COMPUTER INPUT DEVICE FOR INDIVIDUAL WITH MUSCULAR DYSTROPHY

Written by:

Vince Mi – Communicator

Kuya Takami – BSAC

Hyungjin Kim – BWIG

Nathan Werbeckes – Team Leader

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Advisor:

John Webster, Ph.D.

Clients:

Richard Kunz

Mary Sesto, Ph.D.

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Abstract

Muscular Dystrophy is a strongly disabling disease that can leave its victims crippled. The worst part of the disease is that it doesn't affect your mind, so those who suffer through feel that they are trapped in their own body. Our client still has enough motor control to work a computer input device, but not efficiently or well. The group's goal is to build a device to improve the accessibility of the computer input device for the client. Our system must also be setup quickly and without confusing components. We decided that a small joystick would be best to control the on-screen cursor and an adjustable platform would be used to support the client's forearms while using the device. Future work includes designing a left hand clicking device, finalizing the arm support, and finally buying and customizing the device to optimally suit our client's needs.

Background

Richard Kunz (our client) has advanced Muscular Dystrophy. His disease is so advanced that he is unable to ever leave his bed under his own power. Even worse is that he would be unable to breathe if not for a respirator in his home. Although there are many things Richard will never be able to do he is not completely trapped in his body. He can still speak (with the help of the respirator) to communicate with others, but his primary source of communication with the outside world is via his computer. Unfortunately, his disease took a turn for the worse last year and he is now unable to use a keyboard at all. Towels prop up his forearms because he is unable to lift his wrist or elbow enough to resist gravity. He has resorted to moving a trackball with a pencil eraser, but even this is hard and slow.

Figure 1. Richard Kunz in his bed with current computer input device setup.

What Richard can do is move three fingers on each hand. His thumb, pointer, and middle fingers have adequate motor ability to control his computer. With his right hand he grips the pencil and is able to make circles just greater than 1cm in diameter. Each individual finger can not move this much or with as much control, but together they function pretty well. The trackball is rotated about 150 degrees so that his left hand is able to reach the buttons normally on the top of the trackball. However, these buttons are too slanted and in a bad position for Richard's hand to click them properly. Therefore, pieces of plastic have been taped onto the trackball buttons to help him reach and click them properly.

Problems with Current Device

Our client is currently using a trackball as an input device for his computer (Figure 2). He rolls the ball part with the eraser part of a pencil, controlled by his right hand, and clicks the buttons with his left hand. However, he has some problems with this current device. First, the setup takes a long time. In order to use the input device, he needs the trackball in a very specific position. Also, the setup position is slightly different each time he uses the computer due to slight shifts in arm and body positions. Thus, the nurse keeps moving the device slightly until he feels comfortable with the position. In this way, it takes about 10 to 15 minutes to get the correct height of towels to support his forearms, get the correct height of books to raise the trackball, and correctly position his hands on the trackball. The second problem is that the trackball is slippery. As mentioned before, he needs an accurate setup, and if the device slips he will not be able to use the device. When he slips off the trackball, the trackball and his hands must be repositioned, which takes a while. Another problem is that the buttons are inconvenient. On the current trackball, the location of the buttons is

Figure 2. Current device used by client. Right hand holds pencil and moves the trackball, left hand rests on top of buttons.

lower than the desirable position. Previous problem solvers attached plastic pieces on the button with the tape so that the buttons are elevated. However, because his room is humid and warm, the tape slips easily. After a slip the plastic pieces need to be repositioned and taped. Then the trackball and his hands need to be precisely setup again.

Problem Statement

In order to improve the client's input device, we need to minimize the setup time. We also need to make the design easier to use, so that the nurse will not have hard time setting up the device for the client. The input device should be more sensitive, so that the device is easier to use with his limited motor control. Since our client can move his finger only 1 cm in diameter, the device should be designed so that the cursor can travel the entire screen with only 1cm of input. Also, the support system should be more comfortable and durable, since our client's arms will be on the support for several hours a day.

Client requirements

Our client requires a more accessible mouse control device. The input device should be sensitive so that he can use it easily with his limited motor control. Also, he requires better wrist and forearm support. Currently, he is using stacks of folded and rolled hand towels for the support. These towels get old and thinner and then no longer support his forearms to the same degree. The new supports will be more comfortable, easier to setup, and adjustable. The client requires that the support system be not only comfortable, but safe. Safety is a concern because the client has very sensitive skin and he will be resting his arms on the supports for several hours a day. Lastly, the setup time shall be reduced, and the whole device shall be easy to adjust.

Design requirements

Our improved device will connect to the client's computer via USB. Since there are several empty USB ports, we will not encounter any problems even though we use separate devices for moving the cursor and clicking buttons. This will not complicate setup for the nurses, and it will reduce the setup time. The input device will also be required to have great sensitivity so that his limited motor control can adequately move the cursor. The buttons shall be easier to grip. We will adjust the clicking element to a comfortable position, and we will prohibit the device from slipping. Also, the device should not chafe his sensitive skin.

Forearm Support Alternative Designs

Blocks

The first design uses blocks of different thicknesses to adjust the height of the arms. The blocks will be made out of some sort of light polymer with a thickness ranging from 1 to 10 cm. By using multiple blocks with different thicknesses it is possible to create height changes of specific magnitudes. However, the precision of the height changes will not be very good unless there are a large number of different blocks. Also it will cost setup time to switch blocks and the client's forearm will have to be removed from the setup each time. Transportation of the forearm is not a good thing because movement of his body often is accompanied with pain. Also, this design will require larger storage because it needs many blocks to adjust the height precisely. The advantages of this support system are cost effectiveness and also the simplicity of the construction.

Adjustable Shelf

The second design contains a mechanism for both height adjustment and angle adjustment of the forearm (Figure 3). The part directly supporting the forearm is shaped using a semi-circular tube, which increases the area supporting the weight and therefore reduces the pressure on the arm. This in turn will be lined with a soft material to prevent skin chafing. This design can change the angle of the support relative to the table. This design also has the ability to change the height precisely and quickly by using the adjustable mechanism on the leg. However, this could

Figure 3. Adjustable shelf design. The leg height and angle of shelf can be adjusted.

be unstable because it only has a single leg and doesn't have the wide base that the first design would have.

Adjustable platform

The last design uses the adjustable platform and a soft material to support the client's forearm. An example of the adjustable platform is shown in figure 4 and has an adjustable knob on the side of the device and is made of steel (adjusting arms) and aluminum (square plates 15 cm x 15 cm, coated with paint). This example is used in a chemistry laboratory and weighs about 4 lb. It can be adjusted from 5.5 cm to higher than 20 cm. Because this is adjustable while the client's arm is on top of the plate, it will decrease the time required to set up the system and be able to make quick and precise height changes. The most important aspect of this forearm support system is its great stability due to its weight and wide base. The size of the plates shown in figure 4 might be excessively large to support our client's arms, but it is easy to find a different size of adjustable platform.

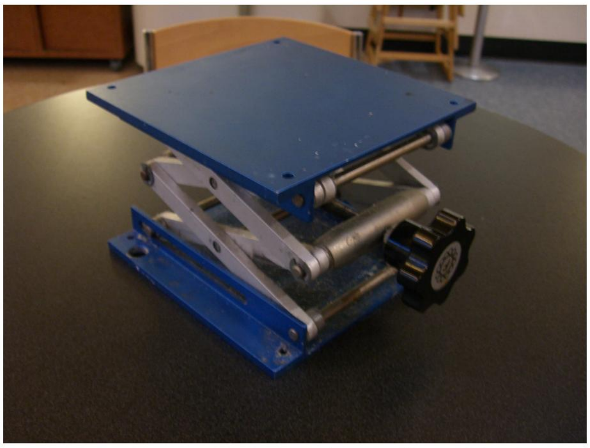

Figure 4. An example of an adjustable platform design. The knob allows careful and precise heights while locking the mechanism in place.

Design Matrix for Forearm Support

In order to determine which design to pursue for the next half of the semester we constructed a design matrix. Weight for stability and ease of adjustment was highest because it contributed most to decreasing the set up time, which was the first priority of this project. We also considered comfort and safety, ease of construction, and cost. For each criterion, the scores were assigned using scale of 1 (worst) to 10 (best). In the end, we decided to pursue the adjustable platform support system because it has most stability and is easiest to adjust. Using this design's ability to change the height quickly and precisely would shorten the setup time tremendously. Even though the adjustable shelf has the same ability it does not have same stability, which is important for the patient's safety. The blocks will not be good due to their lack of precision in setting the height.

	Weight	Adjustable Platform	Blocks	Adjustable Shelf
Stability	0.3	9	10	6
Ease of adjustment	0.3	8	3	8
Comfort/Safety	0.2	9	9	7
Ease of Construction	0.1	5	10	6
Cost	0.1	7	10	8
Result	1	8.1	7.7	7

Table 1. Design matrix for evaluating forearm support mechanisms. Adjustable platform won because of its high marks in both stability and ease of adjustment.

Cursor Control Alternative Designs

Tablet

This apparatus consists of a pen-like device (stylus) held over a receiving surface (tablet) which will detect movements of the stylus and communicates this information to the computer to move the cursor on the screen (Figure 5). The device itself is fairly common among graphics artists and CAD designers and prices range anywhere from $30 to $4000 depending on quality and available features. Sensitivity of the device depends mostly on the quality of the device and usually varies with price.

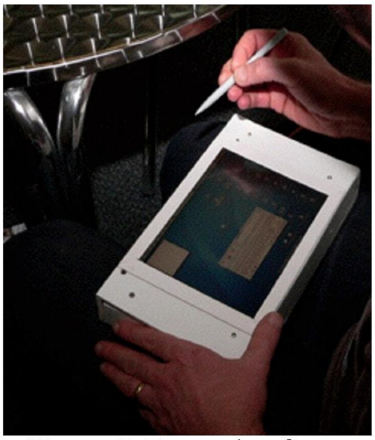

Figure 5. Example of a tablet with stylus. If used we would obtain a more compact model.

More modification will be necessary to fit a tablet to meet the current requirements. The stylus will most likely need to be modified for the client's comfort. Accurate positioning will be required to account for the limited motion of the client. Also, software modification and maybe even hardware modification will be required to allow the client's movement of the stylus to affect the entire area of the monitor.

Joystick

The second design consists of a simple joystick used in place of a mouse or trackball to control the movements of the on-screen cursor. As most joysticks today are fairly large gaming joysticks requiring large arm and wrist movements, most of these did not fit the client's needs. Instead, a small yet precise device will be used, similar to—if not—a modern gaming console controller as seen in Figure 6. These joysticks are usually thumb operated, and therefore require a very small range of motion while being very sensitive. Even with such a small range of motion (about 1 cm in diameter) the client is still incapable of moving the device through the entire range of motion, thus sensitivity adjustments and modifications to the device to increase mechanical advantage will need to be considered.

Figure 6. A small joystick about the size we would use.

Currently, there are multiple companies with hundreds of variations of similar devices on the market, usually at fairly economical prices (less than $50). The large availability provides a wide variety of different joysticks on different controllers with varying designs, increasing the chances of finding an ideal product. After finding a fitting design, the device will be modified to accurately fit the operating environment. This includes height and angle adjustments to allow for comfortable operation, sensitivity tuning to ensure precision operation by the client, and any additional mechanical modifications that may be required to allow for increased performance by the client.

Pointing Stick

The last alternative design, very similar to the joystick design, is the pointing stick, or isometric joystick. These small joysticks are currently found in the middle of keyboards on some laptops (Figure 7). Isometric joysticks essentially do not have any movement, but instead detect applied pressure which is then translated to

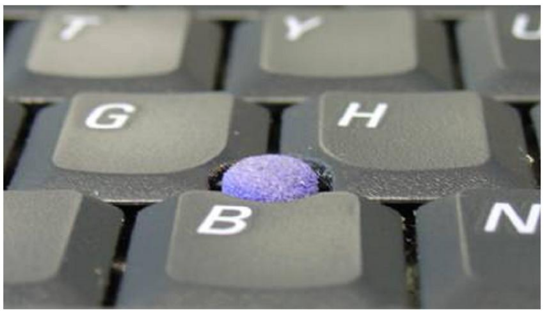

Figure 7. Pointing stick typically seen in the middle of the keyboard on a laptop, small but requires large force.

appropriate signals and sent to the computer as input for cursor movement. The fact that the device doesn't actually need to be moved is very advantageous for the small range of motion our client is capable of. Also, the sensitivity is highly adjustable, and is already very high to account for the small amount of movement.

The largest obstacle of this design is its lack of availability. Although these pointing sticks are currently found on many notebooks, they are basically obsolete as a stand-alone device. The only models currently on the market and available for desktop use are fairly expensive (~$200) and attached to a keyboard, which is unnecessary for the intended application. Thus the device will either need to be heavily modified or a stand-alone device will need to be located.

Design Matrix for Cursor Control

To decide which mouse control device we were going to pursue we again constructed a design matrix. The most important aspect of the mouse control device is that it can be easily moved with our client's limited motion range and that it will be easy for the nurses assisting our client to setup. Ease of operation was also important because although he can move 1 cm fairly well he is not able to produce any large forces. Although the pointing stick has the highest sensitivity it is unlikely that the client will be able to create enough force to move the stick at all. The tablet would be very quick and easy to set up, but would take the client several stylus strokes to get across the screen. We decided to go with the joystick because of its reasonable sensitivity and ease of operation while easily being the cheapest and most customizable device.

Input Device	Weight	Joystick	Tablet	Pointing Stick
Sensitivity	0.3	7	5	8
Ease of Operation	0.3	7	4	5
Setup Time	0.2	5	7	5
Cost	0.1	8	3	3
Ease of Construction	0.1	5	8	7
Total		6.5	5.2	5.9

Table 2. Design matrix for deciding best cursor control device. We will be using a joystick because of its good scores in sensitivity and ease of operation.

Testing

Due to our client's limited motor capability, we found it necessary to limit the amount of force he would need to apply to move the joystick. In order to minimize force while also minimizing the amount of movement needed to control the cursor, testing was done to find a proper length of moment arm.

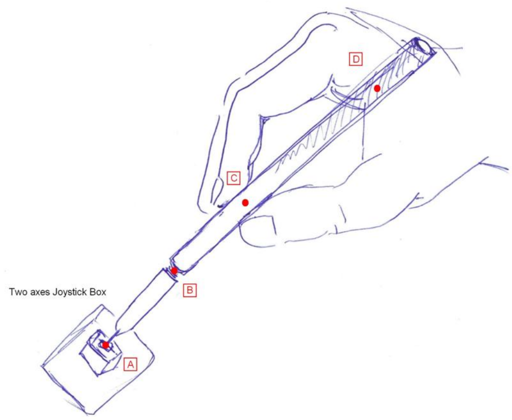

Figure 8. Drawing of modified joystick. The first segment acts as a moment arm to decrease force needed, the second to limit amount of movement needed.

Prototype testing was conducted as follows:

- The distance from the center of two axis joystick to the tip of the stick (between A and B in Figure 8) was in the range of 1.5 cm to 4.0 cm (incremented by 0.5 cm between each trial).

- The force required to move the joystick from the center position was measured using a postal scale. The tip of the stick (Part B in Figure 8) was placed onto the scale and force applied was increased until joystick moved.
- The force required to move the joystick was converted from ounces to milliNewtons.

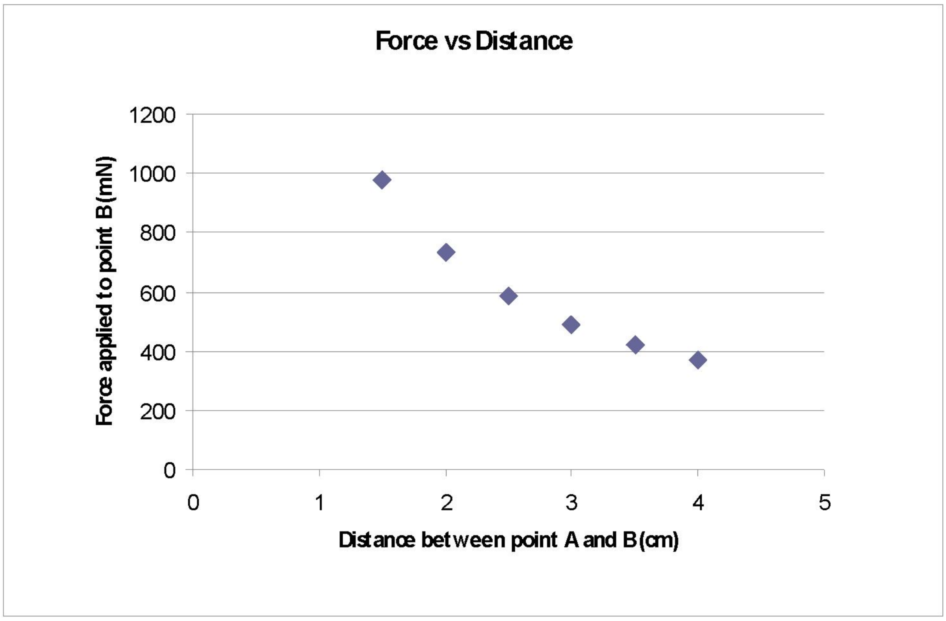

Figure 9. Graph of length of moment arm and force needed to move joystick. A moment arm length of 3.5 cm was used to limit needed force while providing ample length for second segment to decrease amount of movement needed.

As expected, it could be concluded that when the moment arm (distance between A and B) was increased the force needed to move the joystick decreased. The 3.5 cm distance of the moment arm was chosen because our client could easily apply that amount of force, there was no large decrease in force applied when a 4 cm moment arm was used, and because increasing the second part of the joystick decreases the amount of movement needed to change cursor position. When the distance was set to 3.5 cm, the force required to move the joystick at point B was about 420 mN.

The angle that both the joystick and mouse are attached to their respective bases was also tested with our client. However, this testing is qualitative due to our client's condition. To determine positions for the equipment, placement was based on whether our client could easily control the cursor or mouse buttons, and whether the position was or was not painful.

Final Design

Joystick

The design for the joystick came about through much brainstorming and testing. It has been established by our team that the joystick would provide optimal cursor manipulation for the client at an affordable price. Our selection of the joystick is determined on price, connectivity, and use. Large hand-sized joysticks are out of the picture for our client due to his limited physical abilities. Precision isometric joysticks, similar to those found on many laptops appeared ideal, but were scarce to find, steeply priced, and possibly over-sensitive. Thus, through the process of elimination, a gamepad joystick proved ideal for the situation.

For our purposes, just about any gamepad with at least one small finger operated joystick was satisfactory. Our team decided to go with a rather generic Logitech brand game controller, with USB connections (Figure 9). Advantages to this specific game controller include its use of a generic driver, high sensitivity, and a low price. The controller's use of a generic driver allows for easier setup at implementation, as there would be no need to install a separate driver at that time. Sensitivity of the controller is definitely enough to sense the client's small movements and those inputs can thus be easily translated to mouse movement. This Logitech brand controller has a price of only $20.

Figure 9. Game controller with adapted and jointed joystick. Client is seen using the device for the first time.

After controller selection much modification is needed before the client can effectively use the device. These modifications include the implementation of a mechanism that would allow for better access to the joystick by the client, a modification that would position the joystick at a comfortable location and direction, and any other customizations to further accommodate the client to the new device.

To allow for efficient use of the joystick by the client, an attachment was created in attempt to minimize changes to the client's current motions while creating an effective mechanical advantage and therefore increasing accessibility. Since the client presently holds a modified pencil in his right hand for his current device, a pen handle is used as the primary control mechanism in our design. To conserve material used, PVC left over from the arm supports is cut to variable lengths and degrees to allow for angle and height adjustment as required. Most positioning is done subjectively with the client.

On the software side, a free program was found online called Joystick-To-Mouse which is used to convert input signal from the controller to cursor movements on the screen. The software includes lots of advanced fine tune settings to adjust for sensitivity, speed, acceleration, and various other factors influencing cursor movement. There is still work to be done in the area of fine tuning the desired cursor movements to adjust for the client's preferences and abilities.

Figure 10. Client using adapted mouse. No modifications were made to the mouse itself, but the device had to be angled so that client's fingers easily rested upon the buttons.

<u>Mouse</u>

The right hand is used for cursor movement by way of the joystick, but the remaining functions of a normal mouse, specifically select and alternate select, are controlled by the left hand (Figure 10). One major difficulty with the current setup is the inconvenience of having to position the client's current device to align his left hand, right hand,

and the trackball. Thus it was concluded that the left hand's functions would be made separate from the right, to allow for faster, more accurate setup of the entire system.

For this device, an average two-button mouse was found to be sufficient. A few additions to pad and raise to the buttons to account for the client's limited range of motion, as well as height and angle changes were done with some remaining PVC. This extra mouse would only require an extra USB port for communication to the computer. In addition, the trackball on the bottom side of the mouse is removed to prevent interference with the movements of the right hand. The resulting device, although rather simple in appearance, is actually very effective in decreasing setup time and complexity, mostly due to the fact that the two devices operate independently and thus can be set up according to each hand and not both hands at the same time.

<u>Arm supports</u>

Our original design called for a rather intricate mechanism for adjusting the height of our client's arms. However, due to budget constraints and a better understanding of the setup process, this idea was scrapped. Instead, the group focused more on providing a safe, comfortable, and well supported armrest.

The construction of the armrests used 5" diameter PVC piping. This diameter would be sufficient to encompass the client's forearm (measured at about 3" diameter) in soft foam (Figure 11). The piping length was determined by preference of the client and finalized at 10". After the piping length was chosen, arcs of about 150 degrees were cut and all edges were carefully sanded down to prevent any possible injury with contact of client's skin. Tempurpedic foam was then cut to curve with the pipe and cradle the forearm in the middle. Foam was cut longer than the arc length of the pipe so that the edges of the

Figure 11. Client's arm resting upon the specially designed forearm support. There is extra foam so that his arm should never rub against the bare PVC pipe.

pipe should never come in contact with the client's frail skin. In order to provide proper support of the hand, blocks of foam were added to the end of the support. These extra blocks were glued down and positioned, with the help of our client, to support the palm of his hands. With this support he is able to move his other fingers more effectively and with increased power.

Conclusion

The prototype the team built this semester appears to be a viable solution to the problem we set out to solve. However, there is always room for improvement. One issue with our current device is that the adapted joystick is heavier than the initial factory joystick. This extra weight pulls the joystick down very minimally. When a non-disabled person operates the device this slight pull is unnoticed, but our client has a more difficult time moving the cursor up the screen than down. This extra weight can also settle unevenly over the box and can lead to the cursor slowly gliding in one direction. Both of these problems can be solved by adjusting the settings of our current software. In the future we hope to be able to automatically set the center point of the joystick so that glides are eliminated and the weight pulling down does not affect the movement of the cursor.

There are also hardware issues that could be perfected. We had initially intended to make the armrests adjustable. However, due to funding, this part of the project was complicated and ended up being set aside. Although there wouldn't be that much of a need for adjusting the height, it could be helpful to the client to find the ideal position in which to operate the equipment. Along those same lines, we could make the angles of the mouse and controller adjustable. This would allow our client to find the optimal position of the devices for every particular day and posture.

Picture Credits

Tablet: www.blaptops.com/computers/hacks/

Pointing stick: www.fief.org/sysadmin/

Joystick: http://kotaku.com/gaming/

Adjustable legs: www.sammonspreston.com/ca/Supply

Product Design Specifications:
Computer Input Device for Individual with Muscular Dystrophy

Revised:
October 5, 2007
October 6, 2007

Team Leader:	Nathan Werbeckes
Communicator:	Vincent Mi
BSAC:	Kuya Takami
BWIG:	Hyungjin Kim

Function: The goal of the project is to minimize the setup time and improve the usability of the computer input device currently used by the client. Our focus will be replacing the trackball mouse control device with something more suited to his limited motor control. We will also provide wrist and forearm support which can be easily set-up and adjustable.

Client requirements:

- more accessible mouse control device
- Wrist and forearm support
- Comfortable forearm support
- Quick set-up time
- Adjustable

Design requirements:

- Must be able to connect with a normal home computer (probably via USB)
- Easy to set-up without confusing components
- Should be able to reach entire monitor with 1cm of movement he has
- Finger posture on buttons must be maintained with minimal effort
- Should not chafe skin

1. Physical and Operational Characteristics
a. *Performance requirements*: Client must be able to easily have full input control of the computer. Mostly regarding the movement and clicking of the mouse with the

limited motion in his hands. He prefers to use his left hand for clicking; however, we are considering different methods of selecting such as a tapping pad. He has more control in his right hand so we will continue to use that for cursor movement. He can control his thumb, pointer and middle fingers on both hands reasonably well. Wrist and forearm movement is non-existent.

b. *Safety:* Wrist and forearm supports must not cause rough contact or chafing against his skin. Forearm support should be stable and not tip over in any use.

c. *Accuracy and Reliability*: Sensitivity of cursor control device must be maintained over time because of the small range of motion.

d. *Life in Service*: Service should be minimal since device is assumed to be basically permanent. Device would be used for multiple hours daily.

e. *Shelf Life*: Not applicable. Device is used daily; storage conditions are same as usage conditions.

f. *Operating Environment*: Normal room temperature, maybe a bit hotter and more humid than most. Corn syrup in environment may affect moving parts.

g. *Ergonomics*: Device must conform precisely to client's physical capabilities. This includes operating position, padding for comfort, and wrist and forearm support.

h. *Size*: Product must fit client's hand and arms, and fit on his computer desk.

i. *Weight*: No explicit requirements; should be easily handled and supported by the desk.

j. *Materials*: Arm and wrist supports must not wear on his very sensitive skin.

k. *Aesthetics*, *Appearance, and Finish*: Appearance and colors negligible, finish should be for comfortable extended use.

2. Production Characteristics
a. *Quantity*: one.
b*. Target Product Cost*: $500

3. Miscellaneous
a. *Standards and Specifications*: None.

b. *Customer*: Prefers right hand use for movement control. Tactile feedback preferred.

c. *Patient-related concerns*: Skin sensitivity must be considered. He prefers movement to be operated by his right hand. He is not able to lift his arms and wrists so they must be supported at the proper angles to use the device we come up with.

d. *Competition*: Similar but inadequate products are available. No known competition.