Glaucoma Medicine Reminder

Midsemester Report

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Abstract

Glaucoma treatment involves taking various types of eye drops at different times during the day. This kind of disease management requires following strict regiment that numerous patients do not adhere to. In a study done by Stewart *et al.* it was found that 34% of patients admit to non-compliance. This study also revealed that 94% of physicians believe that non-compliance may lead to loss of vision (1). Furthermore, 38% of patients stated that memory is the reason for non-compliance. This is not surprising since the average age of onset of the disease is in the patients in their late sixties. Since non-compliance is one of the most important causes of aggravating glaucoma, it is critical to find a way to successfully remind patients of when their next medication is due to be taken (2). This would greatly improve their chances of stabilizing and retaining their sight. For this reason, our most important goal is to develop a device that will allow patients to successfully take their medications. This would permit them to lead normal lives without either severely impaired vision or being homebound in order to remember to take their medications.

Background

Glaucoma is the leading cause of blindness in the United States. Often called the "silent killer," this disease shows few obvious symptoms until the patient's vision is already compromised. Glaucoma comes in two different forms, open angle glaucoma and acute closure glaucoma. Loss of vision due to intraocular pressure build up in the eye is common in both. In open angle glaucoma, gradual build up of pressure in the eye causes damage to the optic nerve, and can result in blindness in a few years if left untreated. Peripheral vision is usually the first to deteriorate and patients often develop tunnel vision in the advanced stages of the disease. Acute closure glaucoma occurs suddenly due to a rapid rise in ocular pressure. This condition requires immediate medical attention or blindness can occur within a few hours.

The main cause of increasing intraocular pressure in the eye can be traced back to the eye's drainage system. In order to keep pressure constant in the eye, the body constantly regulates a fluid called aqueous humor. Its purpose is to flow in an out of the eye cavity, providing nourishment and keeping the eye free of debris (see Appendix A, Figure 1). In a healthy eye, the body produces aqueous humor at the same rate at which it is drained out of the eye cavity, keeping a constant pressure. In open angle glaucoma, the drainage channel remains open but aqueous humor drains too slowly, resulting in a build up of pressure in the eye. This type of glaucoma occurs in approximately 2 percent of adults over the age of 40 and approximately 8 percent in adults over 70.

The main goal of treatment is to reduce pressure in the eye and to control the flow of aqueous humor. This can be accomplished in many ways including surgery, laser treatment, systemic medications, but most often through eye drops. Because the treatment often consists of several medications per day and the patients are often elderly, non compliance is a major issue for physicians. Also, in terms of our medication reminder device, it is important to realize that patients may have other medical conditions that limit movement or mental capacity. These additional problems must be taken in to consideration. Glaucoma is a condition that affects millions of people in the United States, and although it cannot be cured, early detection and proper treatment can go a long way in retaining a patient's vision.

Specifications

Most importantly, the device needs to remind patients which medication needs to be taken and when. The device must be programmable for up to six different medications in order to ensure that it will provide service to the patients with the most severe cases. In order to minimize confusion as to which medication is to be taken with each alarm, the device should have six different colored stickers that correspond to the same colored stickers on eye-drop bottles. Since these patients may be severely visually impaired, the stickers must be large and corresponding with colors that are easy for the patient to distinguish. Also, the device must have a sound and/or buzzing option along with a flashing light reminder to indicate that the medication should be taken. The alarm should last for about 1 minute. It should have no offensive sounds and be equipped with a volume control button. Volume control must not be changed easily, however, in order to prevent from accidental muting. There also needs to be a large enough reset button that would turn the alarm off once the patient takes the medication.

Next, the device needs to have a digital clock reading the current time to allow for programming. Numbers on the clock must be big, bold and black since the patient may have difficulties reading letters that are too small or colored. Along with the main clock, it may also have additional count-down timers for each medication. These timers would let the patient know how long until the next medication is to be taken, but in order to keep with a reasonable size of the device, the timers may be too small for the patient to see. The device needs to be portable. The ideal size, given by the patient, is 5½” x 2¾” x ½ - ¼”. Even though the majority of glaucoma patients are older than 45 years, the disease may occur at any point in life (2). With this in mind, the device needs to be durable and sturdy enough to accommodate the lifestyles of children, teenagers, and adults. To contribute to this, there should be a plastic, lightweight, durable, washable plastic case that would protect it from bumping and breaking in various situations.

Additionally, in order to prevent patient from tampering with the device and turning it off, the device must be programmable and lockable by the physician. The patient must not be able to change the schedule of the medications. The device needs to be battery operated. Ideally it would be run by a lithium, rechargeable battery allowing the device to remain on at all times. This is important in case that while changing the battery, the memory of the device becomes erased. Also, being powered by a lithium battery would permit physicians to schedule medications for any time of the day, accommodating to the patient, since it would remain on at all times. An alternative to the lithium battery is AA powered device. This would not be as convenient since even if the AA batteries are rechargeable they must be removed from the device in order to recharge risking losing all of the information saved. To ensure that the patient knows when to replace/recharge the battery, there must be a low battery light on the device.
Furthermore, the device must not be easily turned OFF. This would prevent the patient from turning it off if they become irritated by amount and frequency that the medications need to be taken.

Lastly, the device should be accompanied by an easel that allows it to stand while at home. This easel should be able to recess for travel.

Previous Work

Because it is so common for patients to forget their medications, several pharmaceutical companies have created and marketed devices or services to help remind them. Some of devices come in the form of pagers or wrist watches, some also include automatic pill dispenser, there are even telephone services that will call households when its time for a medication.

A common pager-sized device called the "12 Alarm Pager" (Displayed in Appendix A, Figure 2) is marketed by e-pill Medication Reminders and Time Now, Inc. Its key features include support for twelve alarms, vibrating alert, and small size, all for an average price of around $30. This device has bright, easy to press buttons, however the display is dim and the letters are small. These are important characteristics and prevent the "12 Alarm Pager" from being an adequate solution to the client's problem.

Timex and several other companies have created reminders in the form of a wrist watch. The major draw to these is their inherent portability. They typically have bright displays and sounding alarms, some are even marketed specifically for children. They range in price from $30 for single reminders to upwards of $100 for more advanced styles. Most lack a vibrating alert, however, and all have small, hard to press buttons.

B. Independent, Inc. markets several variations of automatic pill dispensing medication reminders (see Appendix, figure 3). The dispensers can be programmed for 31 days in the month or 24 hours in the day. However, they too have small, illegible buttons for the elderly eyes. They also run fairly expensive, ranging between $150 and $250.

Rx Notify and Prescription Reminder are two leaders a group of companies who provide a telephone reminder service. Customers can receive calls or text messages to either their home or mobile phone. These companies also abide by HIPAA standards. Some companies charge per call or some use a subscription. The downside to this method is that the patient requires a mobile phone in order to be reminded when away from home and the overall cost is usually more than for the aforementioned methods.

Each device or method in its own has desirable features, but none fit all of the essential requirements of the client. It is, therefore, necessary to make modifications to existing devices or create an entirely new one.

Design Ideas

LCD system

The first design idea attempts to integrate a wide variety of visual capabilities with an easily programmable and operable user interface. It involves an LCD touch screen and windows based software.

Several LCD screens have been considered. The he first screen investigated is a 6” analog TFT, which supports 262K colors at a resolution of 640x480. The upside to this screen is that it provides plenty of room for large, colorful buttons for the patient to read and press. The display is also visible in the sunlight. Unfortunately, it requires direct connection to the PC in order to be programmed and is ultimately too large to be a viable part of the design. It also exceeds the price range set by the client, costing $900 for only the screen and graphics controller.

The next screen is a much smaller touch LCD. This 2.7" unit has a wide variety of functions, including a resolution of 240x160 and 64Kb flash ROM to support TTF fonts and bitmap images. It is fully compatible with USB 1.1 and Serial ports, and can be programmed remotely. The screen's form is much more compatible for a hand held device; however, the screen itself lacks a protective coating, and is designed to be powered by a stationary source. Also, a separate controller is necessary, raising the total cost of the screen and controller to $250.

The final screen investigated has been selected for the first prototype and can be seen in Figure 4 in Appendix A. It is very similar to the previously mentioned 2.7" screen, with a resolution of 240 by 160, 256 colors for a wide variety of unique button options, and USB 2.0 (faster than the previous) and serial ports for remote programming and data transfer. Its square form is even more compliant with a handheld design. The feature that sets this screen apart from the others is it's built in battery compatibility. The batter pack is an additional cost, but eliminates the need for a bulky power source adaptation that is required for the first two screens. A controller and all drivers are provided. Even with a protected coating on the screen, a case of some sort will be required for protection.

Once the system is constructed the software needs to be programmed. Because the system is windows based, there are many options for languages. Java is the language most familiar to the design group, however, so it will used. There is a wide variety of programming tools, but because UW has licenses to many, the software will not be factored into the total cost.

Once the components were chosen the prices were analyzed. The best option came from EarthLCD.com. The required components are the LCD kit, which includes the 2.7” screen and the graphics the USB drivers, the evolution board to integrate the display and controller, the batter attachment, and a case. Table 1 in Appendix B contains a full price list.

Upon viewing this price list, an overall disadvantage comes to mind. The cost of this system is rather high compared to the technology that is already available. Also, this design requires a fair amount of manufacturing on the group’s part, and will there for have an increased risk of malfunctioning. These factors will be taken into account when deciding the final idea to produce.

PDA System

The second design consists of modifying a Personal Digital Assistant (PDA) by writing a computer program that meets the client’s needs. This design is similar in nature to the LCD system but will utilize a PDA as a base system for programming.

One advantage of this system is that it would be very easy to mass distribute because it would only require a PDA and the suitable program. From a potential marketing perspective this is a large advantage over a product that requires a considerable amount of manufacturing. Another advantage is that it is easy to program a locking mechanism. This prevents the patient from changing the medication regimen directly because physician is the only one able to unlock it. Also, compared to the LCD, the system is relatively cost effective. This is especially true in terms of mass distribution because the programming software is only a one-time purchase. The PDA would also be the smallest design idea, enabling the patients to carry it from place to place in a purse or a pocket.

On the other hand, a major shortcoming of this design is that it would be more difficult to program than the LCD because it is Palm based. Because most PDAs are non windows based systems, the programming difficultly automatically increases and the cost of the programming software can increase as well. Along with the increased cost of programming comes the high cost of the PDA itself, depending on the purchased model. Some patients can barely afford the medications themselves so cost is definitely a factor. A major hurdle that would have to be overcome to implement this design is the short battery life of a PDA. The average battery life of a PDA is around 4 hours. To account for this shortcoming, we must either write a program that extends this time to an entire day, or create a program that only turns the PDA on when an alarm is going off. Unless this is accomplished, the PDA design will not work.

The total cost of this design is estimated to be between $100-$550 (see cause analysis in Appendix B, Table 2), depending on the model of the PDA chosen and the programming software needed. Another important consideration is the interaction that the user will have with the devise. Since most of the patients are elderly, some of them might not be familiar with using a PDA. This could create frustration and potentially lead to non compliance. Also, patients that have other health problems might not be able to control the pen of the PDA well enough to interact with the user interface provided.

Modified Egg Timer

The third, and final design, is named the “modified egg timer”. This design is much more mechanical than the LCD or the PDA and is one of the most basic solutions available for this particular project. The modified egg timer is equipped with six different countdown timers, sets of stop and go lights, and colored lights coordinated with the each medication. It also has a main screen that reads the current time and the battery level. Each screen will be an LCD screen with bold, black numbers against a grey background to allow for easy legibility in sight-impaired patients. Ideally, this device will also have an audio and vibration alert system, volume control, and a USB interface to allow for scheduling (see appendix, Figure)

The idea behind this design is that the patient’s doctor will use the device’s USB port and scheduling program to import the scheduling for up to six different types of medication. The device will then be set for the following weeks/months to go off at the time the patient is supposed to be taking their different medications. When the timer goes off the device will give an audio, visual and vibration alert and the patient will simply hit the “stop” button to turn off the alarm. The patient will then match the illuminated colored light with its corresponding medication, take their medication, and continue with their everyday activities. Upon hitting the “stop” button, the device will reset itself to go off at the next time that particular medication is to be administered.

The major advantages of this design include its cost, alert system, and “locking” mechanism. The modified egg timer is by far the most cost effective of the three designs, it involves the simplest technology and as a result, all of its parts are relatively cheap (cost is further evaluated in the following paragraphs). In addition, this device is equipped with an audio, visual and vibration alert. These three alternatives allow for even very sight-impaired patients to be notified when the device is going off and reduces the chance that a patient will miss a dosage. Lastly, the USB port and doctor scheduling system prevent patient tampering by completely eliminating patient access to the scheduling system. This allows for a very simple “set it and forget it” design.

In addition to the various advantages of the modified egg timer our team also chose to pursue this design because we felt it fit the closest with out client’s needs. Due to the fact that most glaucoma patients are fairly elderly, we felt a simple design made the most sense. A simple design encourages patient compliance by allowing for easy access to the device’s features and allows for use by patients from a spectrum of technological intelligence levels. The modified egg timer is also equipped with bold, black letters and numbers and only colors that are visible by sight-impaired patients common to glaucoma. Lastly, the glaucoma patient we are working with initially favored this design over the other two, indicating that it may also be the most user-friendly.

Despite its many advantages, this device also has a number of disadvantages, including limited capabilities, the requirement of an outside casing system, a high degree of manufacturing and heightened risk of malfunction. Because this device is much simpler than the LCD or the PDA, it is not equipped with any of the “extra” features that the other two devices have. This device still has all of the capabilities it needs to perform the desired functions, they are just more basic. In addition, this device requires an outside casing system to prevent accidental malfunction due to everyday bumping while patients are carrying it around. On the manufacturing level, this device requires the most physical labor on the part of the team members. All of the parts will have to be bought separately and put together by hand. As a result of this high degree of manufacturing on the group's part, this device also has a higher degree of malfunction.

The modified egg timer is the most cost effective of the three designs. All of the parts have to be bought separately and put together by hand thus, reducing costs at the expense of our labor. Most of the modified egg timer's parts; the LED screens with bold black numbers and letters, colored LED lights, plastic casing, speakers and control knobs are under $20.00 per part. The only parts of this design that are slightly costly are the timers and programming circuit which are still only around $50. Altogether, this design will probably cost $85-100 (see Appendix B, Table 3)

Design Matrix

After narrowing the ideas to three main designs, the LCD system, modified PDA and modified egg timer, a design matrix was used to determine which design to pursue. Each idea was evaluated based on ease of unit interface, size, cost, ease of implementation, ease of use, durability, production time, and client requirements. An emphasis was placed on cost, ease of use and client requirements by ranking each of these categories on a scale from 1-10 while (10 being best, 1 being worst) while ranking all of the others on a scale from 1-5 (5 being best, 1 being worst). Table 4 in Appendix B shows the scores each design received in each category. Each score was tallied and, although all were close, the "modified egg timer design" fit the client's design requirements the closest.

Final Design

The Modified Egg Timer has the highest score based on the design matrix (Appendix B, Table 4). It appears to be the best fit to all of the clients design requirements. The most important part of this design is that it is the cheapest of the three ideas. A price of between $90 and $100 was estimated, but with more price analysis, that number may be lowered significantly. However, it will require the most labor, and probably the most time to create. The PDA system may turn out to be more expensive, but may be easier for the team to produce. Because of these two heavily determining fact, the team still needs to have discourse with the client to produce a final decision.

Potential Problems and Future Work

Although he team is confident in its choice to pursue the modified egg timer, there will likely be several obstacles during its fabrication. First, there is a large number of parts that are required for this particular design. As a result, there is a slightly higher risk that those parts may not fit or work together properly when put together. It is likely that the casing will be made by hand, thus presenting a tedious, time-consuming task that may pose problems in terms of getting it the right shape. Another main challenge faced in terms of manufacturing is creating a way for the device to automatically reset. This will probably be the main obstacle, as no one in the group is sure how exactly to implement this kind of mechanism. Furthermore, it may be difficult to get the device to work with a computer for a doctor to schedule in the patients' medication times.

Because types of programming problems may prove difficult, the team needs to search out the help of more experienced professionals. Once that help is found, the team needs to design the circuit and order the components. After that, construction will commence.

Appendix A (Figures)

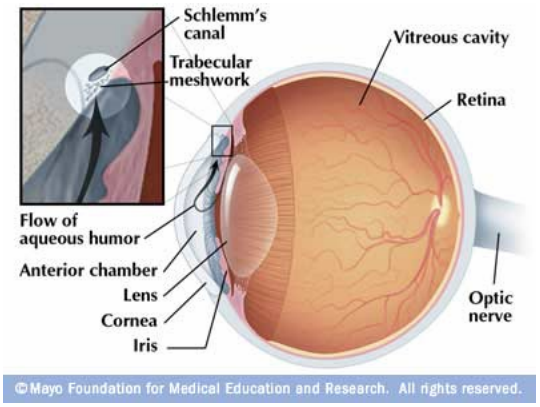

Figure 1: *Depiction of the drainage system in the eye as it applies to glaucoma.*

Figure 2: *"12 Alarm Pager" marketed by e-pill Medication Reminders and Time Now, Inc.*

Figure 3: *Pill dispensing medication reminder marketed by B. Independent.*

Figure 4: *Screen chosen for LCD design, with a 2.7" diagonal.*

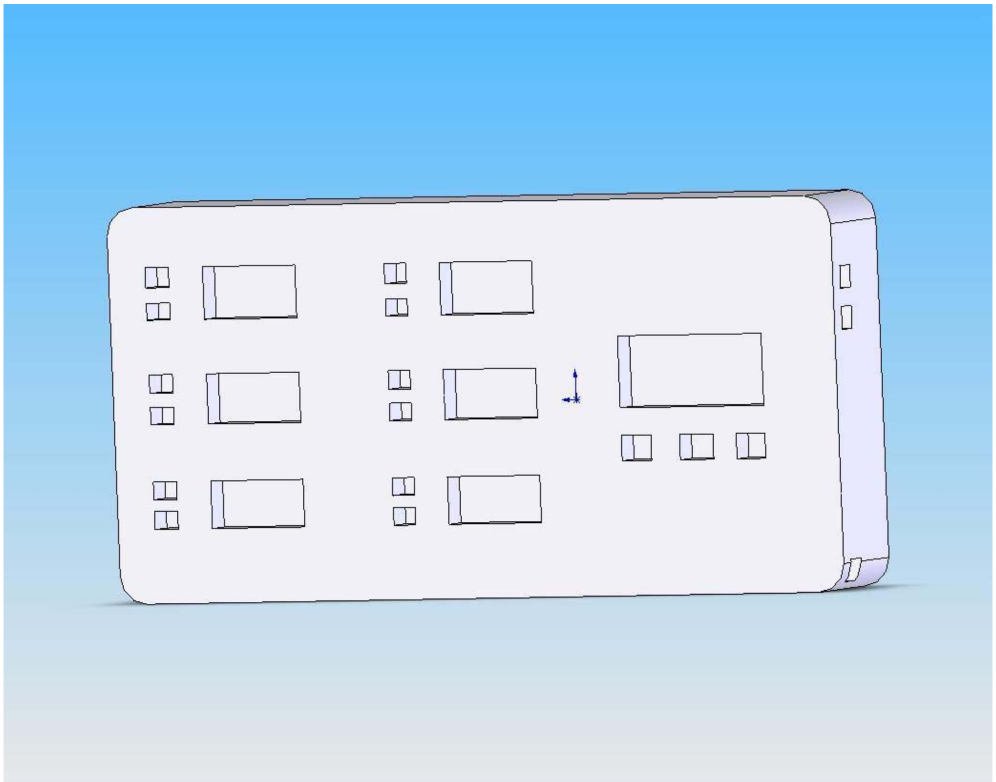

Figure 5: *Solidworks drawing of Modified Egg Timer design.*

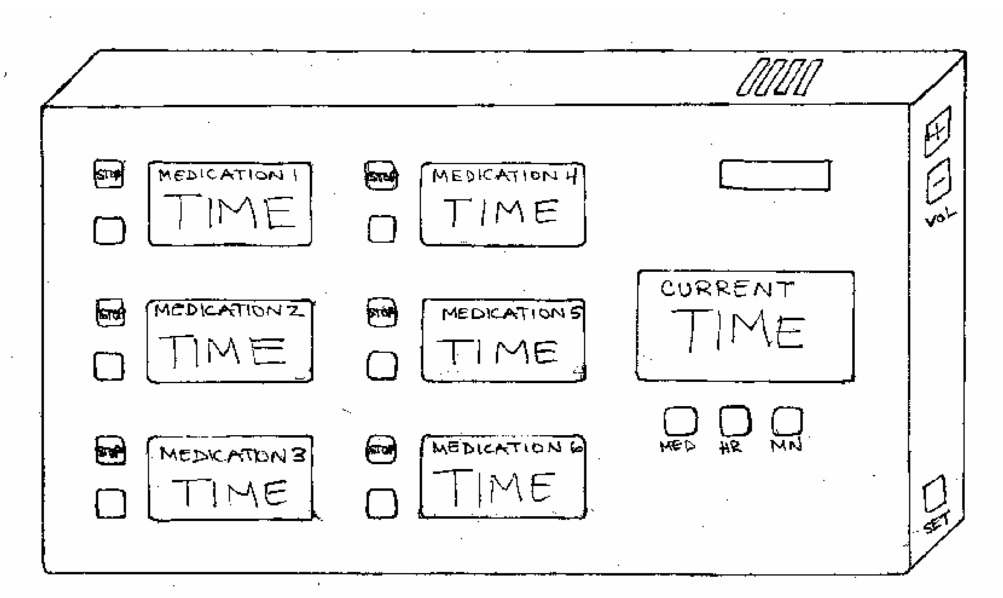

Figure 6: *Sketch of Modified Egg Timer design. It has six different count-down timers for each medication and a main screen reading the current time.*

Appendix B (Tables)

Materials	*Cost*
LCD Kit (includes screen and graphics/USB drivers)	$199
Display Controller	$69
Protective Casing	$10
Battery	$25
Total	**$303**

Table 1: *Cost analysis for LCD system*

Materials	*Cost*
PDA	$50-250
Programming Software	$50-300
Total	**$100-550**

Table 2: *Cost analysis for modified PDA*

Materials	*Cost*
Grey LED screens with bold black numbers and letters	$10-20
Colored LED lights	$5-10
Plastic casing	$10
Timers and programming circuit	$50
Speakers	$10
Control knobs	$2
Total	**$87-102**

Table 3: *Cost analysis for modified egg timer.*

Design	*Modified Egg Timer*	*Modified PDA*	*LCD System*
Ease of Unit Interface	3	5	5
Size	4	5	4
Cost	10	8	6
Ease of Implementation	3	4	4
Ease of Use	8	6	10
Durability	4	4	4
Production Time	5	3	2
Met Client Requirements	10	8	8
Total	47	43	43

Table 4: Design Matrix. *Cost, ease of use, and satisfaction of client requirements were all ranked on a 1-10 scale (10 being best, 1 being worst) while all other components were ranked on a 1-5 scale (5 being best, 1 being worst).*

Appendix C (References)

Mayo Clinic Staff. "Glaucoma overview." Mayo Health. 2006 <http://www.mayoclinic.com/health/glaucoma/DS00283/DSECTION=5>.

Stewart, William C. "Patient and Ophthalmologist Attitudes Concerning Complaince and Dosing in Glaucoma Treatment." Journal of Ocular Pharmacology and Therapeutics. 20 (2004): 461-469

Unknown. "All You Need To Know About Complaince." The Glaucoma Foundation. 2006. April 2003. http://www.glaucomafoundation.org/news_story.php?i=17

Appendix D (PDS)

Problem Statement

Develop a portable electronic device which can indicate glaucoma patient when it is time to take their next dose of medication. An audio will be necessary because many of the patients are severely sight-impaired. The device needs to be programmable for up to six different medications that can be used in different dose regimens. A reset mechanism, types of reminder signals, durability/portability, power options, and power level indicators all must be taken into consideration.

1. Physical and Operational Characteristics

a. *Performance requirements*: The device must alert the user for up to six different medications. The alert must be through sound or vibrations. The device must be turned on all the time. It must be programmable by the doctor, not the patient, with a lock or a password. There must be a button to reset the alarm as well.

b. *Safety*: The device cannot contain any bare wires that may electrocute the user. It should have rounded edges.

c. *Accuracy and Reliability*: The time should be accurate to the second, but needs to only display the minute. It must alert for every dose.

d. *Life in Service*: The device will be used as long as the patient's medication is prescribed.

e. *Shelf Life*: The device may be used for one patient or for several. It should function for many years. The device must either be rechargeable or contain batteries that are easily disposable. There must be an indicator when the batter is going low.

f. *Operating Environment*: The device will be with the patient wherever they go. It may be kept in a pocket, purse, bag, etc.

g. *Ergonomics:* Function and reliability are most important. Look and feel are secondary considerations.

h. *Size*: It must be small enough to be transportable. It must be easy to hold. It would preferably be operable with one hand.

i. *Weight*: The weight must correspond with the mobility requirement.

j. *Materials*: Plastic would be optimal.

k. *Aesthetics, Appearance, and Finish*: The device must be easy to use by elderly and someone with poor sight. Preferably a digital screen.

2. Production Characteristics

a. *Quantity*: Only one unit is needed for the time being. Multiple is a possibility for the future.

b. *Target Product Cost*: We have potentially $1000 available, but product should be as inexpensive as possible.

3. Miscellaneous

a. *Standards and Specifications*:

b. *Customer*: Paul Kaufman, M.D., Dept. of Ophthalmology and Visual Science, UW Medical School; and Liane Seyk

c. *Patient-related concerns*: Easy to use, accurate, and durable.

d. *Competition*: There are several similar products on the market. Our goal is to make an equally functional, more cost effective, and more visually sensitive alternative.