Reptile Face Masks

Preliminary Design Report

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(from 1st paper) Abstract:

The object of the project is to construct two air tight masks for a corn snake and Bearded dragon that can be attached to a pneumotachometer so the affects of opiates on reptile respiration can me measured. The masks should be non-invasive and comfortable for the test subjects while being easy to use and clean for the researchers.

Problem Statement

Dr. Kurt Sladky and Dr. Steven Johnson work in the Department of Surgical Sciences in the School of Veterinary Medicine at the University of Wisconsin – Madison. They have teamed up on a research project to examine the effects of opiates on various reptiles including turtles, corn snakes, and bearded dragons. Specifically, they hope to obtain useful information regarding species' respiratory frequencies and response to pain and use this data to enhance reptilian veterinary practices and surgeries. They are currently running experiments with turtles but cannot begin testing the corn snakes and bearded dragons without functional face masks to collect respiratory data. Our clients need two masks, one for use on corn snakes and the other for use on bearded dragons, that consistently and efficiently function with their pneumotachograph in measuring respiratory rates.

Our goal this semester is to create two face masks, one suitable for use on corn snakes and the other for use on bearded dragons, that meet client needs and produce consistent results. There are currently designs for small animal anesthesia masks on the market but no designs for pneumotachograph masks. These pneumotachograph masks will fit snugly on these reptiles to create an air-tight seal, thus allowing respiratory rate measurements to be collected using a pneumotachograph.)

Problem Statement

Dr. Kurt Sladky and Dr. Steve Johnson are investigating the effects of opioids on reptile respiration and pain response latency. Very little research has been done on the effects of opioids on reptiles and it is not known which drugs reduce pain, suppress breathing, or both. Our clients have already collected relevant data for aquatic turtles, but they lack a device to collect pneumotachometric data from terrestrial reptiles. Two devices for a Corn Snake and two devices for a Bearded Dragon are required.

Background:

Research on Corn Snakes and Bearded Dragons

Corn snakes have smooth even skin and narrow heads. The size or a corn snakes head does not increase proportionally to the body. Snakes can also dislocate their jaws. Bearded dragons have very spiky skin on the sides of the head and prominent brow ridges on the top of the head, the skull is also much wider than the neck. Bearded dragons can breathe through their mouths if their nose is blocked.

Reptile Breathing

At rest, most reptiles breathe very infrequently. A turtle may breathe only once every eight hours, and even less with Opoids. The masks must therefore be expected to be in continuous use for several days at a time.
Reptiles are cold blooded, and tend to have much lower metabolisms then warm blooded animals. Reptiles tend to store energy as glucose in the blood stream, and use this glucose for anaerobic (without oxygen) metabolism when muscle movements are needed [McCluskey]. This gives an overall lower metabolic rate, saving energy and allowing for longer periods without food, and allows the reptile to go longer then mammals without oxygen. The downside is that reptiles are constrained to short bursts of movement, and are not able to keep activity up for as long as a similar sized mammal.

Opoids and Reptiles

The effects of opioids on reptiles are widely unknown even though opioids are commonly used for pain treatment in both laboratory and research settings [7]. The reptile's response to opioid derivatives depends on which receptors (μ, κ, or δ) the species has and which receptors the specific opioid activates. Pain and breathing suppression are both effects of opioids on reptiles but they are not dependent on each other. For instance, the reptile may not have any pain suppression, yet have severely suppressed breathing. Our client hypothesizes that breathing suppression is linked to μ- and δ-opioid receptor activation. They plan to test this hypothesis by using butorphanol tartrate, morphine sulfate, oxymorphone, hydromorphone, DAMGO (a μ-specific opioid agonist), DPDPE (a δ-specific opioid agonist), and U69593 (a κ-specific opioid agonist) [7].

Pheumotachometry

Pneumotachometry is a method used to measure the frequency, tidal volume, and peak air flow of breathing in animals and humans. A pressure difference exists between the two sides of a semipermeable resistive membrane (Figure 3). The high pressure on one side of the membrane forces the air to flow to the low pressure zone on the other side of the membrane. This air flow is directly proportional to the resistance of the membrane. The equation that governs this relationship is $\Delta P = QR$, where ΔP is the pressure difference, Q is the air flow, and R is the resistance of the membrane to air flow [8]. Since we cannot directly measure air flow, we must measure the pressure difference. By hooking a simple differential pressure transducer up to the two sides of the membrane we can obtain this measurement. A sample reading from a pneumotachometer is shown in Figure 4.

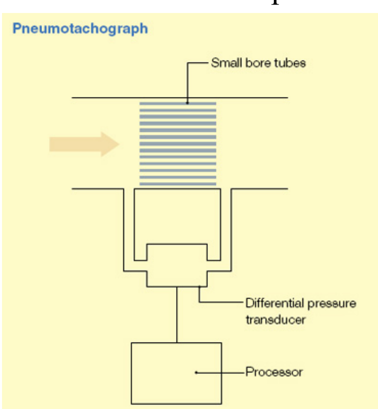

Figure 3: Pneumotachograph Schematic [8].

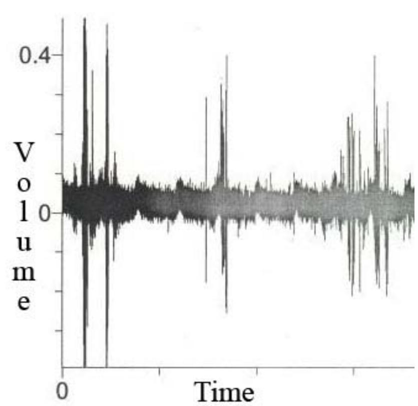

Figure 4: Data from a Pneumotachometer. The peaks represent the tidal volume and the distance between the peaks represents the time between the breaths [6].

Current Methods

Current Device

At this time our client does not have any kind of device to use on the Corn Snakes or Bearded Dragons. In their grant proposal the clients discussed using the end of a plastic 50 mL centrifuge tube for the device; however, they had no set method of attaching the device to the reptile or making an airtight seal.

Design Considerations:

Design Constraints

There must be four seoerate air tight devices, two each for Corn Snakes and Bearded Dragons. The devices muat be large enough to hold the reptile's head with a minimal amount of dead or unused space in the chamber. The snake has a neck ~10mm wide and ~9mm thick; the head is ~13mm wide, ~9mm thick and ~34mm long. The Bearded Dragon has a neck ~22mm wide and ~18mm thick; the head is ~40mm at the widest point, ~22mm thick, and ~47mm long. These devices must be comfortable for the laboratory reptiles. The devices should also be easy to use and clean by the researchers to keep the reptiles healthy.   {FIGURE WITH ANIMAL DIMENSIONS}

There are several design features that must be considered in both pairs of pneumotachometer devices. All pneumotachometer device designs need to have two ports, one to allow air intake for inhalation and the second to allow exhaled air to pass to the pneumotachometer for data collection. The air intake port should be positioned so that the air flowing into the device does not blow directly into the reptiles face to avoid drying out the reptile's eyes. Our Devices need to be rigid and air tight to ensure durability for experiments lasting two to eight hours and to prevent air leakage. The devices need to have the neck openings positioned so that the reptiles are not strained or made uncomfortable. The device must be made of non-toxic, allergen-free materials so the reptiles are not harmed.

Specific to the Corn Snake mask is the need for interchangeable and extra membranes to make cleaning easier and have replacements should a membrane become damaged.

The device for the Bearded Dragon has a few additional design chalanges. This device must fit snugly and create an air tight seal around the Bearded Dragon's spiny protrusions on the sides of the head using materials resistant to the Dragon's spines. Also, the device needs to be secure and resistant to the Bearded Dragon's attempts to push the mask off with its forelegs. The Bearded Dragon has a mandible that is approximately 31.5mm long, and the device must account for this length [6].

Suggested Materials
(inserted from prev. paper)

Body:

A simple piece of PVC pipe was a readily available material for the body of the mask. Alternatively, a clear plastic flexible hose was found. A rubber float for a toilet was also found to have attractive characteristics for both a seal and a body.

Airtight Seal:

Many materials were considered for a proper airtight seal. The first material looked at was a latex glove, as seen in a design by our competition. Rubber in various forms was researched. Rubber washers with a radius of about an inch were obtained, as was a rubber float for a toilet. This rubber float was of a conical shape, ideal for avoiding the spikes on the back and sides of the Bearded Dragon's head. A latex glove was considered, as was a very elastic plastic used in physical rehabilitation. This material was much like latex, but was available in several strengths and thicknesses. It was less prone to ripping then latex. This material was found suitable for the snake only. Some materials used in house thermal insulation were also considered. A putty used to seal windows was purchased, as well as some foam insulation used in doorways. Two sizes of this foam were purchased, each with different pore sizes.

Ports:

A plastic hose adapter was found in the laboratory of Prof. Johnson, and was found to be sufficient.

Joining of materials:

Two epoxies were found. The first was a dual component plastic-to-plastic epoxy, and the second was chosen for its ability to join PVC to Plexiglas and acrylic. Zip-lock bag zippers were also considered for use in joining materials that were not to be permanently bonded.

Competition

Many masks similar to our designs exist for anesthesia, but to our knowledge, masks for Bearded Dragons do not exist. Anesthesia masks (Figure 5) consist of a simple bell shaped rigid frame generally made of clear plastic and a flexible rubber diaphragm over the open end. This diaphragm has a hole in it to fit the head of the animal. An airtight fit is not always guaranteed by this membrane.

Pneumotachometer masks for humans are commercially available, but are not designed for Bearded Dragons and are not small enough to fit a Corn Snake. There is also no guarantee that the input/output ports will fit the pneumotachometer in use by the client.

Previous experiments in pneumotachometry employed a variety of methods to make an airtight seal with the reptile's skin. In two academic papers [3, 4], either

Figure 5: Anesthesia masks [7]

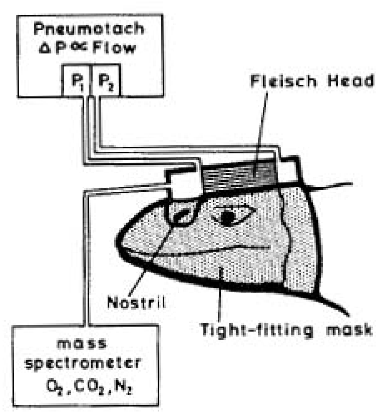

Figure 6: A previous design for a face mask on a lizard [2]

epoxy or dental putty was used to seal the nose and mouth to the input and output ports. The third paper's methods [1] used both a simple mask and a tracheal tube. This experiment showed that results from the mask and the tracheal tube were the same, so the invasive tracheal tube would not need to be employed in future pneumotachometry experiments. The simple mask was created by stretching a latex glove over an empty syringe tube and cutting a hole in the glove for the snake's head to fit in. The best example of a pneumotachometer mask (and one we wish to emulate) is found in a 1978 paper by Glass et al. [2]. This design is portable and stresses low dead space.

Alternate Designs

First Full Head Design

The first design was the First Full Head design. This device would be made up of a hollow, plastic cylinder made of PVC piping – mm in diameter to go around the reptile's head. On the front end of the cylinder, a circular piece of plexiglass would be attached with a – mm hole drilled in the center to insert a pneumotachograph port. Another – mm hole would be drilled in the top of the cylinder to attach a second port. The back end of the cylinder would be attached to a funnel-shaped piece of rubber, approximately 2 mm thick. This rubber piece would be cut down the side and have each edge glued to the top of a Ziploc bag. This would create a quick-release system to remove the animal. The small end of the rubber cone would be lined with weather stripping, approximately 6 mm thick. This end would create an airtight seal around the reptile's neck, without choking it. The hole for the reptile must be approximately the same size as the reptile's neck in order to be considered comfortable.

There are several pros and cons for the First Full Head design. With the rubber funnel around the reptile's neck, we would not have to worry about the Bearded Dragon's spikes affecting the airtight seal. Also, the Ziploc design would allow the device to be removed quickly. This device would be attached behind the head, and would be minimally invasive. It will work for both the Bearded Dragon and Corn Snake. However, it would be heavy for the reptile and contains lots of dead space. The amount of dead space is determined by the readings from the pneumotachometer. If the readings between each peak are above a certain limit, the amount of dead space is too high. This mask may also take longer to put on than other designs, which could make the reptile anxious.

Second Full Head Design

The second Full Head design is slightly different than the first. It has the same design idea except it does not have a rubber cone on the back end. Instead of the cone, it has a thin sheet of rubber material stretched over the end and secured around the edge. In the center of this membrane, a hole is cut to insert the reptile's head.

This design has similar pros and cons to the first Full Head design. This device fits behind the reptile's head and is minimally invasive. It is also relatively easy to use. However, it is still heavy and has lots of dead space. Also, the thin rubber membrane could tear easily. Because the reptile would need to be pushed through a small hole to create an airtight seal, this design would only work on the Corn Snake.

Nose Mask Design

The third design is the Nose Mask. This device is constructed using a plastic cap to cover the reptile's nose. It has straps attached to a collar around its neck to hold the mask in place. Ports are attached to the front end and under the bottom of the mask. Also, to create an airtight seal, there needs to be some sort of space-filling material around the edge of the mask, attaching it to the animal's face.

There are pros and cons to the Nose Mask. It greatly reduces the amount of dead space. While it doesn't hurt the animal's eyes and is relatively lightweight, it is much easier for the animal to pry off its face. Also, it can only be used on the Bearded Dragon.

Nose Plugs Design

The fourth design is the Nose Plugs. This involves construction of small tubes to be inserted into the nostrils of the reptile. Both tubes are connected to allow air input and output. Also, the mouth of the animal is sealed shut to force it to breathe out of its nose.

The only pros of this design are that it is lightweight and there is literally no dead space. However, there are many cons. This design is invasive and requires the reptile's mouth to be sealed shut, which is what we want to avoid. Also, the nose plugs need to be secured to the nose to prevent them from coming out or being pulled out. This could restrict airflow and cause the animal immense discomfort.

Final Designs

Design Overview

Corn Snake Mask

The final corn snake mask incorporates most aspects of the Second Full Head Design. The body of the mask is constructed out of two PVC pipes, -- mm in diameter and – mm length. Both pipe pieces are glued together with a super glue epoxy. On the front of the mask, a circular piece of Plexiglas, -- mm in diameter, is attached to the end with the same super glue epoxy. In the center of the Plexiglas a – mm hole is drilled to glue a pneumotachometer port to measure the reptile's output breathing. On the top of the mask, a second – mm hole will be drilled to attach the input pneumotachometer port. A thin membrane of rubber physical rehabilitation material is cut and glued around the edge of a threaded, circular disk. This membrane piece will be able to be screwed onto the back end of the mask, allowing easy removal for cleaning purposes. The entire mask will be cleaned, sanded and painted to contribute to the aesthetic value of the mask.

Bearded Dragon Mask

The final bearded dragon mask uses some aspects of the First Full Head Design, as well as new changes according to client specifications. The body of the mask is constructed out of a PVC pipe, -- mm in diameter. A circular piece of Plexiglas, -- mm in diameter, is cut and attached with super glue epoxy to the front end of the mask. In the center of the Plexiglas, a – mm hole is drilled to attach a pneumotachometer port with the same super glue epoxy. A second pneumotachometer port is glued into a – mm hole drilled into the top of the mask, to allow air input. The back end of the mask has a Plexiglas rectangle, -- mm by – mm, with a semi-circle and small indent removed to insert the lizard's head. On either end of the rectangle, a slot will be removed – mm wide to insert screws and wing nuts. A second Plexiglas rectangle will be attached to the mask with the screws in four holes drilled in the corners. A small indent is also removed from the bottom to allow room for the lizard's head. The edges of the indentations are lined with a sticky rubber material to create an airtight seal around the lizard's neck. The space between the two Plexiglas sheets will also be lined with the same rubber material to ensure no air escapes during experimentation. Creating a two part head piece will make the mask easier to clean. The entire mask will be cleaned, sanded, and painted upon completion.

Testing

Competition VS Alternate Designs

Design Matrix

To select a final design, a design matrix that addressed the most important criteria for our design was constructed. Using a point-based scale we rated each design on multiple criteria. The point-based scale allowed different requirements to have values based on their importance in the design specifications. As seen in the matrix, the Full Head mask design received the best score.

Design Requirements (points)	**Full Head Mask**	**Nose Mask**	**Nose Plugs**
Safety (15)	13	12	9
Non-invasiveness (25)	21	20	1
Versatility (15)	10	5	10
Dead Space (10)	3	5	10
Ease of Use (15)	12	10	5
Easy to Clean (15)	12	12	5
Cost (5)	3	3	3
Total (100)	**74**	**67**	**43**

Results

The output of the pneumotachometer is a voltage that must be interpreted as a breath. In order to calibrate the instrument that converts voltage levels into breathing rates, a calibration curve is constructed. The pneumotachometer is attached to a large syringe of known volume. The syringe is compressed at a known rate, leading to a known flow rate. The corresponding voltage is determined, and plotted on a voltage-flow rate graph. This is done at different flow rates to give a calibration curve. This allows for any reading from the pneumotachometer to be converted into the appropriate breathing rate of a reptile when the experiment is in progress.

Future Work

To create a smoother surface on the snake mask design, other bonding materials could be investigated to attach the latex membrane to the PVC membrane attachment piece. Our final design used glue that was difficult to apply smoothly before the glue had dried. Sanding could not remove the uneven surface of the glue without the risk of detaching the membrane from the PVC piece.

Time constraints did not allow for further dead space testing of both the snake and bearded dragon masks. Too much dead space or empty area inside the mask may alter pneumotachograph measurements while too little space may cause discomfort in the test specimens. Experimental testing comparing designs with varying amounts of dead space would lead to determination of an ideal mask size for minimal data collection interference and maximum comfort for the snake or bearded dragon. Also, data collected would determine mask efficiency if the results were consistently reproducible.

Further testing should be conducted to test the durability of the latex membrane on the snake mask design. The membrane withstood the poking and handling our team exerted on it, but there was not enough time available to investigate how many times a membrane could be used before wear and tear degrade the membrane and replacement is needed. Such testing would build confidence in product durability.

Ethical and Intellectual Property Concerns

Animal Care and Handling

To comply with live animal research standards, all animals will be stored overnight in the Avian Exotics Ward at the Veterinary Science Building. Animals will be housed at the Charmany Instructional Facility where the reptiles will be monitored daily by the animal care staff and cared for as needed. If an animal becomes diseased, treatment or humane euthanasia using isoflurane will be provided at the discretion of Kurt Sladky.

To gain permission to handle the animals during design testing, all team members were added to Protocol V0123130305. Handling of the reptiles by team members occurred only under tdirect supervision by Kurt Sladky.

Safety of Experimental Procedures

Respiratory data collection will not harm the animals in any way. The second aspect of this research study will examine animal response to stimuli to compare latency periods between control and experimental groups. All animals will receive thermal noxious stimuli to the hindlimb or body using an apparatus commonly used to measure latency in rodents. The animal will be exposed to this thermal noxious stimuli about five times daily for approximately 32.2 seconds. This stimuli is not anticipated to cause tissue damage, chronic pain, or hyperalgesia (Protocol).

Data Collection

To ensure honest data collection, the investigators will be blinded to reptiles receiving injections of drug or saline. This will prevent the investigators from fixing experimental data or drawing biased conclusions. Accuracy will also be maintained by keeping Animal Care records in duplicate in both Steve Johnson's laboratory and the Charmany Research Facility.

Conclusion

Appendices…

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