CLIENT: ST. LOUIS ZOO

Progress Report

Otter Enrichment- Group 21

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Project Scope

The health of any animal in zoo captivity depends on the ability of the caretakers to emulate its natural environment. Oscar the otter is one such animal, and currently its exhibit in the Saint Louis Zoo lacks many characteristics typical of an otter's habitat in the wild. North American river otters thrive in enclosures that are two-thirds land and one-third water, but the Saint Louis Zoo's enclosure has the opposite ratio. Additionally, the space does not give much opportunity for hunting and foraging activities essential for the otter's fitness. The goal is to invent a device that provides enrichment for the otter while tackling some of the other aforementioned issues.

There are many constrictions on possible solutions that the zoo has not been able to work around. First, the otter tends to push items into the pool, which cannot be retrieved until the pool is completely drained, which occurs only once every four months. Second, any toy given to the otter has to be small enough so that the otter cannot use it to climb out of the enclosure. Finally, otters are incredibly strong, so the solution has to be sturdy enough that the otter does not destroy it. The St. Louis Zoo has appropriated $50 to fund the construction of a prototype of our otter enrichment device.

Although the class only requires either a prototype or a physical representation, the zoo desires a functional product, so that they will have something tangible that they can immediately put to use. In order to do this, the help of an undergraduate electrical engineer, Kunal Patel, whose expertise in circuitry will be very valuable, will be enlisted. The solution will also be easily replicable so that it can be put to use in otter exhibits in other zoos.

Specific Design Requirements:

One feature of the device that will be employed regardless of the design is a feedback mechanism. The device will need to take data from the otter's activity and relayed to the zoo employees. This will allow the enrichment activity to be measured and allows staff to study Oscar's behavior. Examples of data being collected are the time spent with the device per sitting, times used per day, etc. Sensors will be needed to measure the data. The basic concept is a simple sensor that will store a voltage whenever it detects movement. With the use of a small microprocessor, these movements can be recorded and archived. Hopefully the staff will be available to extract the data from the device daily using a simply designed interface or by some other method. This feature is important in order to ensure that Oscar is making use of the device and truly being "enriched".

Furthermore, the device will not need constant upkeep or maintenance by zoo staff. The device will be beneficial and enjoyable for Oscar, but it will need to be simple and durable. The durability will depend not only on concept choice, but also material selection.

The device will presumably be used in and out of the water. For this reason, the materials must be waterproof. Potential choices include, but are not limited to, metal, rubber, and polyurethane. The material also must be buoyant enough for the device to float. The pool in the enclosure is only drained three times a year. If the device sinks to the bottom, it is unable to be retrieved for an extended period of time.

An important consideration for the enrichment device is that it doesn't cause obesity in the otter. The zoo weighs the otter on a regular basis as so they will be able to monitor for significant fluctuations in the weight in the otter. If the device causes fluctuations outside the normal range of the otter's weight, the device will have to be modified.

Additionally, the device must be affordable. Currently the zoo has granted $50 worth of funding. This must be used to cover the cost of materials. Further safety precautions will be taken as well. The device cannot cause any harm to the otter. This includes allowing the otter to climb out of the enclosure if the device is near the walls. The device must be low stress and not detrimental to the otter's mental state.

Concept Ideas and Description:

- Otter Ball: This concept is a simple toy ball that the otter can interact with both on land and in the water. One of the key components of this device includes a motion sensing, voltage storing, microprocessor that analyzes the frequency of interaction. The caretakers will be able to see how interaction frequency may predict or indicate the relative health of the otter. Another element that this device will have is a force sensor shell located just underneath the strong polyurethane-protecting coat. The sensor will collect a pressure measurement over the surface area of the ball and output a force map to the caretakers. The polyurethane coating is mandatory to protect the ball from being penetrated by the otter's incisors. Otters have one of the strongest bites in the mammalian class and fluctuations in the force map over time will indicate changes in both dental health and overall activity of the otter. This simple toy will be easy and enjoyable for the otter to play with. From a complexity standpoint, it resembles many pre-existing otter enrichment devices currently in use at the zoo eliminating any kind of learning curve for the otter. The otter will increase its enrichment, and the caretakers will have a wealth of information to understand and improve the otter's environment.

- Puzzle Box**:** This concept is a tactile puzzle that can improve the intellectual fitness of the otter. The puzzle board will consist of a large 4' by 4' square, whole box with four recesses hollowed out of one surface. The recesses will be of different sizes and shapes, including an L shape and a step shape. There will be blocks attached to the large square box that fit in perfectly with the recesses. The purpose of the toy is to encourage the otter to pick up the blocks and use the cognitive ability to put the blocks into the appropriate recesses.
- Moving Maze: The maze would be made of PVC with interlocking parts. The parts would be interchangeable allowing multiple configurations to be made. The trainers can change the layout to keep it novel. A food reward will be placed at the conclusion of the maze so as to incentivize the otter.
- Tether Ball: This concept is an analog of tether ball that the otter can play with. The pole would have a sensor to measure when the ball is being played with. The sensor would need to measure vibrations in the pole. Data would allow zoo staff to keep track of the otter's activity during the day.
- Whack-a-mole: This is a game similar to whack-a-mole where different objects pop out of a device. The otter would then push the objects back into the device. This device's use would be easily measured. Additionally, operant conditioning with a food reward would be used to train the otter to play the game.
- Wotter Wheel: This is concept is a wheel stationed on the water's surface. The inner surface would have traction that the otter can run on. Once the wheel has been spun a certain amount, a mechanical release switch would provide a food reward. A sensor on the axle would measure activity.

- Musical Game: The game would have different shaped buttons that correspond to a note. A display would show a series of buttons to be played based on shape. Upon hitting the correct sequence, the otter would be rewarded with food.

- Box Stacking: In this concept the otter would be given several boxes that were restricted to the center of the exhibit, away from the exhibit walls to prevent escape. There would be a food reward elevated above the stack of boxes. The otter could rearrange the boxes in a way so that it could climb up and obtain the food reward. The primary stipulation in this concept is that the boxes would have to be shaped in a way that the otter would understand to stack them.
- Shell Cracking Device: In the wild, otters use rocks to break the shell of various crustaceans such as mollusks, to get to the meat of the animal. This device would emulate a natural experience for the otter enriching its captive experience. The device would function as a cracking device that, if used accurately by the otter, would break the shells off of its food. The strength of the otter could be very easily measured by a force sensor inside the device. The feeding habits and frequencies are also easily measured by a voltage sensor inside the device.
- Mechanical Fish: This concept would be one of the more complicated devices to construct. The mechanical fish will be a remote controlled toy that resembles the river otter's most common aquatic prey; the common carp. The exterior of the mechanical fish would be comprised of a scaly skin like material, such as snakeskin, complete with the exterior anatomy of a fish. There will be a receiver embedded inside the fish that receives inputs from a transmitter controlled by a trained zookeeper. The receiver will drive two separate motors inside the fish to propel it through the water. To emulate a fish's

swimming pattern accurately, one motor will be located at the anterior end of the fish and one at the posterior end of the fish; both will be controlled independently in the entirety of the xy-plane. This device will help enrich the otter by simulating an authentic hunting experience in the wild. The zookeeper will control the fish along the exhibit's body of water in various naturally accurate patterns that slowly increase in difficulty. This will enrich both the cognitive function of the otter by training it to anticipate the movements and patterns of the fish, and the physical fitness of the otter by encouraging stalking behavior. A GPS tracking device will be implanted in the fish and will continuously output its location. In conjunction with the fish, a tracking camera above the exhibit would monitor the position of the otter as it hunts the fish. The distance travelled, the paths the otter takes, the hunting patterns, and the time it takes the otter to successfully hunt the fish are all phenomenal indicators of its physical and cognitive functions. Continuously challenging the otter thusly will greatly increase the otter's enrichment level.

- <u>Basketball</u>: The toy will consist of a hoop and small ball that the otter is capable of grasping. The otter can be trained to make the baskets using classical conditioning as the method of training. This toy has been created in the past, but does not appear to be patented. An extra bonus of the toy is that it is a good form of exercise and stretches joints the otter does not typically use. This toy could potentially increase the physical fitness of the otter.

- <u>Hoop Diving</u>: This enrichment setup will include a stable platform the otter can climb onto in order to jump into a series of colored hoops, floating in the water. The zookeepers can hold up different colored flags indicating which hoop the otter should jump through. The otter would be given a reward each time it jumped through the correct hoop.

- Puzzle Ball: The idea is to create a ball with four movable parts. The movable parts will be designed to fit together and rotate, but only fall apart if the pieces are in a certain orientation relative to each other. When the ball is together, it will be hollow allowing food to be stored within. One of the pieces will have space for the sensor to be stored. The sensor will store data on use. Work will need to be done to waterproof the sensor.

Analysis

Cost: Our current funding is $50. The materials and sensor together will need to be as close to $50 as possible.

Otter Ball: The main cost of the otter ball comes from basic materials. The otter ball would weigh about 1.5 pounds. Hard plastic 3D printing material costs about $10.00/pound on amazon, totaling $15.

Puzzle Box: The box would be around 4 pounds with each of the four pieces weighing 1 pound individually for a total of 8 pounds. Total plastic cost would be $80.

Moving Maze: To make the maze large enough for the otter to fit through and also have enough pieces for multiple configurations, the maze would need about 10 pieces with 1.5 pounds each. 15 pounds of material would cost $150.

Tether Ball: A small low-end tetherball set would only be $30 and implanting a sensor in the ball will be minimally expensive.

Whack-a-mole: A variant of whack-a-mole would be an exciting toy for otter enrichment. The toy would involve electronics and it would be easy to monitor. However, there is no way that the game and sensors would come to a price under $50.

Wotter Wheel: The water wheel would be made out of a rope bridge supported on each side by wooden supports. The radius is around 18 inches, making the circumference 113 inches. This would require 29 2”x4” panels. Home Depot sells 2”x4”x8’ planks for $3. Each plank could be cut into 4 panels, requiring 8 total planks. The circumferential would cost $24. The wheel would need 8 supports, needing 4 more planks. Total wood cost would be $36. The rope would be $9 from Home Depot, bringing the total to $44.

Musical Game: The keyboard game cost is a very similar problem to the whack-a-mole. Although it would be interesting, there is no way it could be made for less than $50 and include a sensor. The cheapest keyboard is available for $35. This would leave only $15 for the display and sensor.

Stacking Boxes: The boxes need to be a light material like plywood. There would be three cubes with sides of 1.5ft, 1ft, and .5ft respectively. This totals to 21sq. ft. of wood. A 32 sq. ft. sheet of plywood costs $8 at Home Depot.

Shell-Cracking Device: The shell-cracking device would need to be printed out of a material harder than plastic. Unfortunately, 3D printing alloys cost around $8.00/cm^3. The device would undoubtedly be larger than 6 cm^3 making the device too expensive. We may not have the access to a printer capable of working with metallic materials either.

Mechanical Fish: The mechanical fish is an extremely technical design that would require multiple motors, sensors, receivers, and expertise. There is no way for the fish to be constructed at the appropriate budget.

Basketball: A children’s basketball hoop and ball set costs around $40.

Diving Hoops: A 3-piece hula-hoop set would be around $15 and each corresponding flag is $3 for a total of $24.

Puzzle Ball: The puzzle ball would be about 1.0 pounds and made out of the hard 3D plastic. This would total $10 in plastic materials.

Sensor: To monitor the activity each of these designs will have a sensor built into them. There are several possible parameters for measurement. Force transducers could measure strength changes, while vibration or motion sensors could measure frequency of use. It seems that a force transducer, although impressive, would be unreliable to measure otter strength. It's difficult to isolate the forces that the otter applies from the rest of the forces recorded. For this reason, a vibration sensor to measure frequency of use is more reasonable. Further research shows vibration sensors to be around $5. In order to store the data, a microprocessor will also be needed. Several options exist, but our electrical engineering group member is most familiar with the $35 MPU-9150 multicomponent MEMS tracking device. This brings the technical hardware to $40 for each device. Shown in Table 1 are the prices for the different devices including the technical hardware.

Table 1- Cost Analysis

Device	Materials Cost ($)	Total Cost ($)
Otter Ball	15	60
Puzzle Box	80	125
Moving Maze	150	195
Tether Ball	30	75
Whack-a-mole	>>50	>>95
Wotter Wheel	45	90
Stacking Boxes	8	53
Shell-cracker	>>50	>>95
Mechanical Fish	>>50	>>95
Basketball	40	85
Diving Hoop	24	69
Puzzle Ball	10	55

Durability:

Going forward, there are 6 possible devices that are affordable: tether ball, wotter wheel, stacking boxes, basketball, diving hoop, and puzzle ball. Our next category of refinement is durability. One of the largest problems with enrichment devices the zoo has had in the past is durability. The device will be outdoors at all times, both in the water and out. Additionally, otters are strong animals with powerful jaw strength. The device must not be capable of destruction. Looking at the above ideas, tetherball and diving hoops do not meet this criterion. The tetherball could easily be gnawed and destroyed. Furthermore, the diving hoops are made out of soft plastic hula-hoops that wouldn't withstand otter chewing.

Sketches of Available Devices:

Figure 1: Wotter Wheel

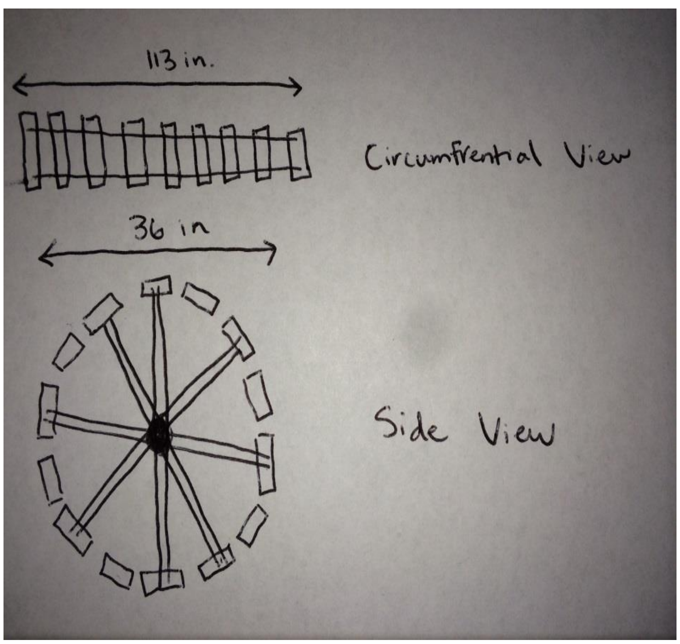


Figure 2: Stacking Boxes

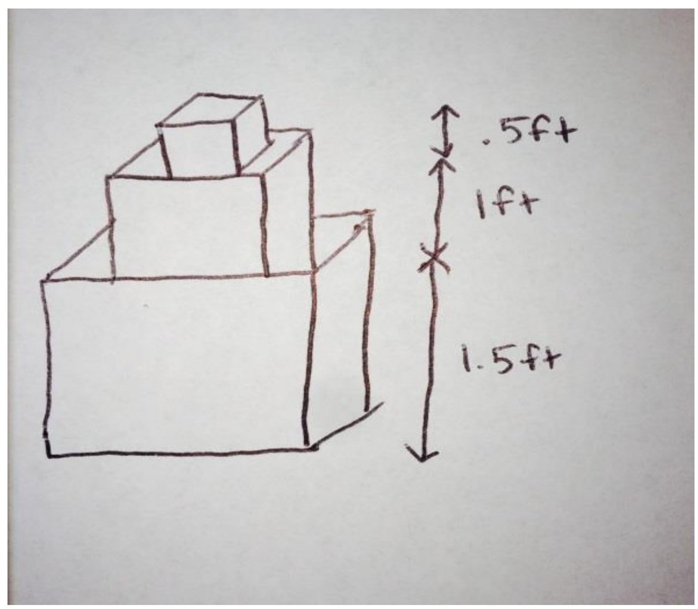


Figure 3: Basketball

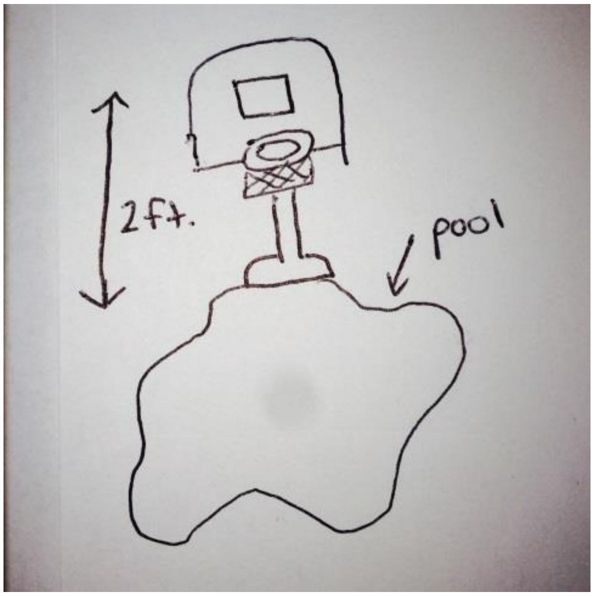
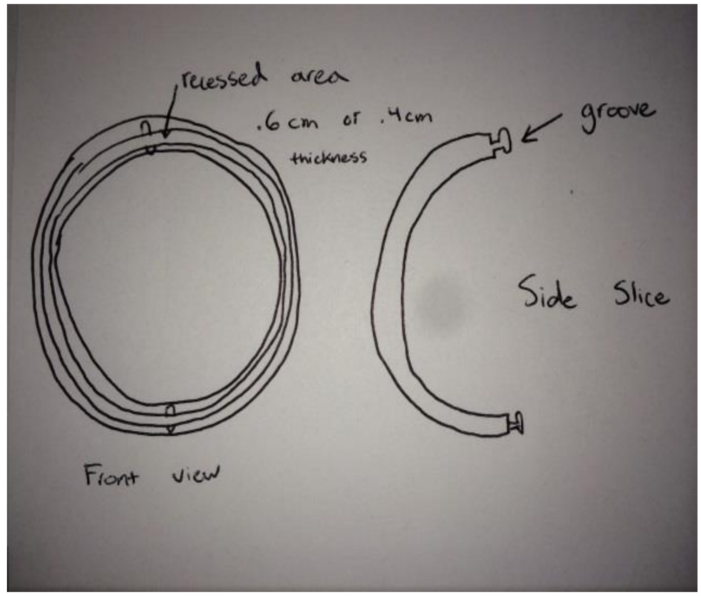


Figure 4: Puzzle Ball



Final Cut:

The main purpose of the device is enrichment. The forms of enrichment that the zoo recommended were either cognitive or physical. Although the otter ball may provide interesting data on the otter's strength, it has little enrichment value. Although the wotter wheel is unique and novel, it does not match with the otter's natural behavior. Otters are natural swimmers although they do spend a large amount of time on land. Their bodies are engineered not for running, but for swimming. Because of this, the wotter wheel is not a good form of enrichment for a river otter. Similar to the otter ball, the stacking boxes offer no form of enrichment other than food and a minimal amount of physical exertion. However, it offers little possibility for data measurement. A basketball hoop is something many other zoos use with their otters. It is undoubtedly a positive enrichment tool. Additionally, it is durable and reasonable to put into action. However, the hoop does not satisfy the engineering requirement very well. The zoo hardly needs our consultation in order to implement a basketball hoop. For this reason, the

Puzzle Ball will be the device we continue to work on for the remainder of our time with the St. Louis Zoo.

Specific Details of Chosen Design

After a variety of analyses concerning the cost, durability, and feasibility the chosen design was the Puzzle Ball concept. The ball will be approximately 2.0 pounds comprised of a plastic polymer from a 3D printer. The diameter of the ball will be approximately six inches (15.0 cm), and the ball will be hollow with a solid shell of thickness one (1.0) centimeter. This will leave a volume of 1770 cm2 inside the locked sphere for the food reward that the zookeeper decides to provide the otter for successfully solving the puzzle ball. The ball will be sized as such since an otter paw, is at most 9.05 centimeters long and 7.62 centimeters wide. The parameters of the ball ensure that it is manageable and wieldable for the otter to manipulate.

In addition to enriching the otter by stimulating it both physically and cognitively, the device will provide information to the zookeepers on the overall fitness of the otter. The frequency with which the otter plays with the Puzzle Ball and the speed at which it orients the various segments of the ball are both key indicators of the impacts of operant conditioning on the otter. The faster an otter solves the puzzle and the quicker it moves the various pieces around into the correct orientation, the greater the impact the Puzzle Ball has on enriching its cognitive and muscular functions. The recordings from the Puzzle Ball can also be utilized as a predictive and diagnostic device. If an otter starts to exhibit a decline in speed of piece-movement or a lack of ability to resolve the puzzle, the zookeeper will be alerted by the decline in acceleration or the incorrect orientation of the Puzzle Ball. This can lead to the recognition of early symptoms that otherwise may go unnoticed. To calculate the speed of the puzzle piece movement and the orientation of the pieces as the otter attempts to solve the puzzle, a MPU-9150 will be embedded in the 1.0 centimeter thick shell.

The MPU-9150 is a device that integrates three different microelectromechanical sensors (MEMS) all into one 16mm3 rectangular device. It integrates a 3-axis gyrometer, a 3-axis compass, and a 3-axis accelerometer. The gyrometer will record the angle of rotation of the device at up to 2000º/second; this will enable the zookeepers to see how the otter performs in improving the ideal orientation of the puzzle during the solving process. The 3-axis accelerometer will aide in understanding the acceleration of the object in all three axial planes. These two components are often used in conjunction to understand the exact location and orientation of a device. Finally, a 3-axis magnetometer, or compass, comes with the MPU-9150, but this device will serve little to no purpose for our project. The MPU-9150 is used in many electronic devices as a fail-safe catch by turning off the hard drive of a device if the acceleration is deemed past threshold and too great. This saves the hard drive of computers, or phones if they fall a great height off a surface. As a result, it is easily embedded in the Puzzle Ball and thus, will not be impacted by the possibility of water damage. Additionally, it is compatible with an I2C, a serial computer bus, which aides in cheap, but effective communication between two objects on the same circuit board. The information is transferred by the I2C and can be accessed by the accompanying interface library code and transmitted to a zookeeper’s data storage device.

The actual construction of the ball is another key aspect to understand the entire design of the Puzzle Ball. There are two options that are currently under consideration for the design of the Puzzle Ball. In the first option, there will be a shell of thickness 0.6 centimeters divided into hemispheres. The two hemispheres are interlocked by a simple lock and key mechanism. One hemisphere will have a slot running the length of the rim and interlocking hemisphere will have a protrusion with a specific shape such that it cannot be pulled out of the slot. At one specific point there will be an expansion of the slot such that the protrusion can be removed from the slot and the hemispheres will fall apart to give way to another pair of interlocking hemispheres with 0.4 centimeter thick shells. These shells can be taken apart with the same mechanism as the prior shells to give way to the food reward inside. In this scenario the MPU-9150 would be placed in the inner pair of shells.

References

"2x4 at The Home Depot." 2x4 at The Home Depot. N.p., n.d. Web. 22 Oct. 2014.

"54 Keys Electronic Music Keyboard Piano Organ Records Playback." Google Shopping. N.p., n.d. Web. 23 Oct. 2014.

"Animal Tracks - River Otter (Lutra Canadensis)." Bear Tracker. N.p., n.d. Web. 24 Oct. 2014.

AZA Small Carnivore TAG 2009. Otter (Lutrinae) Care Manual. Association of Zoos and Aquariums, Silver Spring, MD.

"BBB - Rechargeable On-board Battery System." Element14. N.p., n.d. Web. 22 Oct. 2014.

Carss, David N. "Foraging Behavior and Feeding Ecology of the Otter Lutra Lutra: A Selective Review." *Hystrix*. Scotland, UK: Institute of Terrestrial Ecology. (179-194). 1995 .

"Fisher-Price Laugh & Learn Basketball Set." Kohl's. N.p., n.d. Web. 23 Oct. 2014.

"Flags Importer." Solid Color Flags - 12x18" Polyester Solid Stick - Flags Importer. N.p., n.d. Web. 22 Oct. 2014.

"JET - PLA Filament 1.75mm Diameter for 3D Printing 2.8lbs with Spool 32 Color Options * Lime Color *." Amazon.com: : Home Improvement. N.p., n.d. Web. 22 Oct. 2014.

Lariviere, Serge and Walton, Lyle R. “Lontra canadesis.” *Mammalian Species*. American Society of Mammalogists. Ed 587 (1-8). 1998.

“Oriented Strand Board (Common: 7/16 In. X 4 Ft. X 8 Ft.; Actual: 0.418 In. X 47.75 In. X 95.75 In.) at The Home Depot." The Home Depot. N.p., n.d. Web. 22 Oct. 2014.

"PIR (motion) Sensor." Adafruit Industries. N.p., n.d. Web. 23 Oct. 2014.

"SensorCape Reference Manual." Michael H Leonard. N.p., n.d. Web.

"Sensors Overview." Android Developers. N.p., n.d. Web. 23 Oct. 2014.

"Showing Results For "rope"" The Home Depot. N.p., n.d. Web. 23 Oct. 2014.

"Square Force-Sensitive Resistor (FSR) - Interlink 406." Adafruit Industries. N.p., n.d. Web. 23 Oct. 2014.

"Stainless Steel 3D Printing Material Information - Shapeways." Shapeways.com. N.p., n.d. Web. 23 Oct. 2014.

Stevens SS, Serfass TL. 2008. Visitation patterns of nearctic river otters (Lontra canadensis) at latrines. Northeastern Naturalist 15(1):1-12.

"Tether Ball Set." Bobwards. N.p., n.d. Web. 22 Oct. 2014.