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Abstract

Primate testing is essential in the medical field. Variables such as motor skills can be easily generalized back to humans, but the results are only as reliable as the test. Currently, the devices used tend to be too cognitively challenging. The photodiodes used to measure time become dirty easily, which causes them to fail. The devices are complicated, and difficult to clean properly. Additionally, the software used to record results is overly complicated.

Our client, Dr. Marina Emborg, asked us to design a device to test the fine motor skills in rhesus monkeys. We evaluated three different design ideas, selected one, and proceeded to build a prototype of our chosen design. Currently the prototype is limited to the simple testing apparatus that attaches to the cage, with the possibility of a future team carrying on the project to complete the electrical components of the device.

Introduction

Our client, Dr. Marina Emborg, studies Parkinson's disease, a degenerative neurological condition that results in many devastating symptoms, such as tremor, bradykinesia (slow movement), hypokinesia (diminished movement), and balance and gait disturbances (Emborg, 2004; Wikipedia, 2006). In order to study the effects of the disease and possible treatments, she performs tests on primates. Specifically, she measures the amount of time it takes a monkey to retrieve a food reward from the testing apparatus. By measuring the motor skills in monkeys that exhibit symptoms similar to the disease, Dr. Emborg is able monitor its progression, administer a treatment, and test to see its effectiveness.

I. Current Products

Figure 1: Researcher demonstrates testing using mMAP device.

Dr. Emborg currently utilizes a device called the Monkey Movement Analysis Panel, or mMAP, to perform motor skills testing on rhesus monkeys. The mMAP was developed by the University of Kentucky Medical Center in Lexington, KY (Grodin and Wang, 2000). Specifically, the mMAP measures the speed of coarse and fine motor movement of the monkeys' hands and arms. The device is made of clear Lexan and attaches to the front door of the monkey's cage. The current product allows researchers to test a specific arm.

To test the monkeys' motor skills, the researcher places a small food reward at the center of the device. The monkey then retrieves the reward by guiding its arm through two separate holes in the mMAP (Figure 1). Three photodiodes at each hole measure the amount of time the monkey takes to grab the food. Another physical aspect to this device is the armhole portal door. The first hole the monkey places its hand through has a door that the researcher can close between tests (Grodin and Wang, 2000).

Another device currently in use in other research labs is a detached design. This device is not attached to the monkey's cage, but instead it sits in front of the cage. The detached design consists of a base platform with eighteen divots, nine on each side (Figure 2). In the center is a clear plastic divider to encourage the monkey to use either the right or left hand to retrieve the food reward placed in the divots. Because this device does not have a photodiode system, the data that the device gives is qualitative, not quantitative.

II. Project Motivation

Current devices used to measure motor skills of primates are expensive. Due to the design of the mMAP, the photodiodes used to measure time are difficult to clean. When they become dirty, the signal fails, resulting in poor results. It is also imperative that any device designed to test motor skills minimizes the cognitive portion of the task. Any time spent figuring out *how* to complete a task interferes with results meant to indicate time spent *performing* the task. Dr. Emborg is also unhappy with the current device with respect to this aspect, and would like us to design an apparatus that would further minimize cognitive problem solving (Emborg, 2006).

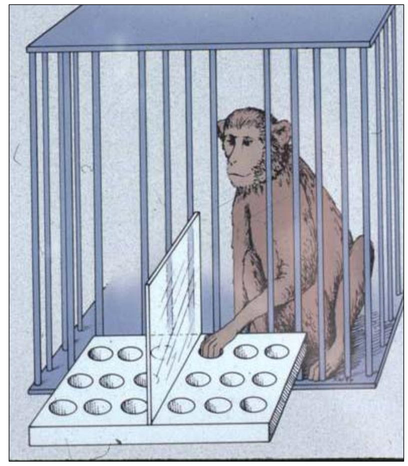

Figure 2: Detached design

III. Client Design Requirements

The apparatus we are designing needs to be easy to clean. It will be used in testing with both monkeys and food rewards, and a clean environment is important for health purposes. The design should facilitate cleaning of the photodiodes as well, so there is nothing obstructing the signal and interfering with the data collected. The device also needs to be less cognitive than the current design in order to test motor skills instead of the time it takes for the monkeys to figure out how to reach the food. The device should ideally be adaptable for human motor skill testing to aid in future research. It should be durable and attach securely to the cage. The device must attach to an “adapter panel” that must be 13” X 15.75” in order to fit into the cage door. The device will ideally be smaller than the adapter panel. The holes that the monkey will reach through in the device and the adapter panel to retrieve the food reward should be no less than 3” in diameter.

IV. Design Alternatives

In each of the design alternatives, similar photodiode systems are used to measure time spent completing the task, as well as facilitate easy cleaning to promote a clear signal. Along the outside of each sensory hole there will be photodiodes to monitor motion of the monkey’s hand as it passes through. In order to keep the photodiodes clean, they will be covered with a clear, durable material that will allow for easy cleaning.

The device chosen will be made from a durable, transparent material, such as Plexiglas. The client has provided a large budget that will allow for the use of an alternative to Plexiglas, such as Lexan. Lexan is more expensive, but may be used to promote cleaner cuts during the manufacturing process. The material should be easy to clean and durable enough to withstand daily abuse from the monkeys. The material chosen should be compatible with any cleaning solvents that may be used.

Hinged Box Design

The hinged box design would attach securely to the cage and the monkey would reach its hand through two holes to attain the reward (Figure 3). The first hole leads just outside the cage, and the second goes into a box. The reward would be placed to either side of the second hole to test each hand individually. The top of the box is placed on hinges. This would allow for easy reset of the device, as well as quick cleaning. Because of the hinged design, the top of the box must be latched securely before the monkey would be allowed to attempt the task. If this is not done, the monkey could grab the top of the device and possibly pinch fingers or otherwise injure itself.

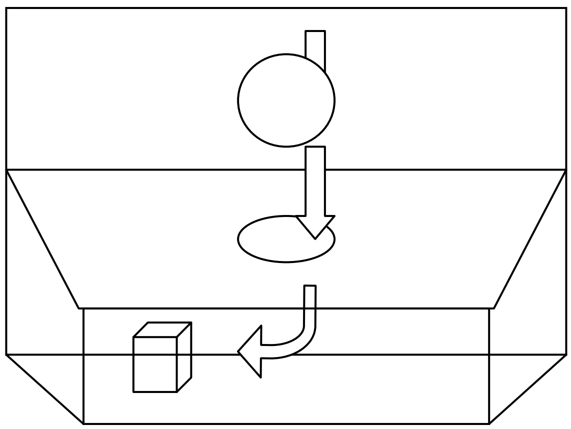

Figure 3: Hinged box design

In order to standardize position of the reward, thus standardizing results, the device would also include small wells on the bottom of the box. This would be where the reward would be placed. It is important that the wells are not made too deep, as many of the older monkeys are missing digits. As a result, it is difficult for them to retrieve rewards from deep wells, and this would compromise results for motor skills.

There are many advantages to this design. Because of the set-up, there would be very little cognitive challenge expected. The device is fairly simple, and would be easy to manufacture. Also, with the hinges on the top of the box, clean up and reset of the device would be fast and easy.

There are, however, several important disadvantages to this design. Although it is quite simple, the motion required of the monkey to retrieve the reward may be physically impossible. Additionally, due to its compact design, this alternative would be difficult to adapt to human

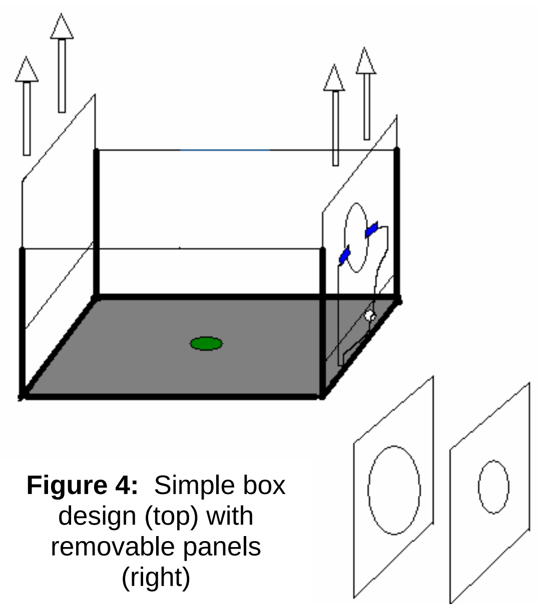

Figure 4: Simple box design (top) with removable panels (right)

testing, should the need arise.

Simple Box Design

The simple box design consists of a box with removable side panels. These removable panels would allow the researcher to conduct either right- or left-handed testing of the monkey by placing the panel with the hole on the desired side (Figure 4). We would also build an alternative side panel with a larger hole to allow the device to be used for human testing. In this design, the food reward would be placed in the center bottom of the box. The device is placed as shown in Figure 4, with a non-removable panel facing the monkey. The monkey would guide its hand to the side of the device and through the hole in the removable side panel to retrieve the food, which will sit in a small well.

This design has many advantages over the current product. First, it would be less cognitively-based; it would test the monkeys' physical abilities instead of its mental abilities. Second, it would be easier to clean because the panels would be removable. This design would also be readily adaptable to human testing with the alternative side panel.

There are, however, disadvantages in this design that must be considered. Because the panels would be removable, they would need to be fastened down so the monkeys would not disturb them. If not, the monkey may interfere with the photodiode system.

Staggered Box Design

The staggered box design consists of two holes with sensors that are slightly staggered in parallel walls. This would create a diagonal path for the monkey to reach the food reward (Figure 5). The path would be directly in front of the monkey, as shown in Figure 5, with only a slight curve to encourage the use of a specified arm. This approach would reduce the cognitive aspect of the test, because the path to the food is more intuitive. The device would also contain a shallow, central well for the food to standardize testing.

The staggered box design has several advantages. It would be easy to clean because of the open top. It would also provide less cognitive challenge than the apparatus currently being used. Additionally, it is a simple design that would be very easy to build.

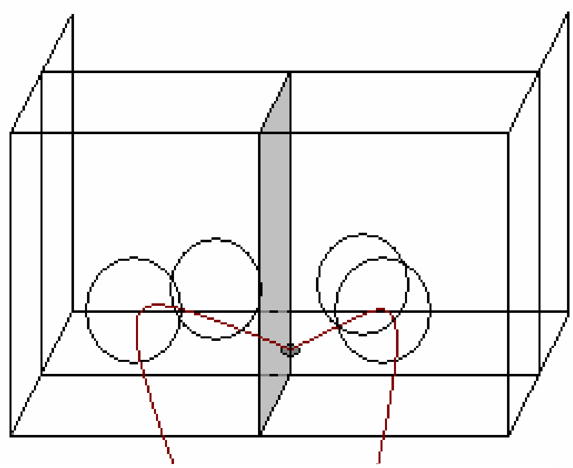

Figure 5: Staggered box design

The disadvantage to this design is that the path to the food would be so direct, it may not force the monkey to use the specified arm.

V. Design Matrix

After the advantages and disadvantages of each of the proposed designs were considered, a design matrix was created to evaluate each design qualitatively and to help decide which design to proceed with.

Table 1*:* Design Matrix

Design Alternatives	Cognitive Simplicity (1-10)	Ergonomics (1-10)	Adaptability for human testing (1-5)	Total Points (3-25)
Hinged Box	8	5	1	14
Simple Box	8	9	5	22
Staggered Box	9	9	1	19

Several criteria were used to evaluate the design, with the more important criteria weighted more heavily (see Table 1). The two categories weighted the most important are cognitive simplicity and ergonomics of the potential design. These categories are weighted highest because they are among the most important design specifications. It is important to Dr. Emborg that the tester is less cognitively challenging than her current product. The tester also needs to be able to test each of the monkeys' hands separately, and it must be physically feasible for the monkey to bend his arm through the holes. Also, Dr. Emborg would like the tester to be adaptable for human testing. The highest score that a design could receive on this scale is twenty-five points and the lowest that it could receive is three points. Using the matrix evaluation, the simple box design scored the highest. This design will be finalized and a prototype will be constructed.

VI. Final Design

For the purposes of the client, the simple box design was chosen. Dr. Emborg had several suggestions on the design, however, including a center divider, fixed panels, and removable bases that would be flush with the holes on either side of the device.

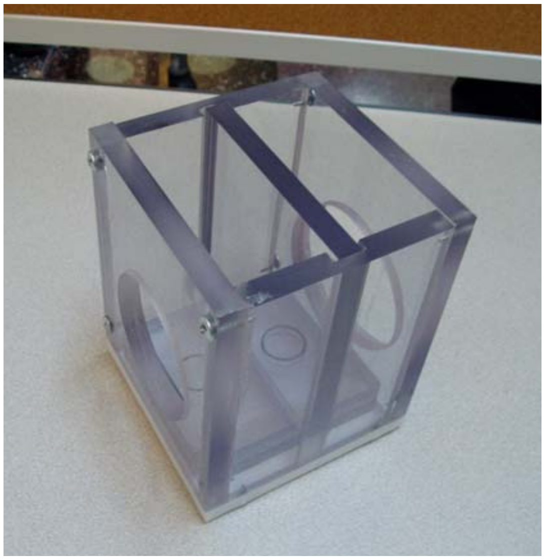

Figure 6: Final device. Shown with removable center divider and marked base.

We constructed the prototype out of 0.5" Lexan, with a square, opaque HDPE base, as shown in Figure 6. The device measured 5" X 5" X 6" and had holes measuring 3" in diameter and 1" from the base on either side. The removable bases were 1" thick and 3.5" X 4" to allow for easy retrieval from the device. One was created with two wells (one on either side) that were 1" in diameter and 0.5" deep to force the monkey to use its thumb and forefinger to retrieve the reward. The other base had two marks (1" in diameter) to standardize placement of the reward. The device was glued together with super-glue for plastics that dried clear, and then screwed together. Due to the durability of the Lexan, we encountered difficulties screwing the panels together. Two screw heads sheared off once the screws were in place. Because they were so securely fastened in the device, we were unable to retrieve them to replace them with new screws; however, our inability to extract the screws indicates they will hold the panels together securely. The result was purely aesthetic. Aside from this small glitch, construction went fairly smoothly.

Figure 7: Adapter panel. Shown with monkey model reaching through holes.

We also constructed an adapter panel that slid into the door of the cage, as shown in Figure 7. The panel measured 13" X 15.75" and had two 3" holes approximately 1/3 from the bottom. The holes were made to allow the simple box to fit between them. For testing, the monkey will reach through the appropriate hole in the adapter panel and through the corresponding hole in the side of the device to grab the reward. Although we had initially planned to attach the device to the adapter panel with hooks, upon completion, we realized that the hooks may become a safety hazard. With the cage setup, the monkeys may have access to the hooks, which may result in injury. In addition, we considered the possibility that keeping the panel unattached will make future electronic work on the device easier. Overall, the device cost approximately $100 to construct. We used about $90 worth of Lexan and HDPE (RPlastics, 2006), and spent $10 on screws and glue.

VII. Ethics and Safety

The motor skills tester will be in contact with food, monkeys, and humans. For this reason, it is important that the device be safe and clean. There should not be any dangerously sharp edges on the tester. Also, any electrical components must be out of reach of the subjects being tested. The diodes on each side of the hole will be covered in transparent plastic so that they the subjects tested are not at risk. The material of the device, the food, and any cleaning supplies used must not be toxic.

The research that this device will be used for has been called into question, ethically. Monkeys are used to study Parkinson's disease treatments because of their ability to perform tasks requiring fine motor skills, similar to humans. The use of monkeys to study possible treatments in humans for a disease is objectionable to some. Moreover, if the monkeys are given symptoms to resemble the disease studied, the ethical treatment of the monkeys may be questionable.

VIII. Conclusion

This semester, we devised three preliminary design alternatives. We chose the best of the three, and proceeded to construct a prototype that our client will be able to use for testing in the future. There is still much work to be done before Dr. Emborg can test with our device.

If the project is continued, the second semester's work will focus on developing a software program to run the motor skills tests, constructing a circuit to connect the tester to the computer, and attach electrical diodes to the panels of the device. Additionally, as with anything used in animal testing, the device will need to be sterilized to ensure animal safety.

Appendix A: Product Design Specifications

Function: Design an apparatus to test the fine motor skills of rhesus monkeys that minimizes the cognitive portion of problem solving; should be easy to clean, durable, adjustable for human testing, and attach to cage securely.

Client Requirements:

- Improvement on fine motor skills tester for rhesus monkeys
- Ability to test specific hand
- Signals / diodes on openings
- Tester easily cleaned

1. Physical and Operational Characteristics
    a. *Performance Requirements:* Device must secure tightly to the cage and withstand force of the monkey banging or kicking. It will be used multiple times a day and must be easy to reset and clean quickly.
    b. *Safety:* Product must hook securely to the cage and all parts must be securely fastened. There cannot be any sharp edges or exposed or lose wires. Only nontoxic food rewards must be placed in the tester.
    c. *Accuracy and Reliability:* Device must be symmetrical to ensure testing accuracy between the right and left arm trials. The food rewards must be of consistent size and location.
    d. *Life in Service:* Product should have a lifespan of at least five years.
    e. *Shelf Life:* Device should be stored at room temperature in a clean environment.
    f. *Operating Environment:* Device should be cleaned regularly to ensure diode function. It needs to withstand shock-loading and corrosive conditions.
    g. *Ergonomics:* Food must be within easy reach of the monkey. If it is too far away, test results will be compromised. Entrances should be large enough for human testing. Food should not be placed in wells that are too small for the monkeys' fingers to reach into. Older monkeys' disabilities should be kept in mind.
    h. *Size:* Device needs to have the same width as the dorr to the monkey cage (13" x 15.75"), and should not be deeper than the monkeys' reach. Holes should be approximately 3" in diameter to allow for the monkeys' hands to easily reach into the device.
    i. *Weight:* Device should be light enough to not put a strain on the cage.
    j. *Materials:* Device cannot be cleaned with toxic chemicals. Materials should not become toxic when corroded.
    k. *Aesthetics, Appearance, and Finish:* Able to slide into monkey cage, transparent, smooth edges and surfaces.

2. Production Characteristics
    a. *Quantity:* At this time the client only requires one unit.

b. *Target Production Cost:* Current unit cost $2,800. Project budget is $5,000.

3. Miscellaneous
   a. *Standards and Specifications:* Local standards and international standards need to be met.
   b. *Customer:* Able to be adjustable for human testing, be cleaned easily, and have working electronics.
   c. *Patient-related concerns:* Device should be sterilized and compatible for monkeys' cages. Electronics should be compatible with computer programs.
   d. *Competition:* Our current competition is the mMAP device. This product costs approximately $2,800.

Appendix B: References

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