.18	-17	17	4.25%	417
	400	1.19	18	18	4.50%	382
Female 2	400	1.19	-50	50	12.50%	450
	400	1.21	-23	23	5.75%	423
	400	1.23	23	23	5.75%	377
Male 4	420	1.2	1	1	0.24%	419
	400	1.22	46	46	11.50%	354
	400	1.18	22	22	5.50%	378
	400	1.16	-6	6	1.50%	406
Female 3	400	1.16	-52	52	13.00%	452
	300	1.18	-20	20	6.67%	320
	300	1.2	-7	7	2.33%	307
	300	1.21	-52	52	17.33%	352

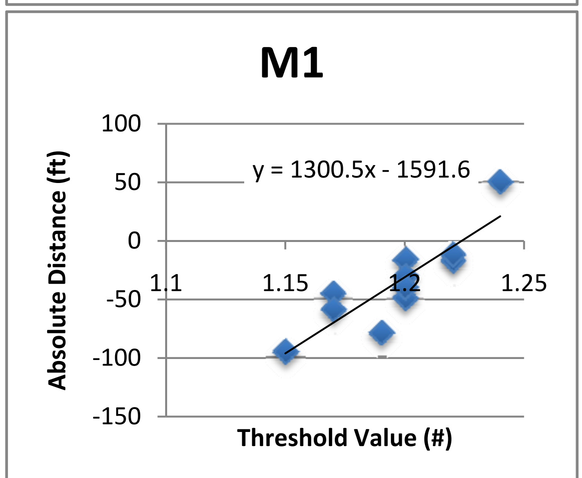
10.5.2 Individual Threshold Charts

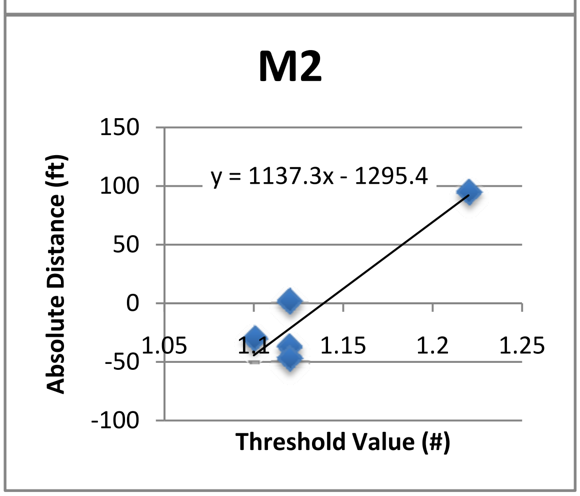
A chart was created for each testing subject to see how the threshold values compare to the absolute number of steps difference between the actual and iPhone reading. A linear correlation can be found between the number of steps and the threshold values for each individual. We used this information to determine the most exact threshold values.

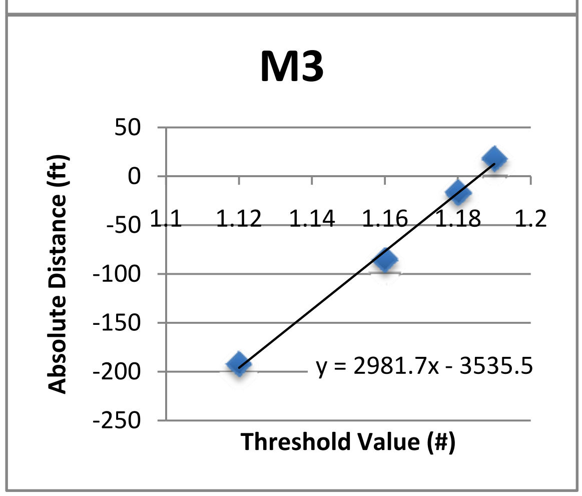


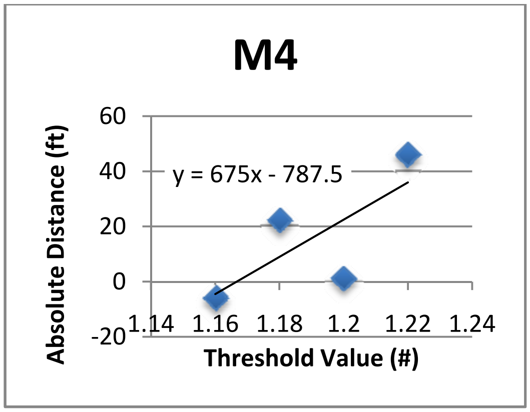












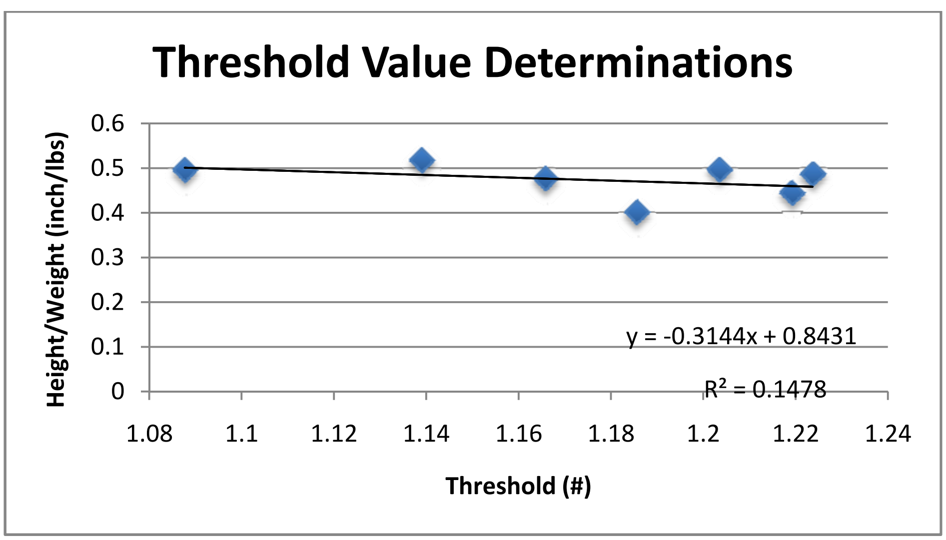
10.5.3 Threshold, Height, Weight Hard Data

The following is a table that tracks the heights and weights or each test subject along with their unique threshold value calculation.

	Height	Weight	Thresh
Female 1	62	125	1.08767
Male 1	68	140	1.22367
Male 2	70	135	1.1389
Female 2	70	158	1.21918
Male 3	72	180	1.18545
Male 4	70	147	1.16593
Female 3	67	135	1.20356

10.5.4 Threshold vs (Height/Weight) Chart

The measured threshold value for each test subject is plotted against the height-weight ratio of the individual.



10.6.0 Stride Distance Testing

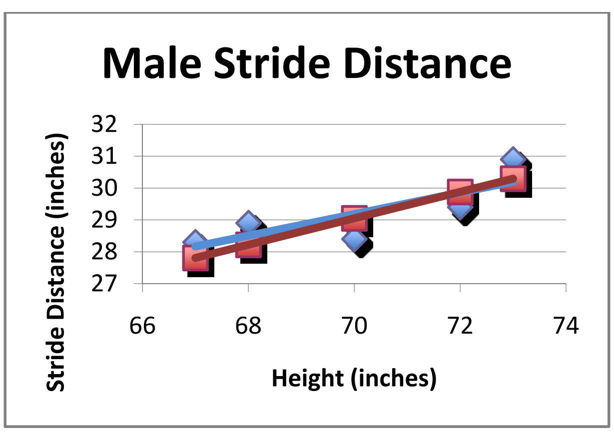
10.6.1 Hard Data

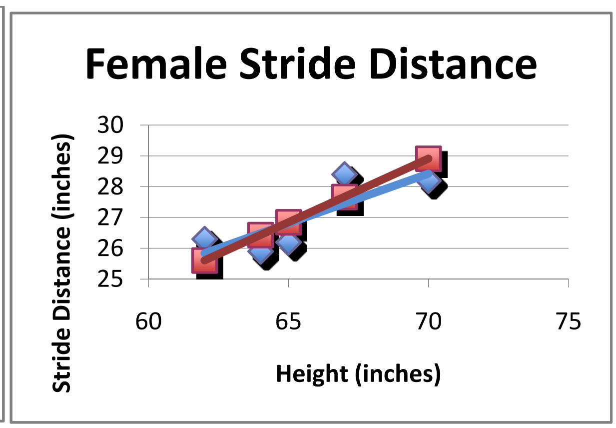
The following is the hard data collected form stride distance testing of five males and five females.

Height (in)	**Clinically found height multiplier**	**Calculated Stride (in)**	**Difference**
67	0.415	27.805	0.495
68	0.415	28.22	0.68
70	0.415	29.05	-0.65
72	0.415	29.88	-0.48
73	0.415	30.295	0.605
		Total	0.65
		Total Difference	0.13
62	0.413	25.606	0.694
64	0.413	26.432	-0.532
65	0.413	26.845	-0.645
67	0.413	27.671	0.729
70	0.413	28.91	-0.71
		Total	-0.464
		Total Difference	-0.0928

10.6.2 Charts

The following charts show the relationship between out stride distance coefficients for both male and females compared to actual stride distance.





10.7 Larger View on Final Design – Screen Flow

This diagram is the final flow design chosen based on results of usability testing. Program is entered from the left-top corner and the yellow highlighted page is the main menu. The blue, green, and purple arrows represent offshoots from the main menu and represent the information storage, testing, and history pages of the application respectively.

11.0 PDS

Walk Test Product Design Specifications

May 5th, 2010

John Renfrew, Kenneth O. Xu, Sarah Sandock, Wan-Ting Kou, Josh Kolz

Problem Statement:

There is a clinically-approved cardiopulmonary health test called the 6-minute-walk-test (6WMT) that accurately gauges cardiopulmonary health through a simple technician-guided walk procedure. Our objective is to create a similar test using an iPhone application that will generate 6MWT data at the comfort of the patient's home or any other setting of the patient's choice. This data will be useful in assessing patient improvement by testing the patient before and after medical intervention.

Client requirements:

- Must work on iPhone.
- Ability to store and organize test and clearly display data
- Consider an internet based application alternative.
- Look into expansion of audience to healthy individuals for early diagnosis of mild Chronic Obstructive Pulmonary Disease (COPD).
- Consider performing statistical tests showing that the application gets reliable data through supplementary GPS comparisons.
- Integrate audio encouragements and verbal instructions to assist in 6MWT.
- Show it is as accurate as the current 6MWT by testing.

Design requirements:

1. Physical and Operational Characteristics

a. *Performance requirements*: Device must be energy efficient. It should be able to upload to central database for interpersonal comparison and analysis from third party. Compare current 6MWT data and compare with previous attempts and/or general population data.

b. *Safety*: Must not cause detrimental visual effects and deter from distract patient while he/she is performing test. Possible addition safety button in case of medical emergency during 6MWT.

c. *Accuracy and Reliability*: Must be able to track distance walked to around +-5% of total walk distance. Must be able to match or exceed performance of clinical 6MWT; must account for varying courses shapes, conditions, and distances.

d. *Life in Service*: N/A

e. *Shelf Life*: N/A

f. *Operating Environment*: In home use or outside

g. *Ergonomics*: Acquire good Fitts' Law and Hick's Law values

h. *Size*: Under 50 megabytes

i. *Weight*: N/A

j. *Materials*: iPhone, iTouch, iPhone Standard Developer Kit (SDK)

k. *Aesthetics*, *Appearance, and Finish*: Large, clear buttons, clean interface, easy to understand voice instructions

2. Production Characteristics

a. *Quantity*: Available for download when finished

b. *Target Product Cost*: To be determined

3. Miscellaneous

a. *Standards and Specifications*: N/A

b. *Customer*: Patients with COPD and others looking for a health test.

c. *Patient-related concerns*: Ability to call for help easily through the program

d. *Competition*: Clinic-run 6MWT, Mechanical Pedometers, iPhone pedometers