Monkey Restraint Device

Department of Biomedical Engineering
University of Wisconsin, Madison
December 7, 2003

By: Miguel Benson, Ka Wai Chan, Brian Frederick, Ross Gerber, Amanindera Ghotra, and Kelly Toy

Client: B'Ann Gabelt, Associate Scientist
UW-Clinic, Ophthalmology Department

Advisor: Willis Tompkins, PhD

Abstract: Our client does glaucoma research that requires administering eye drops to rhesus monkeys. The monkeys are active and strong, making them difficult to fully restrain. The administration of eye drops is particularly difficult because the monkeys are able to duck their chins and cover their eyes. As a result, our client asked us to design an apparatus that would restrain the monkey to make the procedure less time consuming. Moreover, our client needs the apparatus to be user-friendly and be compatible with the current cage in which the monkeys are treated and restrained. Keeping our clients requirements in mind and after brainstorming possible designs, we came up with a chinstrap design that would conceivably restrain monkey's chin. Upon implementation of the prototype, several design flaws were made prevalent. Another design was created to account for these pitfalls; however, there was not enough time to construct this design.

Introduction

Scientists know more about the rhesus macaque monkey (*Macaca mulatta*) than any other nonhuman primate. Research involving these monkeys has yielded some of the most important medical accomplishments of the last 50 years (Philipkoski, 2003). Biological, medicinal, and physiological research has taken advantage of the fact that rhesus monkeys are more than 95% genetically similar to humans. These fields continue to utilize the rhesus for studies ranging from learning and behavior, to bioterrorism anthrax defense.

Our client, B'Ann Gabelt, is conducting three types of studies. Two of the studies are designed to learn more about how certain drugs and procedures affect patients with glaucoma. The third study examines the mechanism that causes humans to lose their ability to focus as they get older. Monkeys undergo the same changes in their eyes, and are an excellent model for the human condition. A large part of these studies involves administering eye drops to the monkeys. This can become quite difficult with certain monkeys, which is why certain restraint systems are used.

Background Information

There are many techniques used for restraining nonhuman primates in experimentation. Depending on the experiment, no restraint may be needed at all. A simple intravenous injection is easily done without a restraint, provided the monkeys receive a reward (Figure 1). For more intensive treatments that necessitate complete immobility of the animal, complex restraints must be used (Figure 2). These restraints generally require that the monkey be sedated or anesthetized prior to restraint, so that the monkey can be placed in the restraint without harm to the animal or the animal handlers. However, sedation often times is not an option if the sedative causes an interference with the study at hand. In these cases, alternative methods must be invented to restrain the monkeys for experimentation.

Figure 1: Monkey receiving intravenous injection without restraints

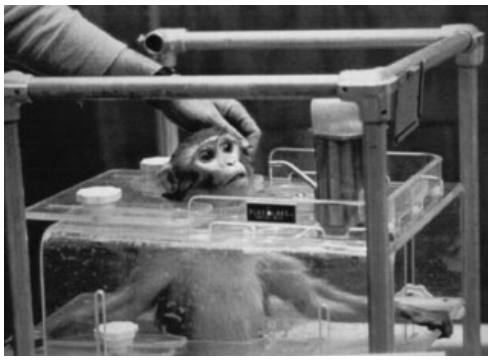

Figure 2: Monkey in complete restraint

For Gabelt's studies, the eye drop administration process is often performed daily, and habitual sedation is not an option. Gabelt received a custom-made monkey restraint device from the Wisconsin Regional Primate Research Center that optimally restrains the monkeys without sedating them. (Figure 3-b)

The monkey is transported from a squeeze-back transportation cage to the restraint device. A squeeze-back cage is equipped with a special back panel that can be moved forward to guide a monkey out of the cage (Figure 3-a). Once the monkey is fully in the Iron Maiden, the device is flipped up into a vertical position (Figures 3 and 4).

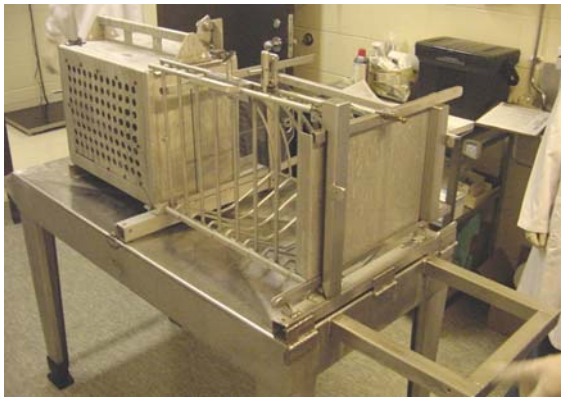

Figure 3: Treatment cage (B) with push back transport cage (A). Here the cage is fully open.

The cage can be adjusted to fit the various sized monkeys, 3.5-12 kg, in order to somewhat restrict their movement (Figure 4). At this point the monkey would be in an upright position, with the lab worker standing behind it. In order to effectively administer the eye drops, the monkey's head must be tilted back. The lab worker reaches through the bars of the cage and holds the monkey's head back by grabbing and holding onto the fur on the back of its head with one hand. With the other hand, the lab worker can then administer the eye drops.

Figure 4: Treatment cage in vertical position. Here the cage is nearly fully closed.

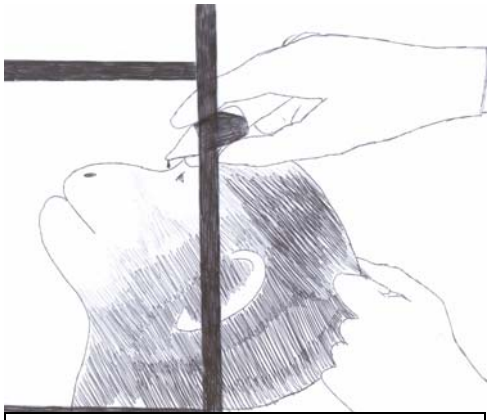

Figure 5: Topical administration of eye drops.

Design Problem:

While the lab worker is administering the eye drops, he or she faces a few obstacles. First, some monkeys tend to be very active and forcibly avoid receiving eye drops. Second, the

monkey's hands are not secured in place, and the monkeys are able to cover their eyes with their hands. Furthermore, the very sharp finger nails of a monkey pose a very serious threat to the researchers. Some monkeys carry the herpes B virus, which can be easily transmitted to a lab worker if the monkey scratches him or her with its nails. By the time the lab worker moves the arms out of the way and grabs the eyedropper once again, the monkey again has the chance to cover its eyes. The monkey's free use of hands makes the procedure cumbersome and time consuming. Third, monkeys tend to tuck their chins in as the lab worker tries to pull the monkey's head back to administer the eye drops. If the monkey continues to tuck its chin it becomes very difficult for the researchers to tilt the monkey's head back due to the fact that an active monkey can be as strong as an average human.

Keeping all the obstacles faced by the lab worker in mind, our client would like us to make the procedure efficient by developing a method of restraining a monkey's head in conjunction with the existing monkey restraint device.

Design Constraints:

The most important constraint on our design is that it must be compatible with the current cage in which the monkeys are treated. This means the depth (d) of our design must be within 8 to 25 cm (Figure 6) and the width (w) must be within 10 to 25 cm (Figure 7). Also, the design must be able to restrain monkeys of various heights (h) ranging from 30 to 60 cm (see Figure 7).

Safety must also be considered when working with the monkeys. Since monkeys can transmit herpes B by simply breaking the skin of a researcher, we need to develop a

design that minimizes the amount of time the lab worker spends with his or her hands in front of the monkey. Along with the lab worker, monkeys must also be comfortable with any device that is forcibly applied to them; it must not harm the monkey in any way during the procedure.

To keep the restraint disease free, it must undergo machine wash. This would mean that any metal used in the chinstrap must not corrode, and that any materials used would not denature at a temperature of 121^{o}F. Moreover, the chinstrap must be able to withstand forces larger than the monkey can exert on it.

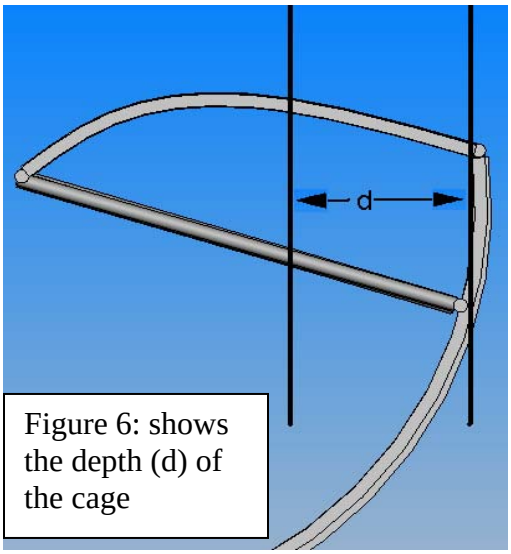

Figure 6: shows the depth (d) of the cage

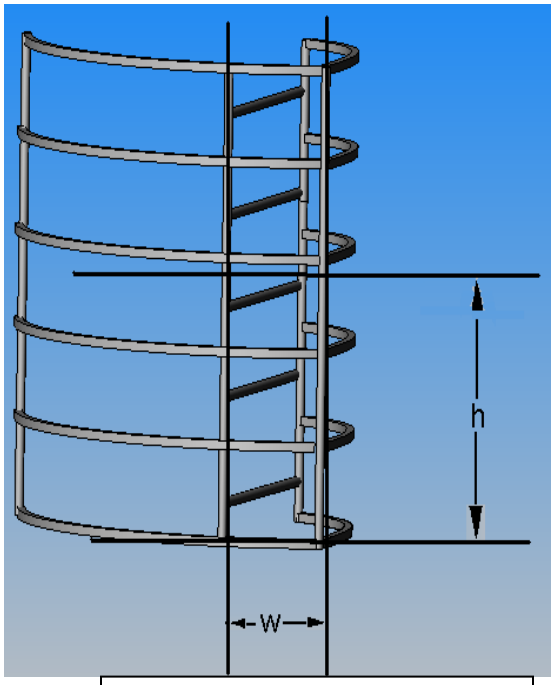

Figure 7: shows the width (w) and the height (h) of the cage

This means that the chinstrap must be made of durable materials that will withstand excessive forces and not break or deform (see PDS for details).

Lastly, the design must be user-friendly and non time-consuming. It must be operable by one person and minimize the time it takes to administer the eye drops.

Alternative Solutions:

Confronted with these design constraints, the group initially brainstormed several different methods that could solve the problems at hand and came up with the following designs: U-Cup and Pin, Chinstrap and Arm rest.

Design #1: U-Cup and Pin

This design is a device referred to as the U-Cup and Pin. As the name implies, this device consists of a U-shaped cup that fits between the neck and jaw of the monkey (Figure 8). The U-Cup is made of thick metal that will be symmetric with respect to monkey's chin. A solid plastic rod is inserted in the holes of U-cup on both sides. The plastic rod can be placed at various increments along the back of the cage to accommodate different sized subjects.

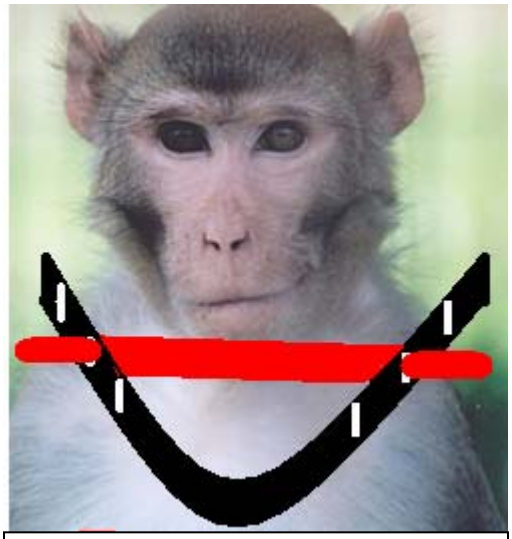

Figure 8: U-Cup on monkey

The device will safely secure the monkey's head, as well as slightly tilt its head to make administering eye drops procedure easier. This design is relatively cheap to make since it only consists of two parts: a plastic bar and metal U-Cup. However, there is a disadvantage to this design. If the monkey does not cooperate with the lab worker, it may be hard to feed the pin through the holes. This may delay the procedure by making the lab worker wait until the monkey calms down. Also, the monkey's hands are still free. Although this device will keep the monkey's head in place, the monkey may at times try to cover its eyes and resist getting eye drops.

Design #2: The Chin Strap

Our second design is called the chinstrap. As the name implies, it consists of a strap, with two hooks and adjustable bindings that have ratchets on the side. These ratchets can be adjusted with a small knob on the side to fit a monkey of any height and head size. This design is similar to design one, but it is more sophisticated in that it has adjustable devices (i.e. ratchets).

This design has a lot of good features. It is relatively cheap to make because it consists of few screws and bolts, two bindings (indicated by black topped cylinders), two ratchets and a chinstrap (indicated by green color). All of these parts can be found easily. Besides being cost efficient, this design conforms to the cage that is used to treat the monkeys. The hooks and the ratchets take into account the heights and various chin shapes of the monkeys. As seen in figure 9, this design is user friendly. Once it is in the cage, it would take only a few seconds to place the strap around monkey's chin. The chinstrap will be in tension once it is around the monkey's chin and will prevent the monkey from tucking its chin down.

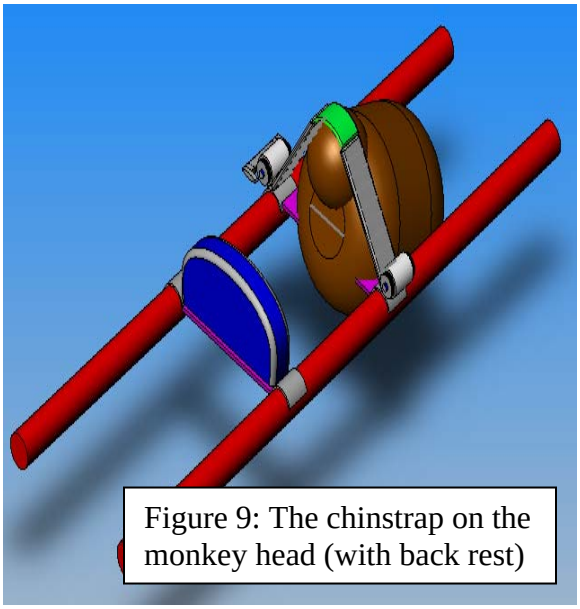

Figure 9: The chinstrap on the monkey head (with back rest)

The disadvantage of this design is that the hands are not secured. The monkey can, therefore, use its hands to take the chinstrap off or cover its eyes. Also, the strap may not conform to the shape of all monkeys: an ill fitting chinstrap could come off if the monkey forcefully moves its head in the cage.

Design #3: The Arm Restraint

The purpose of this design is to give the handler of the monkey a higher degree of safety while administering the eye drops (Figure 10). The hole in this wide plastic sheet would allow just enough room for the monkey's head to project, but the width of the design (~ 35 x 25 x 4 cm) would keep the monkey's hands below the sheet so that the scientist administering the eye drops would not have to worry about the monkey's flailing arms. If the scientist doesn't have to worry about dodging sharp finger nails, the eye drops can be administered quicker, and the monkey can spend minimal time in restraints.

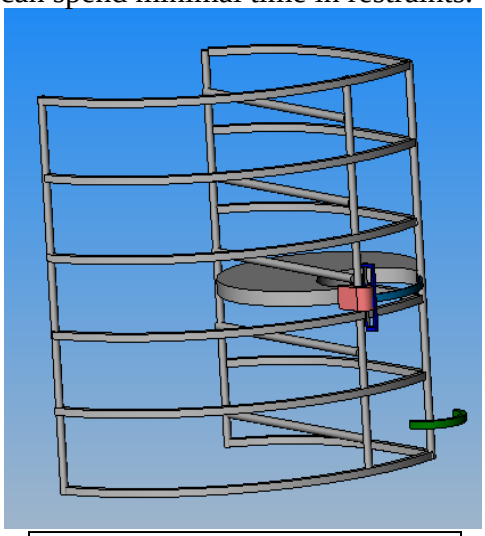

Figure 10: Technical drawing of the arm restraint design

This restraint design would be made of polycarbonate, a high density, tough plastic that could withstand the wear and tear of monkey abuse. It would be designed to be large enough to safely protect the scientist, but slender enough to fit inside the bars of the treatment cage, so that it could be locked in place near the body of the monkey. Unfortunately, this design cannot stop the monkey from tucking its chin. It would still have the freedom about its neck to duck its head and avoid the eye drops.

Analysis of Designs

Generally, the most important factor of design evaluation is cost. However, none of our designs would conceivably exceed our $200 budget. Furthermore, all of our possible prototypes would ideally cooperate with the current restraint device. Therefore,

we had several special guidelines that we used to help determine which design was optimal.

Because we were working with two such variable items— a live monkey and an intricate, size-varying restraint —we felt that the most important part of our project was to quickly make a prototype and implement it into the cage to see how it worked. By doing this we could then learn the positive and negative aspects of each prototype, further improving our product development after each design. This concept was important because we did not have easy access to the restraint device. Measurements and pictures of the restraint would not be nearly as helpful as visualizing the implementation of a prototype. This is especially true, because we were modifying a methodology as well as a restraint. Therefore we developed two subjective criteria that would lay the foundation for our first prototype: effectiveness, and ease of construction.

We felt that we should choose what we thought would be the most effective design, despite the fact that we did not necessarily know which design would work best with the monkeys. We decided that the design having the most strength in restraining the monkey's head in the easiest fashion would be most effective. The Arm Restraint offered little if any head restraint: the monkeys would still be at liberty to duck their chin down. The U-Cup and Pin offered more head restraint than the Arm Restraint, but would have a very limited range to which it could tilt the monkey's head upward. We felt that the Chin Strap, with its ratcheting effect, would easily have the most mechanical strength to combat the notably strong monkeys.

Midway through the semester, none of our designs seemed particularly difficult to build: all of them seemed to have relatively basic and accessible parts. Using these

criteria, a design matrix could be used to help determine the best design (Table 1). As the design matrix indicates, we felt our best design was the chin strap. We felt that, despite

Criteria	Weight	Datum	Design 1--U-Cup and Pin	Design 2--Chin Strap	Design 3--Arm Restraint
Cost	1	S	+	+	+
Operable by 1 Person	2	S	S	S	S
Compatible with cage	2	S	S	S	S
Effective Restraint	3	S	S	+	-
Easy to make	3	S	S	S	S
Total			1	2	0
Weighted Total			1	4	-2

Table 1: The design matrix indicates that the best design is the Chin Strap.

any difficulties that could arise when applying the chin restraint to the cage and using it on a monkey, our best option was to pursue this design, and learn from any flaws that would arise.

Selection of Final Design

After selecting our design, the next step was to collect the appropriate components for assembly. Ratchets and ladders were relatively easy to obtain; although inexpensive on the internet, we were able to obtain bindings from Rick's Water Sports for very cheap (Price Chart, Appendix B). We purchased two snowboard bindings that were each 21 cm in length (Figure 11). What we thought would be a simple task—attaching the chin strap to the cage—proved to be very difficult. We initially wanted to be able to fix them in place

Figure 11: Chin strap prototype (shown with ruler)

with some sort of c-clamp: this way a simple twist of the wrist could raise or lower the ratchets and chin strap (Figure 12). However, we could not find a c-clamp that would appropriately attach to a ratchet. Additionally, the c-clamps would have protruded into the back of the monkey. We ended up purchasing two 6.5 cm hooks, and bolted them to the ratchets. For a chin strap we used the shoulder pad from an old suitcase strap (6 cm x 16 cm). To assemble our chin strap, we bolted each hook to a ratchet and bolted the two ladders together. We then slid the ladders through the chin strap, and fed them through the ratchets to obtain a variable level of tightness.

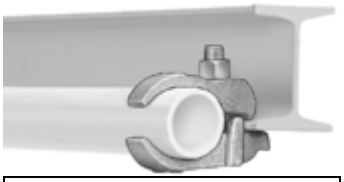

Figure 12 Alternative to a hook.

Several problems arose regarding the construction of the prototype, so alterations had to be made. The bolt heads connecting the hooks to the ratchets were interfering with the movement of the ladders; we were able to grind them down so that they did not interfere. It was also noted that the prototype seemed to long, and that it would not tightly hold a monkey's head. To account for this, we trimmed the hooks so that that the prototype length was shortened.

Analysis of Prototype

Once our Chin Strap design was implemented in the treatment cage we were able to learn a lot about it. We saw that our design was too big for the cage, it was difficult to put it around the cage with one hand, and the cage's shape further impeded our design's performance.

As our design was inserted in the cage, it was fairly difficult to fit the design in between the staggered bars of the cage because of chinstrap's large size. It would not be

reasonable to attempt to try to slide the chin strap through the bars of the cage while a potentially dangerous monkey was in it.

Moreover, our design was also difficult to adjust with just one hand, which is necessary when a monkey is in the cage. The actual chin strap is also much too large for a smaller monkey; it is large enough to cover its whole face. Because the chin strap design does not restrain arm movement, the device would be easily pushed away by the monkey unless hooked onto the cage. As our client pointed out, restraint of both the head and the arms would make the procedure more efficient.

Figure 13: Prototype as seen attached to monkey restraint

Failure of our prototype' performance can be attributed to the awkward shape of the transport cage. Though our chin strap is adjustable, it did not account for the large variability in size of the cage. The cage is non-symmetric, which made it difficult to find a secure place to attach the restraint. The cage is awkwardly built with a handle that would interfere with securing the chin strap at lower levels (see arrow fig. 13). The cage can also vary in range of widths (10 to 25 cm) and depths (8 to 25 cm) that our design could not fully adjust to.

Conclusion and Future Works:

Because of these negative aspects of our prototype, we combined what we had learned from our previous design ideas and came up with an alternate design. By

addressing the individual flaws of the chin strap, this new design could solve all of the problems we had with the prototype.

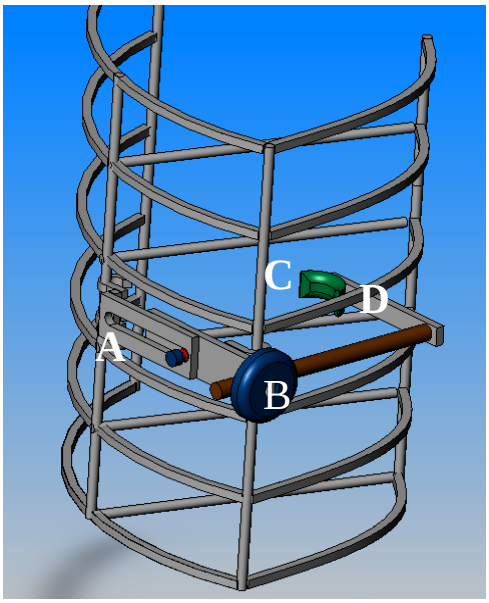

Figure 14: Side View of future prototype

This design consists of a sliding bar (A) that hooks across the back of the cage, a geared dial (B) that adjusts the distance of the chin support (C) from the back of the cage, and a right-angled bar (D) that holds the chin support in front of the monkey's head (figure 14 & 15).

After the monkey is trapped in the cage the researcher can hook the device to the cage at an appropriate height to accommodate the monkey. Then the researcher can adjust the sliding bar to fit the width of the cage. Next, the researcher can pull the monkey's head back to raise the chin, while adjusting the dial to position the chin support so that the monkey's head is tightly restrained.

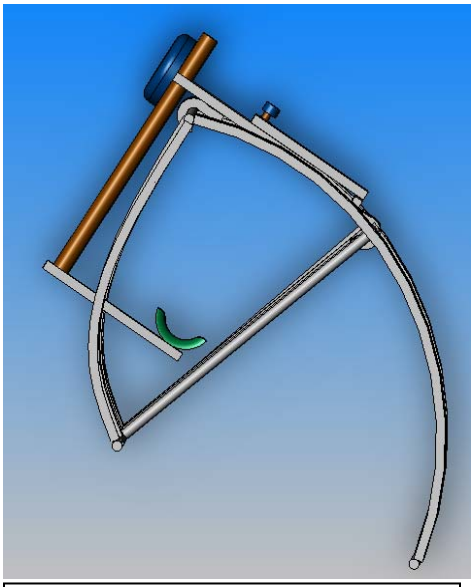

Figure 15: Top view of future prototype

This design succeeds in the sense that the researcher does not need to reach over or around the cage, or near the monkey's face to apply the device—thus keeping the researcher safe. This device also firmly secures the monkey's head without hurting it. The geared dial provides strong mechanical restraint over the monkey: when in the locked position the monkey would be unable to push the restraint away. The hooks

featured in this design are thinner than in the chin strap, but have a large radius of curvature. This feature allows the hooks to fit in smaller places, and also allow them to hook around bulky processes.

Because with this design the researcher does not have to reach near the monkey, the design does not intrinsically restrain the arms. To solve this we can incorporate the previous idea of the arm restraint. The arm restraint system can be hooked up first, giving the researcher the freedom to work without having to look out for its hands. Also this can prevent the monkey from holding the chin support and the right-angled bar away from its face.

Ethics:

Since we were dealing directly with primates, ethics was an important part of our project. With each design that we considered, we had to make sure that it would restrain the monkey in a humane fashion. Any restraint that we designed had to fit the guidelines of our client's lab that are set by the Research Animal Resources Center (RARC) on campus. The RARC follows a guide called the Guide for the Care and Use of Laboratory Animals. According to this guide "restraint devices should be suitable in size, design, and operation to minimize discomfort or injury to the animal" (Guide, 1996). Restraint devices should only be used when they aid in accomplishing research goals by making the procedure more efficient.

Keeping these rules in mind, we needed to design a restraint that would speed up the treatment process without causing any harm to the monkey physically. The bolts and hooks used in our Chin Strap design needed to be arranged in such a way that they would

not scratch or cut the monkey. Moreover, we needed to minimize the discomfort the monkey may feel during the procedure by using a chin strap that would provide firm but soft support. The strap should contain padding to provide comfort, but it must also be durable enough to withstand a monkey's force.

References:

Budkie, M.A. Institutional Animal Care and Use Committee. 1999. "What researchers say isn't always what they do…" Accessed: 09/26/03. URL: http://www.animalsvoice.com/PAGES/invest/budkie.html

Guide for the Care and Use of Laboratory Animals. 2002. UW-Madison Research Animals Resource Center. Acessed: 11/18/03. URL: http://www.rarc.wisc.edu

Philipkoski, K. Americans for Medical Progress. "Research's need for rhesus macaque monkeys grows." *Wired News*. Accessed: 09/30/03. URL: http://www.amprogress.org/News/News.cfm?ID=566&c=62.

Reinhardt, V. 1992. "Improved handling of rhesus monkeys." Accessed: 09/29/03. URL: http://www.awionline.org/Lab_animals/biblio/bond.htm

Singapore Zoological Gardens Docents. 2000. "Rhesus macaque (macaca mulatta)." Accessed: 10/05/03. URL: http://www.szgdocent.org/pp/p-mcrhes.htm

Appendix 1:

Product Design Specification

Function: To develop a method of modifying the existing monkey restraint device to effectively restrain a monkey's head or neck to simplify the administration of eye drops.

Client Requirements:

- Restrain the head of the monkey
- Be compatible with existing restraint device
- Work with various sized monkeys
- Not harm the monkey physically
- Be stationary and not require one to hold it while giving treatment

Design Requirements:

1. Physical and Operational Characteristics

a. Performance Requirements: It will be used at least 10 times a day for the whole year. It must be flexible; it should be able to hold and restrain monkeys of various sizes. The height of the monkeys can range anywhere from 65 to 100 cm and they can weigh anywhere from 3.5 to 11 kg. The device should not hinder the treatment and should be small as possible. **Material should be resistant to monkey claws.**

b. Safety: The device should be comfortable for the monkey otherwise the monkey may react negatively and compromise the treatment process. It

should be strong and have no sharp edges that may cause physical harm to the monkey. As witnessed, monkeys at times can be very aggressive and strong. The device should follow the “animal humane” requirements and must not be harmful physically or psychologically to the monkey.

c. Accuracy and Reliability: The device needs to be compatible with various monkeys, so it should be adjustable for monkeys of various sizes (65-100 cm) and weights (3.5-11 kg).

d. Life in Service: The device will be used on a regular basis. It will be used daily for at least five hours a day and five days a week. It will be kept in one place, the treatment room.

e. Shelf Life: The device must operate under extreme forces and loads. The monkeys may at times be aggressive, so it is imperative that the device is capable of withstanding monkey’s force. Since it will be used regularly, the device must be made of durable material.

f. Operating Environment:

i. Temperature Range: 25 degrees Celsius

ii. Pressure Range: 4 GPM at 20 PSI

iii. Dirt or Dust: very dirty environment.

iv. User: Must be user friendly to people of all sizes and strengths.

g. Ergonomics: The device must be very flexible. It should be compatible with monkeys of various sizes. The device must not need more than a one person to operate. It should be easily adjusted while

wearing latex gloves.

h. Size: The size of the device must correlate with the pre-existing monkey restraint cage. Additionally, it should accommodate 3.5-11 kg monkeys. The device must fit through the treatment cage and removed easily at the end of the treatment.

i. Weight: It should not weigh more than three pounds.

j. Materials: The materials used must be non-toxic, rigid (able to withstand strength of monkeys), tough (able to withstand scratching from monkeys), easily sanitized and nonabrasive.

k. Aesthetics: No bright colors that will scare the monkey. Device must fit around the upper region of the monkey easily.

2. Production Characteristics

a. Quantity: Only one unit is needed.

b. Target Product Cost: The device must cost less than $200.

3. Miscellaneous

a. Standards and Specifications: Probably need some type of approval from the animal rights activists (RARC). Since the device is being used to restrain the monkeys, it must be checked to see whether it is humane or not.

b. Customer: Because this monkey restraint device can be used only with the treatment cage used by our client, it would be impossible to market to other customers.

c. Animal-related concerns: Confidentiality of all processes occurring in Ophthalmology Department involving monkeys is extremely important to our client. Public discussion of this device and the monkeys must be restricted.

d. Competition: No current comparable product has been found or used.

Appendix 2:

Price List

Item	Cost	Quantity
Ratchets	$1.50	2
Ladders	$1.00	2
Hooks	$1.75	2
Screw and Bolts	$0.35	4
Chin Strap	$2.00	1
Total	$11.90	