Medical Device Cart

Advisor: Professor Block

Client: Viasys Healthcare
Peg Rickard and Art Kealy

Joe Cabelka: Team Leader
Jennifer Wager: BSAC
Emily Andrews: Communicator
Tony: BWIG

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Abstract

Our goal is to develop a cart that houses all the components for monitoring an electroencephalogram (EEG). The cart should be designed with respect to ergonomic standards to facilitate easy workflow and ensure the comfort and safety of the users, while maintaining a compact footprint and low production costs. Each of our three preliminary design alternatives focuses on one of the following aspects: usability at various heights, optimizing usable work surface, and storage and cable management. Our final design will likely be a combination of all three of our preliminary design alternatives. We will choose our final design based on feedback from our clients and data collected from a survey we distributed to a sample user population. Once we have compiled our design concepts we will buy or build parts for a prototype of the design.

Background

Project Motivation

The goal of this project is to create an ergonomically correct device cart to house an Electroencephalography (EEG) system produced by Viasys Healthcare. The current cart that accompanies the components of the EEG system is often not purchased by Viasys' customers because it does not adequately meet their needs. The current cart has no options for adjustment to accommodate multiple users, no leg or foot space, minimal work surface, minimal storage, and no solution for cable management. Additional measures to ensure an ergonomically sound cart would be necessary to provide leverage for Viasys over their competitors. [15]

Current Device

Viasys Healthcare currently produces approximately 30 carts to store medical device equipment. They have had many complaints from their customers regarding the usability of all of their carts. They have approached us to come up with a new design for their mid-sized cart which houses EEG equipment. They anticipate transferring and applying many of our design concepts into a new line of carts.

Figure I: Above is the current mid-sized cart from Viasys that would house EEG equipment.

Figure II: A current Viasys cart in use at the UW hospital fully loaded. Note the lack of additional storage space.

The main problems encountered with the current cart regard usability at multiple heights, lack of work surface, and minimal storage and cable management. The current cart has no adjustable components making it very uncomfortable people of various heights to use. The push bar on the back of the cart is mounted at one height which is not ideal for pushing. Also, the push bar is mounted too close to the back of the cart for the user to walk and push the cart comfortably with hitting their feet. Additionally there is virtually no work surface on the cart for filling out charts and other tasks that may need to be performed in addition to the EEG procedure. The monitor and keyboard occupy all of the desk space. Furthermore, there is no additional storage space for items, including cleaning supplies, the user may require aside from the components of the EEG system Finally, the cords from the EEG components are loose and not organized. The cables get in the way of task performance and are often run over when moving the cart. In general, the current cart from Viasys hinders work flow and is not adequate for its user population. [15]

Figure III: Note the minimal storage space on a current fully loaded cart.

Figure IV: A view of the loose cords from the EEG components on the current cart.

Electroencephalography

The electroencephalography or EEG procedure records brain waves used to detect electrical activity in the brain. Abnormalities in the brain can be detected by recording the electrical impulses that the brain uses to communicate. An EEG primarily records the impulses from the cerebellum which controls speech, thought, memory, and voluntary actions. This procedure is also often used to measure the electrical signals in the cerebral cortex, the thalamus, and the reticular activating system. The cerebral cortex is responsible for higher brain functions, the thalamus carries signals from the sensory organs to the brain, and the reticular activating system sends signals to the body to sleep and wake.

Figure V: Here you can see a picture of the EEG procedure taking place. [6]

The procedure involves a technician arranging electrodes, typically around 12, on the patients head. The electrodes are fixed into place with sticky paste. The patient must remain still during the procedure as movement can interfere with the signals. The electrodes transmit the electrical signal to an amplifier and the results are recorded in the system's software.

EEGs aid in diagnosing and managing several disorders. The EEG is a critical test in diagnosing and managing areas of unstable electrical impulses in the brain that result in epilepsy. Other rare seizure disorders can also be identified with EEG and treatments can be monitored as well. Encephalopathies are also diagnosed by EEG. An encephalopathy is any disease that alters brain function and can be caused from many different sources. EEG results may identify coma or stupor by a marked lack of electrical activity. EEG is the main procedure used to identify and monitor many brain disorders.

The essential components of an EEG machine include electrodes, an amplifier, a computer, and a monitor. An EEG machine may also include a camera and/or a photic. In designing a cart to house an EEG system, all of the components must be accounted for. [5] [11] [16]

Ergonomics

Viasys Healthcare's existing EEG cart is designed with little attention to ergonomic standards. As expressed in customer reviews, both the comfort and ease of use during sitting or standing have been neglected. Users have also articulated their need for more surface top workspace and reduced keyboard and monitor footprints. The current cart has proved inappropriate for its user population, as it is designed without respect to anthropometric data or adjustability standards.

In order to ensure that our team's final design will improve upon the EEG designed by Viasys Healthcare, we have completed diverse research into athropometric data, standards, and guidelines. Both FDA and AAMI standards documents have lead us to consider several ergonomics and human factors design approaches including the evaluation of the user population, environment characteristics, and interaction between the device, its user, and the environment. Additionally, in interviewing EEG technicians, we have informally observed a walk through of the procedure to better understand importance, frequency of use, function, and sequence of use. Our team has distributed a brief survey internationally in order to more accurately collect such data, but anticipate this numerical data to reflect our personal observations. Finally, we have accessed anthropometric data regarding the workspace and tasks involved in the EEG procedure. This data will be applied in our final design as a means of addressing this device's ranging user population.

Our goal in approaching our design from an ergonomics perspective is to correct immediate issues as demonstrated in Viasys Healthcare's customer reviews and mitigate the potential for future problems. After incorporating ergonomics concepts into our design, we expect that a ranging audience will be accommodated to more effectively and comfortably perform the intended task.

Competition

In order to gain a better understanding of existing models, our team researched competitors' EEG systems and carts. There are some advantages and disadvantages to many of the carts we looked at. Many have a very small footprint to optimize space, but in turn lack work surface and storage space. Other models incorporate storage, but are generally bulky and may be obtrusive in medical environments.

Figure VI: This cart from Grass-telefactor is very compact with a small footprint, but has minimal workspace and storage. The wings are also awkward and intrusive [4].

Figure VII: This cart from XLTek is also compact, but is lacking workspace and storage.[13]

Figure VIII: This cart from EGI gives a neat appearance, but is somewhat bulky and has minimal workspace. [9]

Figure IX: The cart from Hospital Management is compact, but requires an additional component and has no workspace. The keypad is also obtrusive. [2]

Design Constraints

Our new cart must remain approximately the size of the mid-sized cart currently produced by Viasys; the footprint must maintain the same dimensions. The cart must house all of the components of the EEG systems including a computer, monitor, amplifier, camera, photic. The cart must address usability concerns with regards to ergonomics so Viasys can offer a more comfortable and efficient cart. The materials used must agree with health and safety standards of medical environments. The material used to construct the cart must also be durable and light enough to easily maneuver. Additionally, the cart must be cost efficient in that elevated costs are justified by the advantages. [15]

Materials

To construct our cart we require a material that is durable, light and preferably inexpensive. We evaluated durability by Young's Modulus (or its elastic modulus) which is a measure of rigidity. A material with a higher elastic modulus requires more stress for the same strain as another material. Stress is a measure of force per area and strain is its deformation. We evaluated its weight based on its density in pounds per cubic inches and we looked at each materials price per cubic inch.

We evaluated low-carbon steel, grade 2 titanium, and aluminum alloy 6061 as potential construction materials.

Material	*Density (lb/in3)*	*Elastic Modulus (ksi)*	*Price ($/in3)*
Low-Carbon Steel	0.28	29,000	0.75
Grade 2 Titanium	0.17	16,000	18
Aluminum alloy 6061	0.098	10,600	1

Table I: Low-carbon steel, Grad 2 Titanium, and Aluminum alloy 6061 are compared based on density, elastic modulus, and price.

As noted from the table, steel is the strongest and least expensive material of the three, but also the heaviest. Titanium is way too expensive for our use. The aluminum seems to be the best choice because it is the lightest material and while it is the least strong of the three materials, it has a high elastic modulus and would serve its purpose. Aluminum is also inexpensive. [7] [10] [14] [17]

Alternate Designs

For our alternated designs, we addressed each of the three main concerns: usability at various heights, workspace, and storage and cable management.

Design I: Usability at various heights

In this design we address the push bar, uncomfortable workstation, and camera and photic placement. We propose to make the push bar adjustable through appropriate heights for both males and females and to mount it further back from the cart to allow a comfortable pace when walking and pushing the cart. The mechanism we propose for the adjustability would be a simple peg such as in crutches. To make the workstation more comfortable, we will rearrange system components to create an open footprint allowing for more foot space. We will also use a sliding keyboard to create expandable depth, providing knee space when sitting at the cart. The camera and photic are currently mounted in an obtrusive manner and are difficult to reach and adjust. Our solution is to mount the camera and photic on a single central pole so as to eliminate awkward reach angles.

Figure X: The crutch above demonstrates the form of adjustment we propose for the push bar on the back of the cart.

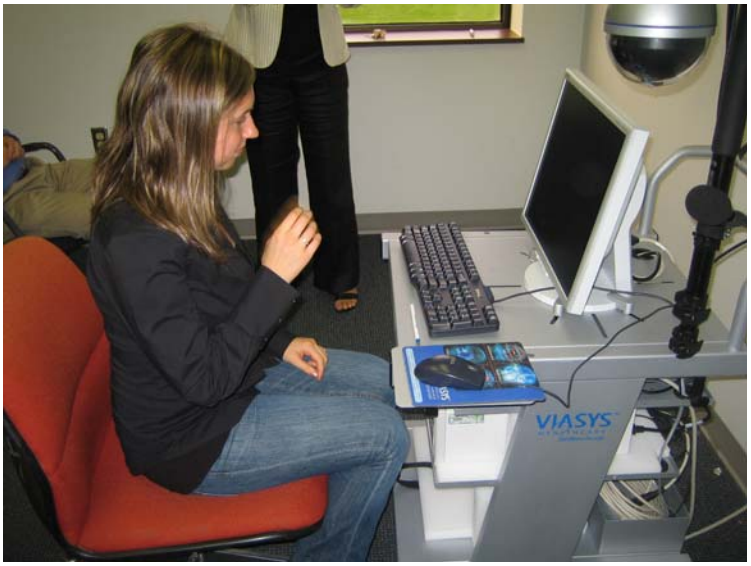

Figure XI: Here you can see the limited knee space when sitting at the current Viasys cart. With a sliding keyboard moved under the cart, there will more knee space to make working at the cart much more comfortable.

Design II: Workspace

Our second design focuses on maximizing the usable worksurface of the cart. Many EEG technicians had difficulties finding a workspace to take notes during the procedure. Nearly all usable workspace was covered by components such as the keyboard, mouse, and monitor. To combat this problem, we propose to mount the monitor on a fully adjustable boom. Not only would this lift the monitor off the cart surface, increasing workspace, but make the monitor easy to view from many different angles. For example, many times EEG technicians need to be next to the patient while setting up all the equipment. Previously, a technician would constantly be looking back and forth between the patient and monitor, and even moving back and forth between the cart and patient. As one can imagine, this was very inconvenient. By mounting the monitor on a boom, however, this problem can be eliminated. The boom operates around a single pivot point, allowing the monitor to move up and down, side to side, and even pivot on the end of the boom. With such a wide range of motion, the monitor can be seen from all over. Secondly, we found it beneficial to add a swiveling mouse pad on the retractable keyboard, which is mounted below the cart surface. Once again, this removes the existing awkward mouse pad from the cart surface increasing workspace. The original mouse pad hinged into place on the side of the cart during use, but when removed for transport, the thin steel plate just sat on the surface of the cart. The new swiveling mouse pad, located under the cart surface, does not need to be removed during transport, and even swivels under the retractable keyboard for easy storage.

Figure XII: A fully adjustable boom with a mounted computer would give more workspace and allow the monitor to be viewed at different angles. The camera would also be mounted to the

Figure XIII: Here is a sliding keyboard with a swivel keyboard mounted underneath. [8]

Design III: Storage and Cable Management

Our third designed focuses on the problems with cable management and storage space. Right now, cables are generally unorganized and greatly interfere with cart movement. Many times the cables slide off the cart and get tangled in the wheels, creating a mess that is aesthetically unpleasing. Also, the less intimidating equipment a patient sees, the more comfortable they feel during the procedure. To address the cable mess, we decided to make the two most frequently used cables retractable, coiling up into a semi-permanent housing. The other cables will be labeled and stored in a cable caddy, which will contain pegs that the cables will coil around. The cables would also be concealed with a door to hide cables from the patient, while still allowing easy access for maintenance. Storage space on the cart for additional supplies is minimal. At the UW hospital, many technicians had to add their own small basket to the bottom of the cart to store sterilizing supplies. To optimize storage space, we felt a combination of several ideas would be the best approach. First, by rearranging some of the system components, shelf space already existing on the cart could be maximized. We also made the shelves slide so as to gain easier access to any stored items. Finally, we decided to add pegboard to the sides of the cart. By adding pegboard, baskets and hooks can be hung on the cart for any additional storage

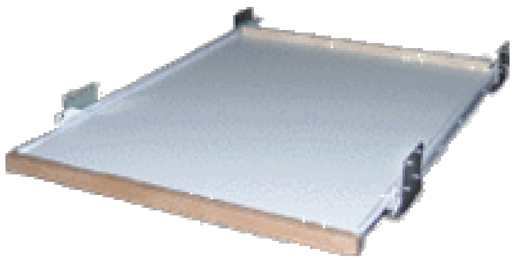

Figure XIV: Here is a simple sliding shelf that would be used to give more storage space and allow the CPU to be easily accessible. [12]

Figure XV, XVI: On the left a retractable cord casing would be used for the power cords that are used frequently and on the right is a peg set up that could be employed to coil the additional cords. [3]

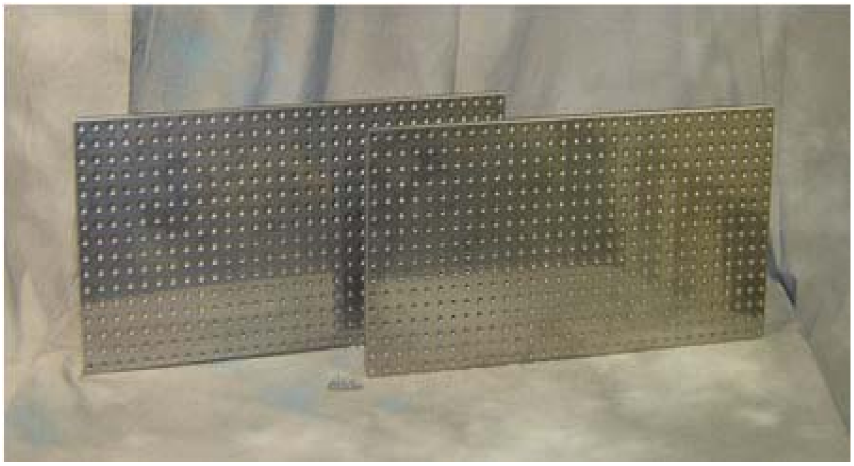

Figure XVII: Metal peg board where storage bins could be attached would give additional storage space. [1]

Future Work

At this point, we need to choose a final design and then build a prototype. In choosing a final design we will need to analyze survey data and our client's input. The survey will give us insight as to what is most important to Viasys' customers and what components of the cart they use the most frequently. The input from Viasys will help us balance the cost versus the benefit of each design component. Our final design will likely be a combination of some components from all three designs including solutions to the most commonly reoccurring problems. We will need to decide which combination of solutions is most effective while considering their cost.

Once we choose a final design we will need to build and buy parts in order to construct our prototype. Many components of our design include parts that can be purchased, but some items such as the cord caddy must be custom made. The construction of our prototype will be an assembly of different components. Because it may be difficult to construct a fully functioning cart that meets our initial vision, we may have to produce intricate sketches of the final design so the components are better understood. If necessary, we made need to develop assembly instructions to accompany our cart so our clients and its users will be able to assemble the cart efficiently.

Ethics

It will be important for us to consider intellectual property in developing our design and prototype. Because there are many EEG carts on the market, we need to insure that our cart is not a replicate of another.

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Appendix A

Project Design Specifications

Project #42 – Medical Device Cart

Function: The purpose of the medical device cart is to provide a work area that houses all components for monitoring an electroencephalogram (EEG). The cart should be compact and facilitate easy work flow. It should also be designed with ergonomic standards in mind to ensure the comfort and safety of the users.

Client requirements:

- Cart should be conform closely to the measurements of a current medium size device cart
- Issue of cable management should be addressed
- Cart must be comfortable and have ergonomic design in mind

Design requirements:

1. Physical and Operational Characteristics

a. *Performance requirements*: Device must have room for a monitor, computer, printer, amplifier, camera, photic and power supply. Device must be maneuverable and easy to transport.

b. *Safety*: Device must have regulatory power supply. Non-regulated safety considerations include sharp corners and dangling cords.

c. *Accuracy and Reliability*: N/A

d. *Life in Service*: Cart should be able to withstand 10 years of usage. Cart should also be designed with future considerations in mind to prolong life.

e. *Shelf Life*: N/A

f. *Operating Environment*: Device will be used in a medical setting. As such, it must be easy to clean. Materials should comply with safety standards for a medical environment.

g. *Ergonomics:* Two points of concern are keyboard height and ease of mobility. Keyboard and surface top should be appropriate for use while sitting or standing. It also must be easy to push and rotate. Customers need to view the monitor from various angles.

h. *Size*: Cart should not differ greatly from existing medium size device cart.

i. *Weight*: Should be kept to a minimum for shipping (ideally 50-75 lbs) and should be easy to push or pull.

j. *Materials*: Any material that can be used in a medical setting and reduces weight.

k. *Aesthetics, Appearance, and Finish*: Must be aesthetically pleasing to customers. A unique image will help build product identification.

2. Production Characteristics

a. *Quantity*: 1

b. *Target Product Cost*: Total cost of cart: $800-$1500

3. Miscellaneous

a. *Standards and Specifications*: Cart must meet The Health and Safety (Display Screen Equipment) Regulations of 1992. It also must meet IEC 60601-1 [Medical Electrical Equipment – Part 1] and in particular clause 24 which requires that the device will not overturn if tilted through an angle of 10 degrees. Additionally the cart must comply with the Association for the Advancement of Medical Instrumentation (AAMI) and Food and Drug Administration (FDA) Human Factors regulations.

d. *Competition*: Several other companies produce similar carts intended to assist in various medical procedures. Some customers purchase EEG systems from Viasys, but prefer carts designed by other companies.

Appendix B

Cart Usage Survey

Questions:

1) How long do you use the cart each day while standing?
    a. 1-2 hours
    b. 3-4 hours
    c. 5-6 hours
    d. 7-8 hours
    e. >8 hours

2) How long do you use the cart each day while sitting?
    a. 1-2 hours
    b. 3-4 hours
    c. 5-6 hours
    d. 7-8 hours
    e. >8 hours

3) On a scale of 1-5, with 1 being the most uncomfortable and 5 being the most comfortable, rate how comfortable it is to sit at the unit.

    ____

    Elaborate if possible:____
____
____

4) On a scale of 1-5, with 1 being the most uncomfortable and 5 being the most comfortable, rate how comfortable it is to stand at the unit.

    ____

    Elaborate if possible:____
____
____

5) What part of the cart do you use the most?
    a. Monitor
    b. Keyboard/Mouse
    c. Camera
    d. Amplifier

6) On a scale of 1-10, with 1 being the least mobile and 10 being the most mobile, rate the mobility of the cart (e.g. at a 10, you would feel comfortable taking the unit outside across cobblestone, and at 1 one you would not wheel the unit down the hall.

____

Elaborate if possible:____
____
____

7) On a scale of 1-5, with 1 being large enough only to keep stationary and 5 being small enough to fit anywhere the unit needs to go, rate the size of the cart.

____

In this next section, we will ask your opinion about features of the cart. Put an X next to the option that you feel best describes your reaction.

	(Yes)	(Probably)	(Indifferent)	(Probably Not)	(Definitely Not)
1. Would a rotating top be beneficial?	____	____	____	____	____
2. Would additional storage be beneficial (such as a basket on the side)?	____	____	____	____	____
3. Would a sliding keyboard be beneficial?	____	____	____	____	____
4. Would a sliding or retractable mouse pad be beneficial?	____	____	____	____	____
5. Would sliding shelves be useful?	____	____	____	____	____

6. If there was just one thing you could change about the cart what would it be?

____
____
____
____