FELINE ACOUSTIC AND VISUAL ORIENTING ARENA

BME 200/300
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Abstract

Dr. Tom Yin of the University of Wisconsin-Madison Department of Physiology has requested the design and construction of a feline acoustic and visual orienting arena. A similar arena has been used in previous studies and will be used by Dr. Yin as a control experiment for his current research question. The design team has created four design matrices taking into account general setup, food type, valve choice, and switch choice. Upon comparison of the matrices the team has determined that a four speaker setup using wet food delivered using one pump and four pinch valves activated by a load switch is the best design option. The team will proceed by testing this equipment and creating the orienting arena

Problem Statement

The aim of this project is to develop a testing apparatus to aid in determining the effect of deactivation of the auditory cortex on feline sound localization. A previous testing apparatus has been developed by Lomber et al., but there is concern that this method introduces human bias. A key goal of this project is to eliminate any interaction between human and feline in the testing procedure

Background

The ability to hear and interpret sounds is no doubt an important sense, but what is often taken for granted is the ability to determine where exactly a sound originates. Physiologists and Psychophysicists have long been interested in achieving a better understanding of sound localization, an important aspect of human audition. Unlike the visual and tactile senses, the human central nervous system does not bear a spatial map that corresponds to sound perception. Instead, the nervous system has a frequency map that corresponds to differing frequencies of sound

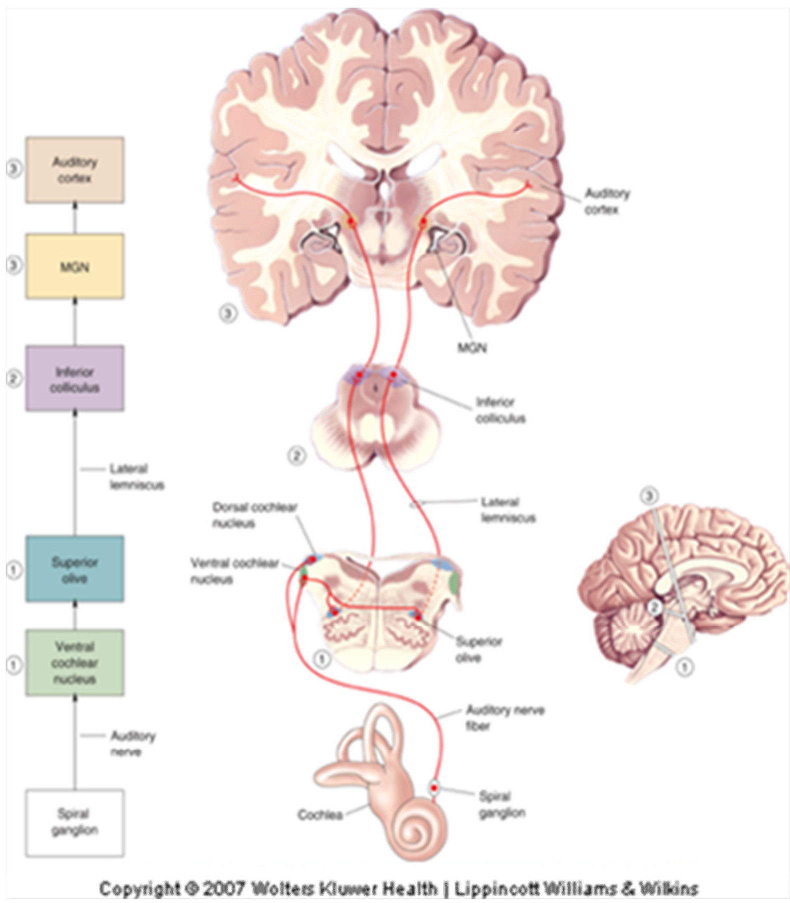
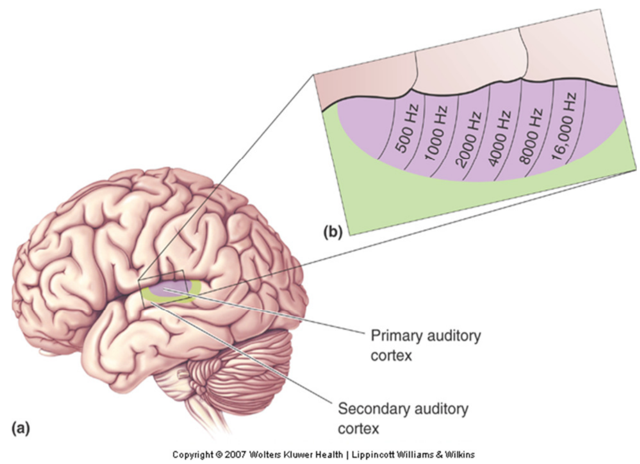


Fig. 1 Mammalian central auditory pathway [8]

rather than space [8]. Azimuthal (horizontal) localization is determined by the very small differences in the time delay from one ear to another, i.e. a sound directly off to the right will reach the right ear slightly before it reaches the left ear. Loudness is also a factor in localization, in the previous example, the sound will also be perceived as slightly less intense (quieter) to the left ear in comparison to the right ear because the head "shadows" the sound. These two phenomena are referred to as Interaural time delays (ITDs) and Interaural level differences (ILDs) respectively [3]. The signals from each ear converge for the first time at the medial superior olive (MSO) located in the brainstem (fig. 1), and it is at the MSO that the ITDs are first encoded. Upon convergence, the binaural signals generate an action potential that eventually reaches the auditory cortex of the brain. The cortex interprets the action potential based upon the frequency of the initial sound according to a specific frequency map (fig. 2)



(Above) Figure 2 Frequency mapping of the primary auditory cortex [8]

(Below) Figure 3 A neurologically implantable cooling loop [4]

Through the use of a *Cryoloop*, Dr. Tom Yin – University of Wisconsin, would like to investigate the result of cortical inactivation on the ability of felines to localize sound. A cryoloop (fig. 3) is an small, neurally-implantable, device that facilitates localized cooling of the brain as cold methanol is circulated through the loop. Eventually, this cooling leads to reversible inactivation of that specific locus along the cortex. A similar experiment has been run by Stephen Lomber et. Al. – University of Ontario [].

In Lomber's experiment, a cat's brain was implanted with a cryoloop and it was subjected to the following experimental procedure (see fig. 4):

1. Animal was first required to fixate on the central (0°) LED.
2. It then had to orient to, and approach, a secondary acoustic (100-ms broad-band noise) or visual (illumination of an LED) stimulus
3. . Animal is given positive reinforcement through a food reward

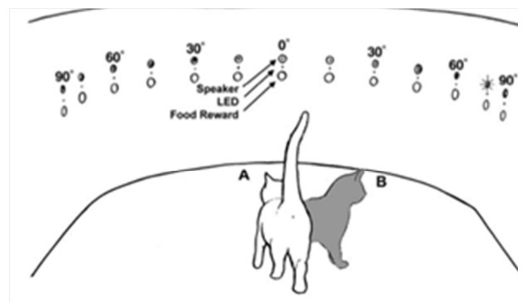


Figure 4. Acoustic and visual orienting arena. A loudspeaker (*top* circle) and a light-emitting diode (LED, black dot) were located above a food reward locus (*bottom* circle) at each of 13 regularly spaced (15°) intervals (for sake of clarity, only 30° intervals are labeled). [5]

Previous studies of the auditory system of animals has determined that sound localization, a mechanism required by mammals for prey location involves multiple sites in the brain including the brain stem, midbrain, thalamus, and cortex. [7]. In a test to determine what sites in the brain were necessary for sound localization in cats (Felus catus) it was determined that the cortex was necessary for localization [5] This was done through cooling the cortex to a level in which it no longer functions and giving the cat auditory queues from different locations. The cat then walks to the area in which it received the queue. When the cortex was cooled severe sound localization deficit was recorded [5].

This has led to our client, Dr. Tom Yin, to hypothesize that while the cortex is necessary for movement towards a sound but the cat is actually able to localize the sound. In order to test this Dr. Yin has designed a test in which a cat sits in an arena surrounded by speakers and when one goes off the cat looks towards the sound. A device implanted in the eye of the cat determines the eye movement and if the cat's eyes moved toward the location of the sound. As a control for his experiment Dr. Yin plans to setup the same experiment run by Malhorta and Lomber [5]. The device is necessary because the results from this experiment will act as a control for Dr. Yin and allow him to determine the validity of his findings.

Dr. Yin is looking for an improvement on the auditory localization arena used by Malhorta and Lomber [5] in which all parts will be automated. In the arena used by Malhorta and Lomber [5] human intervention was used both to guarantee the cat was looking straight ahead before the experiment and to administer the food reward at the end of the experiment. Dr. Yin would like to make those functions automated to reduce the chances of human influence.

Client Requirements

The client has specified six design requirements besides the reduction of human intervention. The first is that the system should have only a minimal chance for device miscue. This avoids giving that cat a reward for going to the wrong speaker or not giving it a reward for going to the right speaker which encourages the cat to do the wrong thing. The second requirement is that the automation must be easily reset to allow for multiple replicates in one testing session. In order for enough data to be collected for the results to be valid the system must run efficiently and not need to be manually reset after each test. The next requirement is that speakers must have the ability to be manually relocated to a different position between testing sessions. This will reduce the likelihood of the cat developing a frequency-location correlation during testing. The system must also be durable. Because of the amount of testing to be done and the length of time the auditory arena will be in service for it must be able to sufficiently stand up to the rigors of testing. The background noise needs to be minimalized as well. This is key because any background noise could give the cat a signal to walk towards that sound and reduce the effectiveness of the test. Finally, any magnetic fields used cannot interfere with magnetic fields used in eye localization mechanism. These requirements set by the client will help to ensure the efficiency of the system and guarantee the best results possible are obtained.

Design Options

The design options are broken into four categories; general setup, food reward, pumps and valve options, and switch options. The general setup design options include a swing arm, 4-speaker arrangement, and track option. The swing arm (Fig. 5) would consist of a large arm centrally located above the cat and supported by the hollow cube, which has the magnetic field generating wires in it. The motor would be placed directly above the home position for the cat to eliminate noise being generated near the speaker before the test begins. The speaker would move to random locations in front of the cat generated by a random number generator from the computer. This would eliminate some human bias. Only one food pump would be needed on the arm and go down near the speaker.

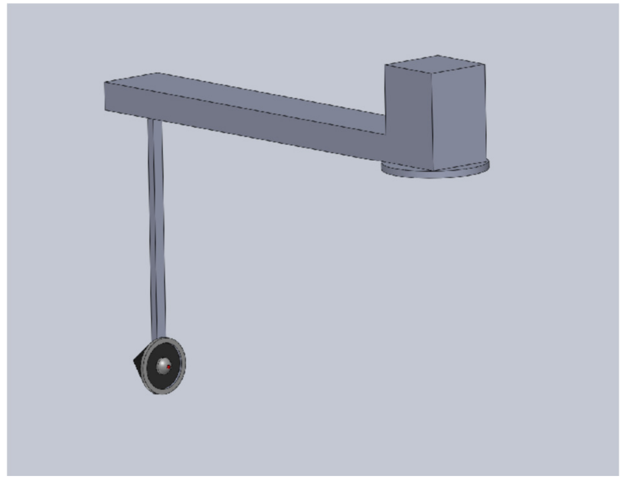


Figure 5, SolidWorks diagram of the swinging arm general setup option

The 4-speaker arrangement for the general set up would consist of 4 speakers placed in a semicircle around the home position for the cat (Fig. 6). Each speaker would be able to create white noise and also an LED flash to test different aspect of cat recognition. An LED would be placed directly in front of the cat so

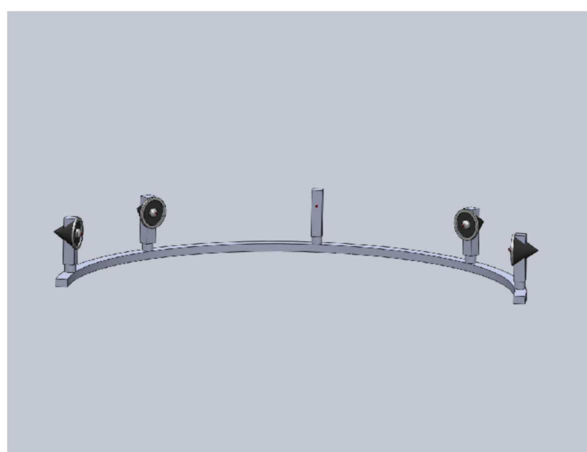


Figure 6, SolidWorks diagram of the 4-speaker general setup option that the cat would put its head forward before the test begins. Food pumps would be needed at each speaker setup to reward the cat after it has made the correct speaker choice.

The final option is the track option for general setup. The track would consist of one speaker and food pump placed on a car that has the ability to move in a semicircle around the home position of the cat (Fig. 7). A random number generator would determine the car position allowing many angles to be tested without limiting the speakers to a specific location.

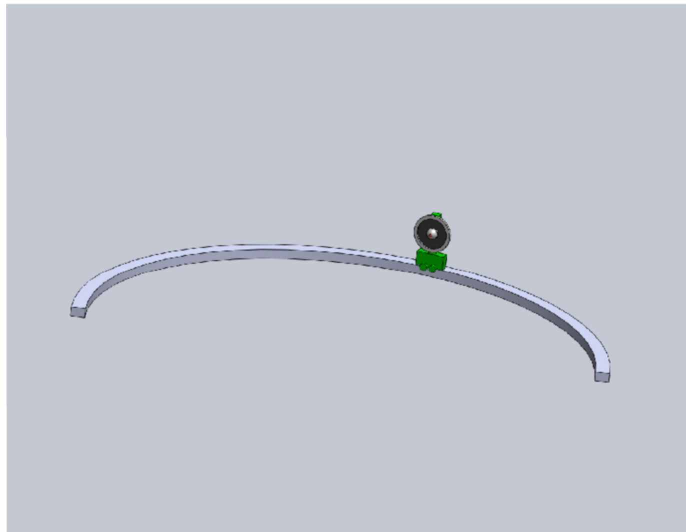


Figure 7, SolidWorks diagram of the track general setup option

Food Reward

The food reward options consist of dry pellets, wet food controlled by ball valves, wet food controlled by pinch valves, and an instant mix option. The dry pellets would allow a consistent amount of food to be rewarded at the end of each trial. Also this would eliminate the need for pumps within the system. A dropping mechanism could be utilized to distribute the dry pellets to the needed location.

The second option would be to use wet food and control the distribution by ball valves. The ball valves would be controlled by a DC electric motor and come into direct contact with the food.

This may lead to contamination if not cleaned properly. The ball valves would enable the line for food to be opened different amounts between closed and open.

The third options would be to use wet food controlled by pinch valves. Pinch valves do not make contact with the wet food, but instead pinch the tube closed that the food would be inside. This would keep the overall system more sanitary. The pinch valves are controlled by a solenoid.

The final option would be to instantly mix the wet food at the location of the speaker. This would consist of a dry mix of cat food that would be added to water when the cat made the correct choice. This system would eliminate waste food and resemble a soda machine. This system would utilize a complex system of computers and valves.

Pump and Valve

The pump and valve options consist of using a Masterflex digital drive (Fig. 8) with different pump head configurations. The pump heads utilize a peristaltic pump to push fluid through the line. The alternative would be to use compressed air to create pressure within the wet food system. The valve options consist of using pinch valves or ball valves (Fig. 9). Pinch valves (Fig. 10) have the advantage that they do not come into contact with the food being dispersed. Pinch valves only have the ability to open and close, with no

Figure 8 Masterflex digital drive capable of attaching up to 4 pump heads

settings in between. Ball valve has the ability to open to different degrees, but the system comes into contact with the food being delivered.

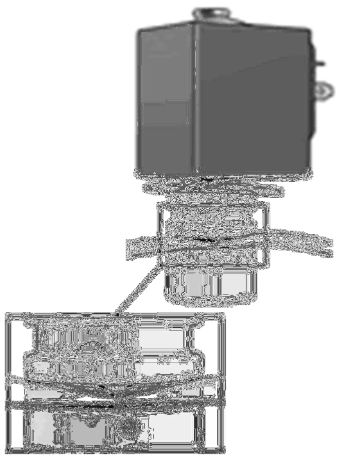


Figure 9, pinch valves close without contacting liquid food [6]

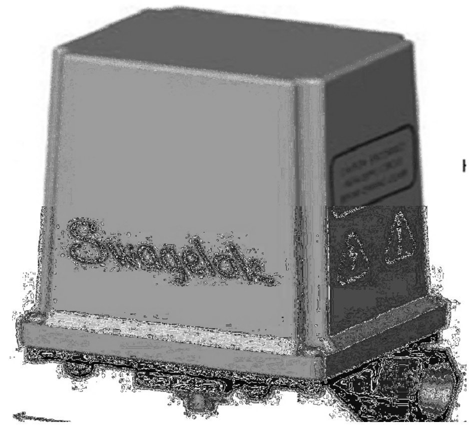


Figure 10, ball valves close using DC electric motor, contact food [6]

Figure 12, peristaltic pump head [1]

The Masterflex digital drive would be able to accommodate 4 separate pump heads. This would allow for a consistent pressure to be distributed to 4 separate locations distributed directly from the pump heads (Fig. 11). This would eliminate the risk of one tube clogging and disrupting the rest of the setup, but would also an expensive option. The pumps would supply the pressure and the opening and closing of tubes would be controlled by either pinch or ball valves.

Figure 11 Masterflex digital drive with 4 pump heads attached [1]

The Masterflex digital drive could also be utilized with only one pump head, (Fig. 12). This single pump head would lead to a food reservoir, creating pressure. The reservoir would have 4 separate tubes branch off to different speaker locations. Pressure would build within the reservoir and then when pinch of ball valves opened the end of a tube food would be dispersed. This would eliminate some of the cost. The disadvantage to this design would be maintaining pressure in the reservoir and also potential clogging issues.

Switch

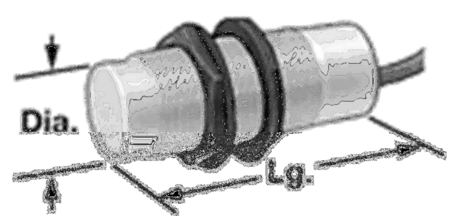


Figure 13 proxy sensor [6]

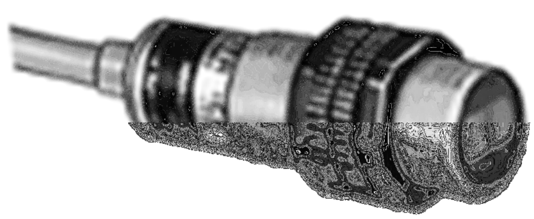


Figure 14 light sensor with photodiode at end [6]

The switch options consist of using a proximity sensor, light sensor or load sensor. Each of these switches would be placed on the speaker rig and the cat would need to trigger the switch in order to receive a food reward. The proximity sensor (Fig. 13) utilizes an electromagnetic or electrostatic field, or a beam of electromagnetic radiation, and looks for changes in the field or return signal. An inductive proximity sensor could be used to detect the metal surrounding the cat's eye. The disadvantage of this sensor is that the cat would have no tactile feedback of the sensor being triggered.

A second switch option would be the light sensor (Fig. 14). The light sensor uses a photodiode to convert light into a voltage or current. This sensor could be triggered by the cat's nose blocking the incoming light on the photodiode resulting in a change in signal back to the computer. This change in signal would trigger the valves to open and food reward to be administered. A disadvantage to this sensor is that it may be easily triggered by the cat walking past. This would result in false data collection.

The final switch option, the load sensor (Fig. 15) uses a mechanical spring loaded switch to transmit a change in voltage or current back to the computer. This switch forces the cat to places its nose at a specific location. This known trigger location could then be used to determine a convenient location for food dispensing. The cat would also receive positive tactile feedback when pushing the load sensor switch closed. This sensor option was found to be the least expensive.

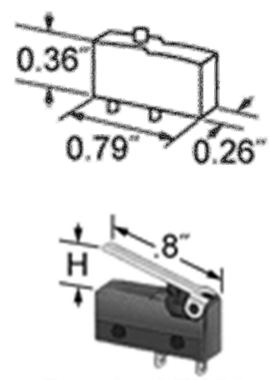


Fig 15 Spring action load switch [6]

Design Matrices

Based on our assessment of the problem we determined four key areas in which design decisions needed to be made: general set-up, type of food reward, pump/valve set-up, and switch choice.

Factors	Weight	Rating (1 to 10)		
		Swing Arm	4 Speakers	Track
Mechanical Noise	0.35	3	7	5
Time to Set up	0.15	3	9	4
Cost	0.05	3	6	5
Ease of Use	0.25	2	8	4
Repeatability	0.20	8	7	6
Total	**1.00**	**3.75**	**7.50**	**4.80**

Figure X1: Design matrix for general set-up

Figure X1 contains the design matrix for the general setup of the device. Mechanical noise was weighted as the heaviest factor in this matrix. Any noise generated in moving speaker components into position (swinging arm and track options) could result in the cat being alerted to the position of the speaker before a white noise signal is generated. As this would nullify the results of the experiment, such noise has been strongly discouraged by the client. The motor used in the swinging arm design would generate the most noise, while the track would create slightly less. The 4 speakers design would only produce mechanical noise when pumps were in use and since pumping occurs after the cat has already made a decision, this would not influence the results of the experiment. Ease of use was weighted second highest because set-up designs that are unnecessarily complicated would impact the speed of research. The swinging arm set-up and track set up would both require that the speaker be reset to a position in front of the cat before relocating to a new position. This would greatly slow the process of testing. Repeatability was weighted third highest as the client indicated that this was an important factor in reproducibility and validity of results. The swinging arm rated highest in repeatability since a stepper motor could be used with a fairly high degree of positioning accuracy. The 4 speakers design was chosen as next best due to the constancy of speaker position implemented in this design. The only drawback of the 4 speaker design is that it is possible for the 4 different speakers to have a different frequency response range. This would result in the cat receiving slightly different auditory stimulus from different speakers which the cat could learn to associate with speaker placement. The track design was rated poorest in repeatability due to the error in speaker position that this option would create. The client indicated that cost was a relatively unimportant factor and that he would rather have the team focus on creating a testing apparatus that works with a high degree of repeatability.

Factor	Weight	Rating (1 to 10)			
		Dry Pellets	Wet Food (Ball Valves)	Wet Food (Pinch Valves)	Instantly Mixed
Client Preferences	0.40	1	8	8	5
Simplicity	0.10	9	3	6	1
Repeatability	0.30	3	8	7	2
Cost	0.05	8	2	5	2
Resistance to Error	0.10	2	8	8	2
Restock Requirement	0.05	8	3	3	8
Total	**1.00**	**3.20**	**6.95**	**7.10**	**3.40**

Figure X2: Design matrix for food type

Figure X2 contains the design matrix for food type. Client preference was weighted most heavily because based on Dr. Yin's experience he felt strongly that dry pellet food would not be appropriate for this study. Dr. Yin seemed skeptical of the 'instant mix' option for food, so both wet food methods were rated highest in client preference. Repeatability was chosen as a second highest weighting for similar reasons to those described above for general set-up. Both wet food options were rated high in repeatability due to the ease with which a precise volume of food could be provided to the cat. The ball valve delivery method scored slightly higher due to the fact that pinch valves could compress the food in the pinch area, making it nonhomogeneous. The dry pellet option rated poorly due to the difficulty that would arise in trying to produce a constant number of pellets for each reward. The 'instant mix' option rated lowest due to the fact that it introduces several more steps to the food delivery process which could all be potential sources of error.

Factors	Weight	Rating (1 to 10)			
		4 Pumps, 4 Pinch Valves	1 Pump, 4 Pinch Valves	1 Pump, 4 Ball Valves	Compressed Air into Reservoir
Safety	0.25	8	8	8	4
Cost	0.05	4	7	3	5
Ease of Use	0.20	8	8	2	4
Clogging Probability	0.40	6	6	3	6
Ease of Repair	0.05	8	6	3	2
Size	0.05	5	7	7	2
Total	1.00	6.85	7.00	4.25	4.65

Figure X3: Design matrix for pump and valve choice

Figure X3 contains the design matrix for pump and valve choice. Clogging probability was given a high rating based on advice from the client. The ball valve option was rated lowest in this category due to the fact that food could remain lodged in ball valves between trials and harden. This could build up over time and result in clogging of the system. Safety was weighted next highest again due to client preference. The only design option that did poorly in this category was the compressed air option. If this design were to fail by rupture of the air reservoir, there would be a possibility of injury to testing animals and researchers.

Factor	Weight	Rating (1 to 10)		
		Proximity Switch	Light Activated Switch	Load Sensing Switch
Force Exertion Needed	0.05	10	10	5
Cost	0.05	3	3	8
Minimize False Positive	0.35	4	2	9
Ease of Use for Cat	0.25	8	8	6
Lifetime	0.05	7	7	5
Repeatability/Reinforcement	0.25	5	5	8
Total	**1.00**	**5.65**	**4.95**	**7.55**

Figure X4: Design matrix for switch choice

Figure X4 contains the design matrix for switch choice. The most important factor in choosing a switch is the minimization of false positives. Light activated switches could be triggered by ambient light entering the room or could trigger on their own due to electromagnetic drift; for these reasons light activated switches were rated lowest in this category. Proximity switches could be triggered by fluctuations in the electromagnetic field directly in front of the sensor or the movement of any flies present in the room. Such events are less likely to occur than the false triggering of light activated switches. The load sensing switch was chosen as the best at minimizing false positives due to the fact that it is either in an on or off position and thus is not susceptible to electromagnetic drift. Ease of use for the cat is important since the experiment cannot be performed if the cat cannot successfully learns to operate the switches. The proximity switch and light activated switches would be ideal in this aspect since the cat would not need to produce any force to operate these switches. The load sensing switch rated less highly due to the fact that the cat would need to push slightly to activate this switch. The repeatability/reinforcement category refers to the repeatability of cat nose placement and the tactile feedback the cat receives in activating the switch. When using the proximity and light activated switches, the cat's nose simply need to move close enough to the sensor to produce a response. This means there can be variability in the placement of the cat's nose and this would make it difficult to deliver a food reward close to the cat's mouth. In addition the cat has no tactile feedback in these cases so it could be difficult for the cat to learn to perform these actions. When using the load sensing switch, the cat's nose would have to end up in the same place every time due to the fact that it would use its nose to press this switch. This makes it easy to locate the cat's mouth for food delivery. In addition the presence of tactile feedback in this switching option would help the cat learn to perform this action more easily.

Future Work

The next step in completing this project will be the selection and purchase of specific parts. Once these parts are obtained we will run general diagnostic tests on them to determine if they will be sufficient for our intended use. Speakers will be tested for frequency response range to ensure that none of the speakers significantly influence the results of the experiment. Pinch valves will be tested for their maximum applied strength and to see if pinching of tubes can cause compacting of food over time. Tubing will be tested for compliance with pinch valves and optimal resistance. After testing individual components we plan to make a small-scale setup using one speaker and one food pump. We will use this model to test our overall setup and diagnose any early problems before completing the testing apparatus. After we are confident that the small-scale setup works we will add these components into a full size testing device apparatus that we will install at the client's location.

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Appendix A: Product Design Specifications

Feline Acoustic and Visual Orienting Arena
Product Design Specifications
James Madsen, Mike Nonte, Drew Birrenkott, Caleb Durante

Function: Dr. Tom Yin has requested a feline acoustic and visual orienting arena that will send auditory signals to a cat in the middle of the arena from four speakers located around the arena. The cat will walk towards the speaker that it heard the sound from and activate a switch by that speaker to receive a food reward. The cat will then have to move back to the middle of the arena and look at an LED light before the device resets and the process begins again. The system is meant to serve as a control experiment for Dr. Yin's research.

Client Requirements:
- Reduce human interaction to the greatest extent possible
- Reduce or eliminate chances of miscue and give the cat a reward if it goes to the wrong speaker
- System must be easily reset and be able to run many replicates in a short period of time
- Speaker alignment must be adjustable in case they emit different frequencies
- Be easily maintained and durable
- Reduce background noise
- Eliminate or ensure that magnetic fields don't interfere with magnetic fields already used for research

Design Requirements

1. **Physical and Operational Characteristics**
    a. *Performance Requirements*: The system must be able to handle many repetitions in one session without the need for elements to be manually reset. The system must provide white noise sound emissions, the speakers should not sound on different trials systematically.
    b. *Safety*: The cat cannot sustain any injury from the use of the system. The switches the cat must trigger to receive its reward should not require an excessive amount of force. The food being dispensed to the cat should be free of contamination and safe for consumption. The frequency of the speakers cannot exceed decibel levels that can cause loss of auditory function.
    c. *Accuracy and Reliability:* The system must be accurate to the greatest extent possible. Miscues in which the cat doesn't receive a reward when going to the correct speaker or receives a reward when going to the correct speaker will greatly reduce the validity of the experiment.
    d. *Life in Service*: The system needs to be in service for the entirety of the experimental testing. The parts must be easily available and replaceable so they can be exchanged in case of a breakage.
    e. *Shelf Life*: The only element that has a shelf life concern is the cat food being used. Because it is in slurry from it must be occasionally replaced and the lines cleaned to avoid the food going bad or bacterial growth. The shelf life of all of the other parts should last the entirety of the testing.
    f. *Operating Environment:* The system will work in a small testing room. The room will be acoustically insulated so no outside noise can affect the results. The room should be able to be sealed off with no human intervention in the chamber.
    g. *Ergonomics*: The system must be programmed to run on its own and need minimal human intervention. The speaker setup needs to be easily interchangeable to avoid variances in speaker frequency
    h. *Size*: The system must fit in a small testing room that is approximately 6ft x 6ft x 6ft and give the cat ample room to move to different speakers.
    i. *Weight*: The parts in the system must be light enough to be easily interchanged

j. *Materials*: The tubing feeding the food reward must be pliable and be able to be run by a peristaltic pump. The switch used must not become less effective as it gets worn and misfire.
k. *Aesthetics, Appearance, and Finish*: The system should be well organized. The design should be easy to follow from the food pumps to the reward distribution. The arena in which the cat is should be as clean and all parts as similar as possible.
l.

2. Production Characteristics

a. *Quantity*: One device needed
b. *Target Product Cost*: Current Budget is $2000

3. Miscellaneous

a. *Standard and Specifications*: The system must fit within the constrained space and be able to effectively deliver the reward upon the cat activating the correct switch.
b. *Customer*: The device must meet all client requirements and be as user friendly as possible. The device should be completed by the end of the semester.
c. *Patient-Related Concerns*: The food being provided to the cat must be fit for consumption, activating the switch should not require excessive force, and the arena must provide ample room for the cat to maneuver
d. *Competition*: Stephen Lomber of the University of Western Ontario created a similar device in 1999 that required extensive human input. We are now working to improve the device and make it more automated to reduce human impact on the experiment.