iPhone Holder for Use in Motor Vehicles

BME 300/200

University of Wisconsin-Madison

Department of Biomedical Engineering

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Group:

Nick Schapals—Leader

Anyi Wang—Communicator

Arun Kousik—BWIG

Derek Pitts—BSAC

Client:

Mr. Jonathan Rubin

Advisor:

Professor Paul Thompson

University of Wisconsin-Madison Department of Biomedical Engineering

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Abstract

Multiple Sclerosis (MS) is a degenerative condition caused by the destruction of the myelin sheath of neuronal axons. It is usually caused by an auto-immune response and is characterized by decreased signal propagation, resulting in patients losing motor function, memory, and sensation. Our client has MS and copes while driving by using his iPhone for navigation and reminders. Currently his iPhone is attached to the center of the steering wheel, which is the optimal position for him due to his condition, but this causes problems because the iPhone turns as the wheel is rotated, sometimes completely upside-down. The client requires a new iPhone holder that will keep his iPhone upright at all times, regardless of steering wheel rotation. This holder needs to be at the optimal position for him, safe, and aesthetically pleasing.

Background

The human body has approximately 100 billion neurons that are innervated through multiple systems. These neurons propagate electrical signals, whose effects range from voluntary movement of the limbs to pacemaker neurons that regulate heart rate. The length of any given neuron can range from 4 microns to 1.5 meters in length (Enchanted Learning, 2001). If these neurons cannot properly propagate electrical signals, which happens in Multiple Sclerosis, various debilitating symptoms may occur.

Multiple Sclerosis is an inflammatory disease affecting the central nervous system (CNS), which consists of the brain and the spinal cord and contains a specific type of neuron that is only found in the CNS, called an interneuron. These interneurons, like other neurons, contain dendrites that receive electrical signals, cell bodies that maintain the integrity of the cell, and axons that propagate electrical signals. In the CNS, interneurons form large networks that are pivotal in consciousness, memory, and cognition. The brain and the spinal cord both contain white and grey matter; Grey matter that corresponds to the cell body of the interneuron while white matter corresponds to the axons of interneurons (Widmaier et al, 2008). Multiple Sclerosis affects larger portions of white matter of the CNS than it does gray matter; thus, the interneurons of an individual affected by Multiple Sclerosis may be able to receive a signal, but it may either be damped or staunched out completely when it reaches the white matter or an affected axon. More specifically, Multiple Sclerosis degrades myelin, the fatty insulation around axons that helps propagate electrical signals along faster.

Little is known about the causes of Multiple Sclerosis. However, it is clear that the immune systems of individuals afflicted with MS attack the myelin sheath and cells responsible for maintaining it (see figure 1), instead of protecting the body against foreign agents. The myelin sheath is a fatty insulation created and maintained by oligodendrites, a type of glial cell (Compson, 2002). The insulation provided by the myelin reduces signal loss and helps propagate action potentials down axons. When the glial cells are attacked, the myelin no longer has as many cells to maintain the myelin surrounding the axons. Without maintenance, the myelin sheath undergoes the process of demyelination, where the myelin sheath degrades and builds up scar tissue. In some cases the nerve may be destroyed, or other symptoms may develop.

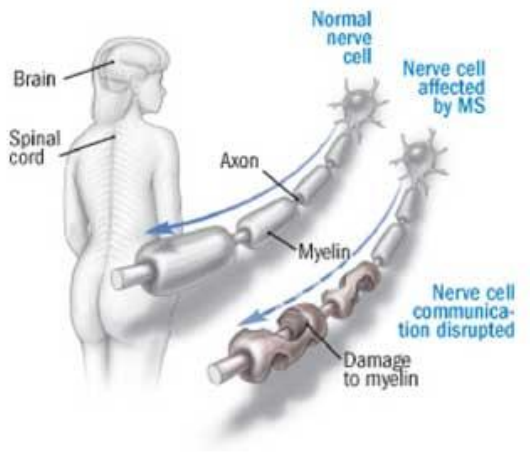


Figure 1: Depiction of how MS degrades myelin on axons of neurons

Individuals with MS may experience a myriad of symptoms that range from paralysis of body parts to memory impairment. The National Multiple Sclerosis Society has established four degrees of Multiple Sclerosis progression: relapsing remitting, secondary progressive, primary progressive, and progressive relapsing. Relapsing remitting is defined as unpredictable attacks of with a very low frequency; these attacks can vary from dizziness to loss of motor control. Most individual classified with relapsing remitting may move into secondary progressive, which is characterized by a decline in cognitive ability. Primary progressive individuals are characterized by an immediate onset of symptoms, like cognitive degradation or muscle motility loss, but may eventually show some improvements. Progressive relapsing individuals have a very sharp decline in cognitive ability (Lublin FD et al, 1996).

Motivation

MS limits the client's memory and range of motion, and causes hypersensitive vision in him. As a result, he relies heavily on his iPhone while driving for navigation, his calendar and for calling people. Any device that is off-center and requires rapid movement of the eyes disorients him due to his hypersensitive vision. Currently, the client has the iPhone taped to the center of the steering wheel, which is at the ideal elevation, horizontal position, and focal distance for him. These are important factors to be considered during the design process and should be maintained as much as possible.

Problem Statement

Our client, Mr. Jonathan Rubin, is an individual affected by Multiple Sclerosis and is a regular commuter by his car, a 1995 Ford Taurus GL 4-door sedan. Because of his disorder, he requires his iPhone 3GS in front of him while driving for navigation and reminders. The iPhone is currently taped to the center of the steering wheel (see Figure 2) which maintains it at an optimal elevation and focal distance for him, minimizing the disorientation experienced due to hypersensitivity in his eyes. However, as the wheel is turned, the iPhone rotates with it, posing a problem especially while navigating. A device is required to securely mount the iPhone in front of him while he drives and maintain its upright position regardless of steering wheel movement. It should be stable and not cause any obstruction of the air bag or other safety concerns while driving.

Figure 2: The current position of the iPhone in the client's car

Client Requirements

The device has to allow convenient attachment and removal of the iPhone prior to and after usage. It has to securely maintain the iPhone at its initial position and configuration as determined by the driver, independent of the steering wheel movement. It should allow the driver to choose between vertical or horizontal iPhone orientations, depending on his preference. It has to be within the elevation

Figure 3: Driver's view of steering wheel with client's height requirements depicted in red

Figure 4: Side view of steering wheel with client's depth requirements depicted in red

and distance constraints specified (see Figures 3 and 4). It has to allow complete access to the iPhone and steering wheel while mounted and cannot obstruct the driver in any way. It cannot obstruct the deployment of the airbag and should not endanger the driver or any passengers in the event of an accident or airbag deployment. It should allow charging of the iPhone if required by the driver. It should be aesthetically pleasing and accommodate different phone models and be able to utilized in differnt car models. The device should not cause any permanent damage or alteration to the car interior. It should not exceed dimensions of 15cm x 10cm x 1.5cm and should weigh below 150g. It should be storable under normal car conditions of temperatures between 0°C and 30°C, and humidity between 50% and 75%. Finally, it has to below the $300 budget.

Existing Devices

There are currently no products on the market that fit all of our client's requirements. IPhone holders currently on the market are stationary and clip on the dashboard. There are no iPhone holders that are mounted on the steering wheel, possibly due to the safety concerns related to airbag deployment. There are a few products that have long adjustable necks that can be manipulated to move in different positions and have the ability to stick on a dashboard or windshield, such as the NAJA King Form by the Thought-Out company (see Figure 5). These products range between $5 and $60.

Figure 5: The NAJA King Form a portable media holder for cars.

Ethics

Due to the sensitive nature of MS symptoms, the disclosure of specifics about our client's condition has to be handled carefully. It is unclear as to how much information he wishes to divulge about his disease, and therefore his privacy should be respected. However, there is no need to release any information about the client should the product be released on the market. Safety concerns should also be considered when examining the ethical issues of the design and may have an impact on the marketability of the product. It has been shown that many distractions already exist while driving, such as text-messaging, calling and using other applications, which poses serious dangers while driving (Statistics and Facts About Distracted Driving). It raises concern that allowing the driver greater access to a mobile device while driving could further exacerbate the problem, especially if the driver has to stare at a map on an iPhone for extended periods of time. This device must not present itself as risk to

the driver or others around them. There may also be legal repercussions that could arise from accidents caused by distracted drivers using the product, and the product must have adequate warning labels to inform the user of the risks taken while using it.

Ergonomics

The user of this device will be operating a motor vehicle. Therefore, a key ergonomic issue is to minimize the amount of distraction caused by both the iPhone and the device. This is most easily achieved by limiting the amount of user input required in the device and the iPhone. The device should not hinder the driver's ability to manipulate the steering wheel or any controls in the car. It should not interfere with the rotation of the steering wheel in any way or cause any alteration to the driver's driving style. The device should not interfere with the driver's view in any way (i.e. no reflective surfaces). It should not move or shift while driving, except for those parts intended to move during normal function of the iPhone holder. It should allow for easy access and manipulation of the iPhone at all times. The device should be relatively easy to mount when the car is not in motion and should not detach itself during driving. Overall, the device should not distract the driver or cause the iPhone to be any more of a distraction than it already may be. It also should not be a distraction to other drivers on the road or interfere with any other drivers/vehicles during regular usage. The holder should not pose a safety threat to the driver while driving, especially in the event of a vehicle collision, and should not interfere with proper airbag deployment.

Design Proposal Overview

The device functions as an iPhone holder for our client, who has MS, for use in his car. Therefore, it has to be customized to fit his disability, specifically the hypersensitivity in his vision and his limited range of motion. As previously mentioned, the device has to operate within fixed elevation and distance constraints. It has to allow maximum access to the iPhone and cause minimal obstruction to the steering wheel and other important driving and safety features in the car, especially the airbag. The client aims to eventually market the device, so it should accommodate different phone models and be adaptable in various car models to fit different people's preferences. The three designs proposed below are all possible iPhone holders for use in motor vehicles and can be adapted to fit different phone or car models. All the designs are distinguished by unique features and provide solutions to the problem.

Design 1: Solid Arm Support

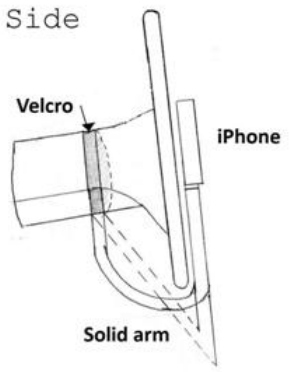


Figure 6: Side view of Solid Arm Support Design

The first design is the solid arm support, characterized by a rigid arm attached to the steering column behind the wheel (see Figure 6). The steering column extends behind the steering wheel and attaches to the interior of the car, and therefore does not rotate with the steering wheel. The arm will be attached to the column by Velcro straps, which allow the device to be easily attached and removed from the car, and will extend under the steering wheel to reach the center of the steering wheel. An arm reaching over the top of the steering wheel was considered as well, but determined to be impracticable because it would interfere with steering if the driver were to perform an over arm turn.

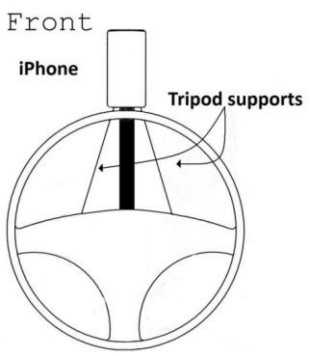
This design allows the iPhone to be in front of the driver in the client's preferred location without the issue of the iPhone turning with the steering wheel, simplifying the design considerably. Also, the simplicity of the components of this design significantly lowers its production and maintenance costs, which is a factor to be considered if the device is to be marketed eventually.

Because the iPhone is located at the center of the steering wheel, there remains the safety issue pertaining to airbag deployment in the case of a collision. This can be resolved by attaching a hinge mechanism to allow the iPhone to swing out of the way of the airbag in the case of deployment. The mechanism would be designed to ensure that it does not endanger the driver.

Design 2: Tripod Support System

This design features an iPhone holder attached to the steering column of the car via a Velcro strap and a rigid stand (see Figures 7 and 8).

The iPhone holder is secured by tripod supports on either side, which are anchored on the steering column. Placing the iPhone holder directly above and behind the steering wheel prevents the iPhone from rotating as the steering wheel is turned, while ensuring the airbag is not obstructed in any way. Furthermore, it is within the elevation and distance constraints set, and therefore is comfortable for the client to use.



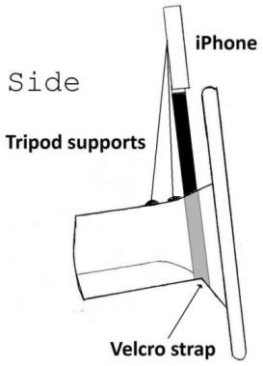


Figure 7: Front (Driver's) View of Tripod Support Design

Figure 8: Side View of Tripod Support Design

The iPhone holder can be attached and removed easily on any car model, provided it has a steering column. The device can be strapped easily to the steering column using the adjustable Velcro straps, and the height of the iPhone can be adjusted by varying the distance of the tripod supports, similar to a camera tripod. The tripod supports are fitted using rubber bottoms to ensure sufficient friction against the steering column, preventing slipping of the iPhone while the car is in motion. The position of the iPhone (vertical or horizontal) can be changed by detaching the holder and reattaching it in the desired position.

One of the greatest advantages of the design is its safety. Because the iPhone holder and all the other components of the design are located behind the steering wheel, there is no chance of the airbag deployment endangering the driver or passengers by ejecting any material in their direction. The versatility of the design and its adaptability to various phone and car models is a bonus too. However, there is a possibility of the device tilting as the car makes a sharp turn due to the centripetal force causing a moment about one of the tripod supports. The device may block the driver's hands while turning the steering wheel as well. However, these issues are specific to different drivers and may be solved by adjusting the position of the Velcro strap or tripod supports on the steering column.

Design 3: Gravity Dependent Spinner

This design uses gravity as a passive response system to keep the iPhone held upright. It consists of a free-spinning stepping motor from a CD-ROM drive attached to a solid flat base (see Figures 9 and 10). This base has Velcro straps attached to it that keep it fixed in the center of the steering wheel. There is a CD fixed to the top of the stepping motor; this CD is weighted at the bottom and has Velcro on the face of the CD facing the driver. Finally, there is a plastic iPhone holder with Velcro on its

back that can attach to the top side of the weighted CD. As the steering wheel turns, the stepping motor axle turns, but since the CD is free-spinning, the weighted CD remains upright and the iPhone remains in the position it is attached in.

Figure 9: Front (Driver's) View of Design 3

Figure 10: Side View of Design 3

This design is very similar to the client's initial concept and therefore really interests him. Since the device is held in the center of the steering wheel, it is in the optimal position for him. It is easily accessible, within arm's length, and at just the right focal point for him. This is crucial because he will use this device repeatedly while driving, and as his MS progresses, he will become more dependent on it. This device will allow him to still be able to drive safely even as his MS progresses.

It is also a very versatile design. The Velcro straps on the base allow for it to be adjusted and fit almost any steering wheel. In addition, any object can potentially be attached to the rotating CD with Velcro, so the design can actually accommodate other smart phones or mobile devices.

The main drawback of this design is safety. Since the design requires it to be mounted to the center of the steering wheel, proper airbag inflation in the event of a collision is an issue. The device has to be designed carefully to ensure it does not interfere with the airbag in any way, nor hampers its life-saving abilities. The device itself should also be securely attached to the car so it does not become a projectile in the case of airbag deployment.

Design Evaluation

Various factors were taken into consideration in evaluating and choosing the final design. The criteria chosen were (in order of importance): client satisfaction, safety, feasibility, cost effectiveness,

marketing potential, and versatility. Weights were assigned to each criterion based on importance, and each design was evaluated based on these weights. Table 1 (below) shows the final design matrix with the scores awarded to each design. Each design could receive a maximum of 100 points.

Criteria	**Weight**	**Solid Arm Support**	**Tripod Support**	**Spinner**
Client Satisfaction	30	15	18	29
Safety	30	15	25	17
Feasibility	15	7	13	14
Cost Effectiveness	10	5	7	5
Marketing Potential	10	4	5	8
Versatility	5	1	4	4
Total	100	47	72	77

Table 1: Design Selection Matrix showing the criteria chosen, assigned weights, and scores of each design in each category with the final total shown at the bottom. The Spinner design scored the highest overall.

Client satisfaction was one of the most important factors to take into consideration, and was thus given a weight of 30. The solid arm support did not stand out as a satisfactory design because the positioning of the arm may be awkward and uncomfortable for the driver. It was therefore given a score of 15. The client expressed interest in the tripod support, but the position of the device was not ideal and would require the client to reach over the wheel while driving, giving the device a score of 18. The spinner was by far the most accurate design based on our client's design requirements. When it was tested, it managed to keep the iPhone stable and upright while the wheel turned, meeting the client's request. This gave the spinner a score of 29.

Safety was also given a weight of 30 because it is an important consideration in any device to be used in moving vehicles. The scenario of a collision and possibly airbag deployment had to be carefully considered and examined. The solid arm support was given a low score of 15 for various reasons. Depending on the rigidity of the arm, the support may partially obstruct the airbag. Also, the driver might be subject to a collision with the device itself. The tripod support is the safest design of the three because its position does not interfere with the wheel or the airbag, giving it a score of 25. The spinner presented similar safety issues to that of the solid arm support. Because it is strapped on the wheel, the spinner might prevent the airbag from deploying properly. However, the problem can be resolved by including a hinge mechanism to allow it to be pushed aside, giving it a slightly higher score of 17.

Given our time constraint, the feasibility of constructing the prototype within the given time frame was important, and was given weight of 15. The solid arm support requires a material capable of

resisting motion, yet flexible enough to be adjustable. This, coupled with the difficulty in constructing the mechanical components of the design, gave the solid arm support a score of 7. The tripod support is relatively simple because it does not have any specific material requirements, and is mechanistically simple, giving it a score of 13. The spinner was awarded the highest score of 14 because the components of the device are readily available, such as a CD-ROM drive.

Cost effectiveness was given a weight of 10. All the designs are currently significantly under the budget of $300, but the solid arm support would be the most expensive design because it requires a rigid material to be fashioned in the desired shape for the device. Therefore, it was given a score of 5. The tripod support utilizes relatively inexpensive components such as rods and straps, giving it a score of 7. The spinner was a slightly more expensive design due to the CD-ROM motor and CD, giving it a score of 5.

The client wishes to eventually market the product, therefore marketing potential had to be taken into consideration and was assigned a weight of 10. The solid arm support is not aesthetically pleasing and did not appear to be a marketable product; therefore it received a score of 4. The tripod support is potentially marketable because it provides a similar function as GPS systems, but for mobile devices. However, it might obstruct the driver's view of the speedometers, giving it a score of 5. The spinner is the closest design to the client's original concept for a marketable product, scoring it at 8.

Versatility is a subset of marketing potential, but was evaluated separately because it was a specific client requirement, so it was given a weight 5. As the client's MS progresses, he will need to change to another car model better suited to his abilities, and possibly another phone model as well. Therefore, the device has to be adaptable to fit different models. The solid arm support was the least versatile design because it is rather specific to steering wheel sizes and dimensions, so it received a score of 1. The tripod support and the spinner are better able to accommodate different vehicles and phone models due to their detachable components, giving them both 4 as their score.

The final design was chosen based on the total scores for each design. As shown in Table 1, the spinner design received the highest score, and is therefore the final design. The tripod support was a close second and may be taken into consideration as a backup design.

Prototype Construction

The first step in building the prototype was acquiring a CD-ROM drive, which was accomplished in the Mechanical Engineering department at the University of Wisconsin-Madison. The stepping motor and one of the circuit boards were extracted from the drive, forming the spinning and rigid backing of

the prototype. Next, a CD was glued to the stepping motor and a black clip was attached to the bottom of the CD, to which the weights were attached. Velcro straps were bought and glued to the corners of the circuit board base, as well as to the CD in a 'T' shape. A plastic iPhone holder was obtained and attached to the CD via Velcro straps glued to the back of it.

This first prototype was tested by the client who gave provided feedback about the convenience and practicality of the device, specifically the angle of tilt of the iPhone and the effectiveness of the weights in keeping the iPhone stationery. Based on his feedback, the prototype will be modified and improvements made to suit his requirements.

Future Work

The remainder of the semester will be dedicated to changing the current prototype according to client feedback. Additional materials such as Velcro and weights may be purchased. The angle of the tilt will be adjusted to keep the iPhone completely vertical as much as possible. Also, the design will be modified to ensure there are no issues with safety and airbag deployment. To test the safety of the device, computer simulations will be performed at the Mechanical Engineering department at the university if possible. Advice from car safety experts and car mechanics will also be obtained in that regard. Finally, all details of the design will be finalized and the finished product will be made aesthetically pleasing and ready to market as a complete product, including a user manual and any safety warnings required.

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Appendix A: Product Design Specifications Report

Problem statement/Function:

Our client, Mr. Jonathan Rubin, is an individual affected by multiple sclerosis (MS) who regularly commutes by car. Because of his condition, he has to maintain his focus while driving. This is especially crucial as he has to use his iPhone 3GS for navigation, calling and reminders while driving. Currently, he has the iPhone taped to the center of the steering wheel. However, this creates a problem every time the steering wheel is turned because the iPhone turns with it. A device to securely mount his iPhone to the steering wheel and allow it to remain upright and independent of the steering wheel movement is required. It should be versatile enough to incorporate other phone or car models should he decide to change to a different car or phone model.

Client requirements:

- Securely attach the iPhone to the steering wheel
    - Be at a convenient angle and elevation for him so he does not get disoriented
    - Be at a suitable distance for him to access the iPhone
- Maintain the iPhone at a vertical or horizontal position regardless of the steering wheel position
    - Position of the iPhone chosen by him
- Allow complete access to the iPhone and the steering wheel while mounted
- Allow charging of the iPhone if required
- Aesthetically pleasing
- Can accommodate a variety of iPhone models
- Can be adapted for use in a variety of car models
- Storable under normal car conditions
    - Temperature between 0°C and 30°C
    - Humidity between 50% and 75%
- Dimensions not exceeding 15cm x 10cm x 1.5cm
- Weight under 150g
- Under $300 budget

1. Physical and Operational Characteristics

a. Performance Requirements: The iPhone holder must secure the device in position on the steering wheel and should allow the driver to change its position. While in operation, the device should be able to stay in the desired horizontal/vertical position regardless of steering wheel motion or position. During use, the electronic device being held should not rotate more than 20^{o} in either direction about the axis coming out of the steering wheel while the steering wheel is being turned.

b. *Safety*: The product should not pose a safety risk to the driver or any passengers. It should not distract the drivers in any way while driving. A warning label should be placed on the device to ensure that drivers focus on the road and do not operate the device while the car is in motion.

c. *Accuracy and Reliability:* The model should securely stay in place and in the right orientation on the steering wheel as the driver turns the wheel. The model should not protrude out from the steering wheel beyond 5cm. The device should be able to maintain true vertical or horizontal position and stay within 20° of it when the steering wheel turns. Any adhesive used to attach the model on the wheel should be strong but removable should the client need to remove it. The model should ultimately be functional for various models of iPhone and other smart phones as well.

d. *Life in Service*: The model should be able to withstand normal usage, and should not fall off the steering wheel if the driver touches it. The model should be able to withstand all temperature conditions in the car, such as extreme cold during the winter (0°C) and heat in the summer (30°C). Any adhesive and components used should not change properties in such conditions. The holder must be able to withstand at least one year's worth of driving or 50,000km of driving distance, with the bearings and rotating mechanism being able to handle hundreds of possible turns during every use.

e. *Shelf Life*: Because there are no biodegradable parts in the model, it should have a shelf life of at least 10 years, excluding any adhesive used. Once installed on the steering wheel, the device should last at least 6 months of driving under normal conditions or until the client decides to remove it.

f. *Operating Environment:* The device will be used on the steering wheel of a car. Therefore, it must be able to handle the range of temperatures found inside a car during any season. However, if the model proves to be more versatile enough, it can work for other motor vehicles such as bikes or scooters provided the operating conditions are similar to inside a car. Adapting the design to external environments is an option that can be explored later.

g. *Ergonomics*: The device holder should allow for easy access to the entire screen of any iPhone model and allow for charging without the cord being an obstruction. The device should be held at an angle that does not block or obstruct access to the screen. The holder must not catch on the user's clothes or other items. Finally, the holder should allow for devices to be held stationary both vertically or horizontally.

h. *Size*: The dimensions of the device should be within 15cm x 10cm x 1.5cm. If the holder is detachable from the base, it should be no more than 1 cm thicker on any side than the iPhone itself. The entire device, including the iPhone, should not extend more than 5 cm from the steering wheel's center.

i. *Weight*: The entire device should weight no more than 500g, including the iPhone itself, which weighs approximately 135g.

j. *Materials*: The device should consist only of lightweight materials. Glass, sharp metals, and toxic substances should not be present in the device. In addition, the materials used should be able to withstand the temperature range of 0°C to 30°C.

k. *Aesthetics, Appearance, and Finish*: The final design should be aesthetically pleasing and have a professional minimalistic finish. It should be smooth and glossy and be as monochromatic as possible.

2. Production Characteristics

a. *Quantity*: At the present time the client only requires one device, but is aiming to market the product in the future, so production ease is a factor to be considered.

b. *Target Product Cost*: The marginal cost of production of the device will be approximately $20-$25. Compared to the average cost of a stationary iPhone holder ($14.97), the device is about $5-$10 more expensive, which will be worth the added advantages it brings.

3. Miscellaneous

a. *Standards and Specifications*: This model will not require any approval by the FDA because it is not a medical device, food-related, or a radiation emitting device. However, the Wisconsin state law prohibits any texting while driving or "being so engaged or occupied as to interfere with the safe driving of that vehicle." Therefore, a warning label or disclaimer is required on the device. Also, there may be safety issues related to the airbag deployment if the device is attached directly in front of the steering wheel in the way of the airbag.

b. *Customer*: Our client has multiple sclerosis (MS) that causes hypersensitivity in his vision and disorientation by excessive head turning. The product must be secured directly in front of him and be able to rotate smoothly without wobbling as the wheel is turned, keeping the iPhone upright.

c. *Patient-related concerns*: This product will not be in contact with any patient or research subjects except the client himself and his family members in the car.

d. *Competition*: There is no present model for a self-correcting iPhone holder in cars. Various stationary iPhone holders range from $5-$30 and may include an adjustable neck to adjust the height of the iPhone as needed.