FELINE ACOUSTIC AND VISUAL ORIENTING ARENA

BME 200/300
Department of Biomedical Engineering
University of Wisconsin-Madison
December 8, 2010

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Abstract

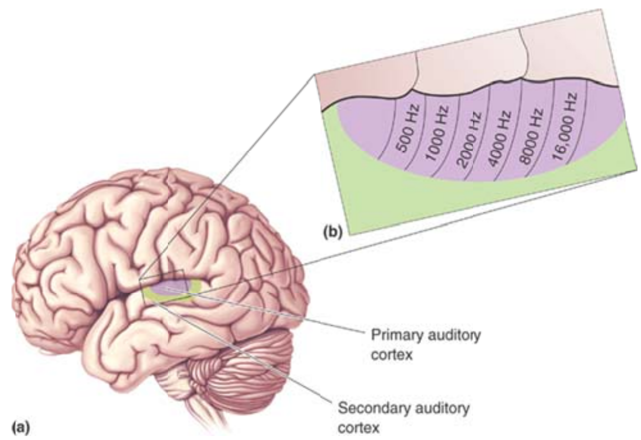
Dr. Tom Yin of the University of Wisconsin-Madison Department of Physiology has requested the design and construction of a feline acoustic and visual orienting arena. A similar arena has been used in previous studies and will be used by Dr. Yin as a control experiment for his current research question. 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 rather than space [1]. 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 [2]. The signals from each ear converge for the first time at the medial superior olive (MSO) located in the brainstem (figure. 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 (figure. 2)



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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 [4].

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

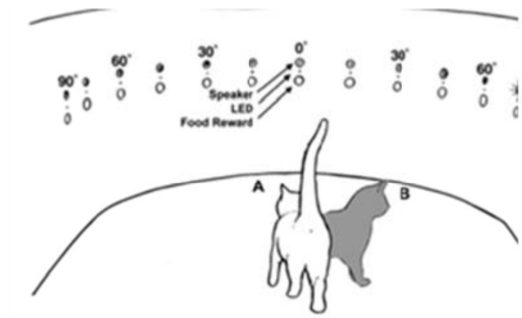


Figure 4: Acoustic and visual orienting arena. A loudspeaker (*top* circle) and a light-emitting diode (LED, black dot) were located above a food reward locus (*bottom* circle) at each of 13 regularly spaced (15°) intervals (for sake of clarity, only 30° intervals are labeled). [5]

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. [5]. 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 [4] This was done by 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 speaker from which it received the queue. When the cortex was cooled severe sound localization deficit was recorded [4].

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 proposed a test in which a cat sits in an arena surrounded by speakers and when a noise is generated from one of the speakers, the cat shifts its gaze towards the sound. A coil is implanted in the eye of the cat and the entire experiment takes place within a 3-foot cube that generates an AC magnetic field. When the cat shifts its gaze a computer in another room measures the induction current generated and concludes whether 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 [4]. Dr. Yin believes that the cat's motor function will be impaired by the cooling but that its ability to localize sound will not be adversely affected by cooling. The impairment of motor function will be a positive signal that neural cooling is occurring. 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 [4] in which all parts will be automated. In the arena used by Malhorta and Lomber [4] 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 automate those functions, thereby reducing the chances of human influence and by extension errata in his data.

Client Requirements

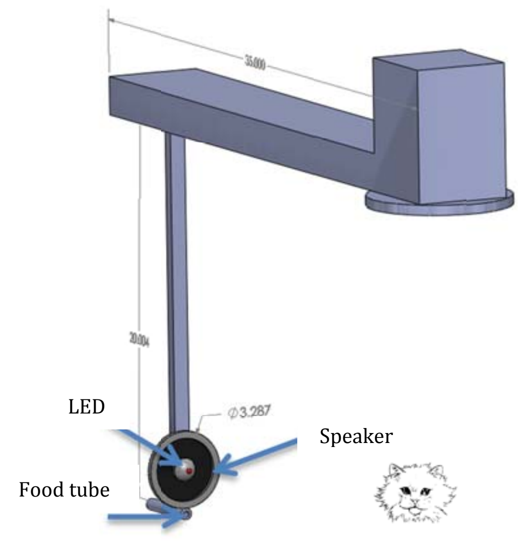
The client has specified six design requirements besides the reduction of human intervention.

- 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 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.
- 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.
- 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 (figure. 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.



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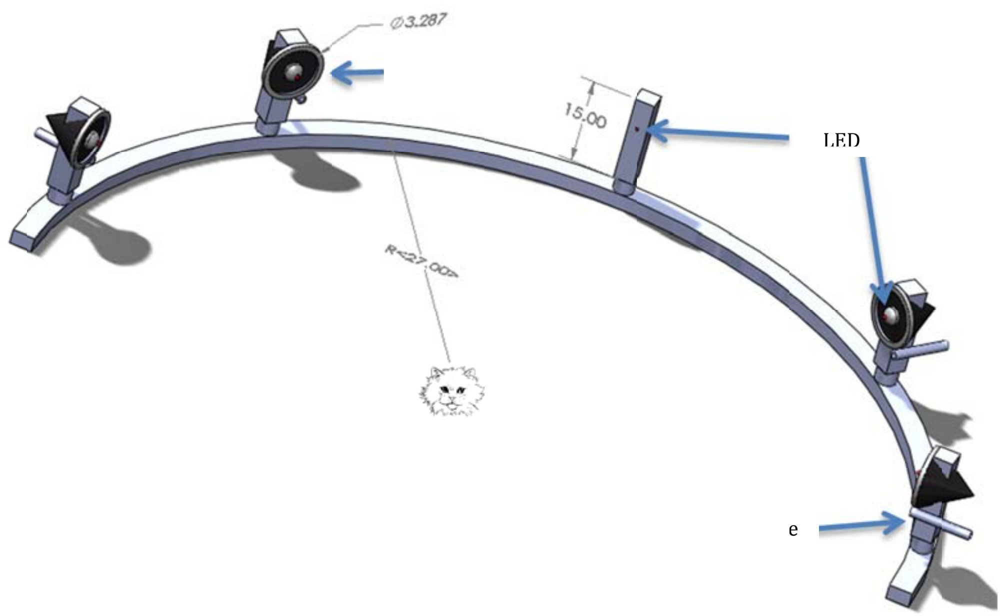
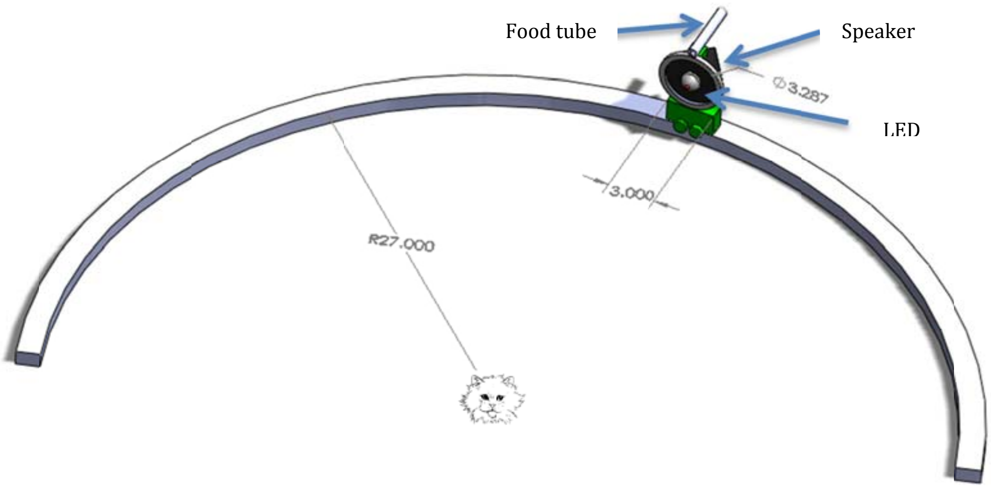


The four-speaker arrangement for the general setup would consist of four speakers placed in a semicircle around the home position for the cat (figure. 6). Each speaker would be able to create white noise and also an LED flash to test different aspect of cat recognition. An LED would be placed directly in front of the cat so 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 (figure. 7). A random number generator would determine the car position allowing many angles to be tested without limiting the speakers to a specific location.



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

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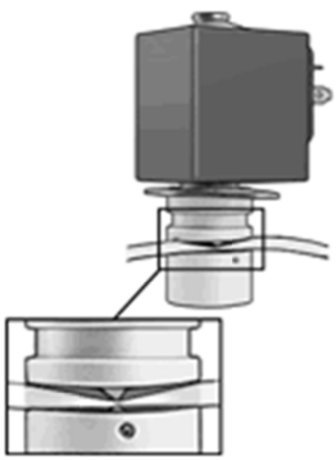
peristaltic pump to push fluid through the line. The alternative would be to use compressed air to create pressure within the wet food system. The valve options consist of using pinch valves or ball valves (figure 9). Pinch valves (figure 10) have the advantage that they do not come into contact with the food being dispersed. Pinch valves only have the ability to open and close, with no settings in between. Ball valve has the ability to open to different degrees, but the system comes into contact with the food being delivered.



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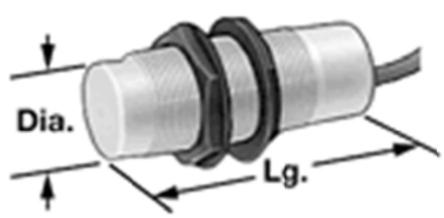
The Masterflex digital drive would be able to accommodate 4 separate pump heads. This would allow for a consistent pressure to be distributed to 4 separate locations distributed directly from the pump heads (figure 11). This would eliminate the risk of one tube clogging and disrupting the rest

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.

The Masterflex digital drive could also be utilized with only one pump head, (figure 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

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 (figure 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 (figure 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 (figure 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.

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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**

Table 1: Design matrix for general set-up

Table 1 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 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**

Table 2: Design matrix for food type

Table 2 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

Table 3: Design matrix for pump and valve choice

Table 3 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**

Table 4: Design matrix for switch choice

Table 4 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. 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 may help the cat learn to perform this action more easily.

Final Design

The final design utilized the four-speaker arrangement with a slit that utilized some of the track design advantages for the general setup. The speakers had two position options on each of the speaker mounts, one at 10 inches above the table and one at 11 inches above the table to account for variability in cat height. An LED was mounted in the center of the speaker to allow for visual and acoustic testing. The speaker mounts were made from 1 inch square aluminum tubing to ensure the material did not affect the magnetic field reading. The speaker mounts also had mounts for the pinch valve that controlled the food output and the load switch that determined if the feline has made the correct decision. The switch, model Rigid-Lever snap acting Limit Switch # 7090K37, was located directly in front of the speaker and LED. The switch would be pushed by the cat to activate to opening of the pinch valve and the food reward to the cat. The pinch valve, model 98305-10 from Cole Parmer, would only open if the cat had made the correct speaker choice from which the sound was originated. The pinch valve was mounted high on the speaker mount to allow for gravity to help with the flow of food down to the cat's mouth. The diameter of the tube from which the cat fed was 5/16 inch, and was made from nonporous material suitable for food distribution. This material was Tygon B-44-4X tubing. The four speaker mounts were each 15 inches tall and have been built to exact specifications of a SolidWorks model. This ensured that the cat did not see any of the speaker mounts differently. Each of the speakers was fitted with a plug to enable them to be compatible with Dr. Tom Yin's previous lab setup. Within his previous lab Dr. Yin can run tests of frequency response of each of the speakers by creating an FFT plot.

A large piece of plywood was cut to create a half-circle ribbon around the magnetic field generating cube. This plywood was then painted to seal the wood from any liquid or misplaced food during the experiment. The half circle contained three slits to allow for the speaker mounts to be mounted to the plywood. These slits enable the speaker mounts to be located at many different angles at a radius from the center of 33 inches. The 33 inch radius was suggested by Dr. Yin and was determined sufficient amount for the cat to move from its starting resting position to where the cat needed to push on the load switch. The slits were not cut through the entire plywood piece to ensure the plywood would have enough

Figure 16: Individual speaker post. Shown image does not include pinch valve that will be mounted in the top set of holes

strength to securely hold the speaker mounts. The plywood ribbon was then mounted to the existing wood platform in the soundproof booth. The ribbon was mounted using 5 wood blocks with 3 bolts each in a triangle pattern. This allowed for a great amount of stability within the plywood ribbon and ensured it would withstand hours of testing and the sliding of the speaker mounts from location to location. The speaker mounts were fastened to the plywood ribbon by using a half inch bolt and nut. The half inch bolt had the ability to slide through the slits within the plywood ribbon. This enabled the speakers to be moved to any position within the slit. The current setup had the speakers located at 30, 60, 120, 150 degrees going from left to right, but a large range of motion of each speaker mount enables almost any possible angle setup. A 15 inch LED mount was located directly in front of the cat starting position at 90 degrees. The LED mount could also be positioned along any of the slits throughout the plywood ribbon. But would primarily be used to ensure the cat is looking forward before the each test would begin. The LED mount consisted of a 15 inch tall, 1 inch square aluminum tube with an LED located at 11 inches from the ground.

Figure 17: Perspective view of hemi circular wooden arc mounted just outside of the magnetic cube with speaker posts placed in slot cut into wood. Speakers can slide within the track for varying positions.

The pump used to create a flow to the four speaker setups was a Peristaltic Pump model EW-07523-80 from Cole Parmer. This pump was chosen because it had the ability to change flow rates as needed directly on the face of the pump. This made the pump easy to use and the technicians have the ability to change the settings during the experiments as needed. The diameter of the tubing from the pump head was ½ inch. This tubing led into a manifold that had ten output ports. In this design only five of the outputs were utilized but the ten outputs allows for more speaker mounts to be added in the future if necessary. The output tubes were 5/16 inch in diameter to allow for a pressure increase in the tubing by downsizing the tubes. This pressure increase ensured the flow of food throughout the system. The fifth output port was used to feedback to the food reservoir from which the pump was collecting food. This feedback loop kept the force on the peristaltic pump lower and at a more controlled level. All of the tubing used within the system was Masterflex Tygon B-44-4X tubing suitable for use with food products. This tubing had a durometer reading of 65 which helped determine the specific pinch valve used. Five pinch valves were utilized within the setup. One pinch valve was located on each of the speaker mounts and one pinch valve was located near the feedback reservoir loop. When the cat activated the correct load switch, the pinch valve near the reservoir would close and the pinch valve near the correct speaker would open. This opening and closing was set to be within a few milliseconds and allowed for an easier flow of food from the feeding tube.

System control

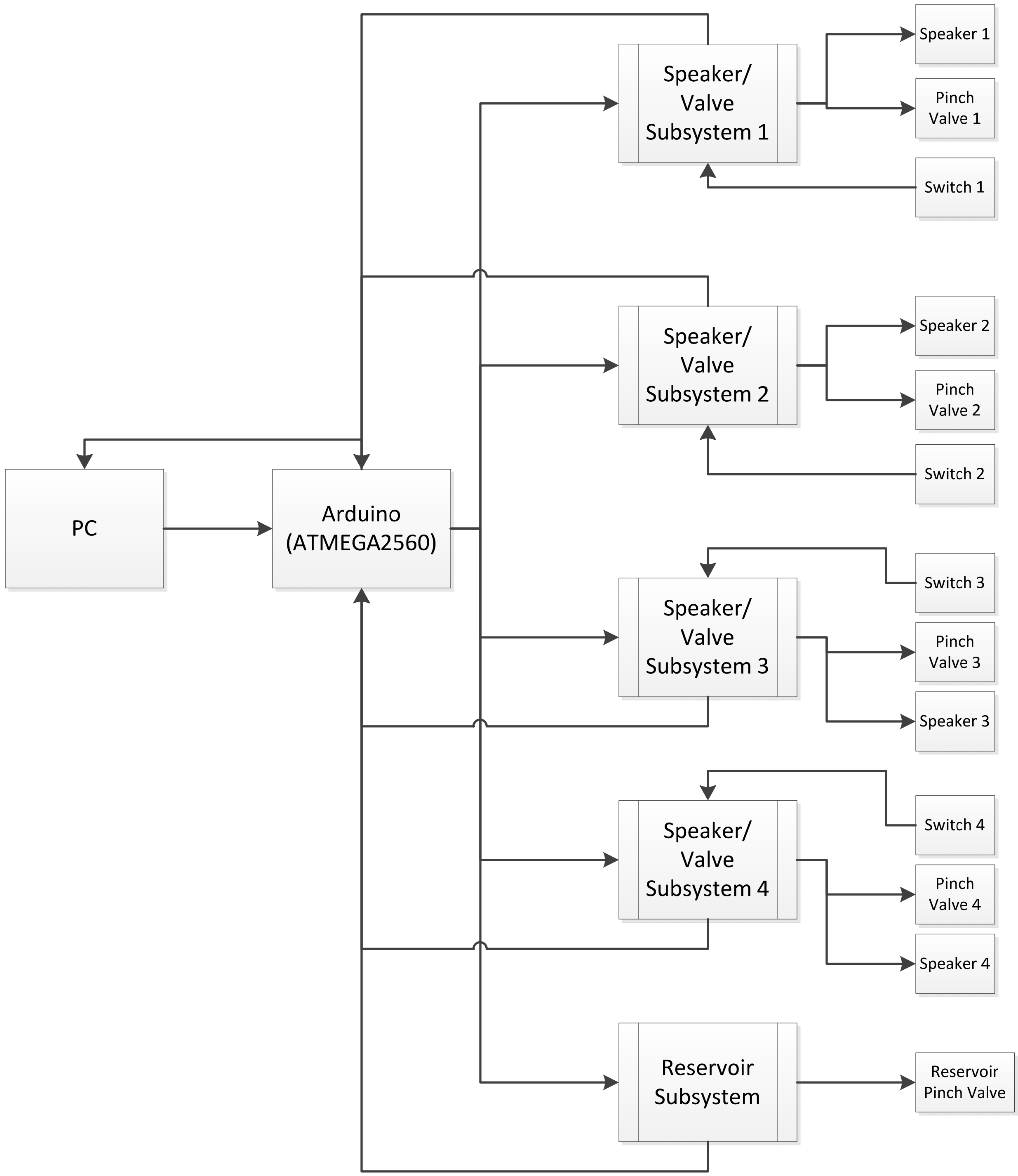

Figure 18: Control flow diagram for entire system.

The complete system consists of a PC, an Arduino microcontroller, four speaker/valve subsystems, and one reservoir subsystem. Figure 18 contains the control flow diagram for this system. The PC communicates with the Arduino using asynchronous serial transmission via a USB connecting cable. The LabView program chooses a speaker/valve system at random and sends a bit pattern specific to that system to the Arduino over the USB cable. The program embedded in the Arduino then enters the state transition diagram specific to that speaker/valve subsystem. Figure 18 contains the state transition diagram for a single speaker/valve subsystem.

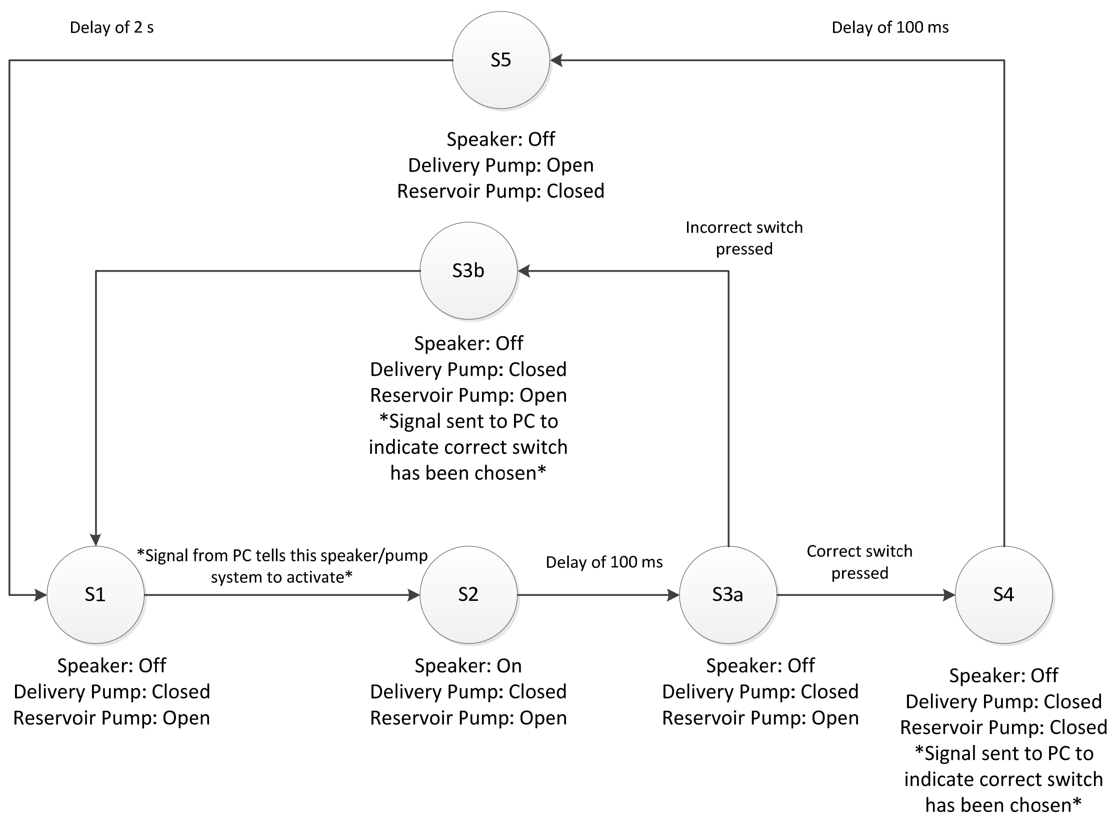

Figure 19: State transition diagram for a single speaker/pump system. Four speaker/pump systems exist and the PC controls the specific system that is activated.

State 1 (S1) is common to all speaker/valve sub-systems and is the state from which the system leaves when the Arduino receives a control signal. In this state the speaker is turned off, the flow of food to the cat is blocked, and the flow of food to the reservoir is open. State 2 (S2) is entered when the Arduino receives the bit pattern specific to a particular speaker/valve subsystem. In this state the speaker is turned on and food flow is the same as in state 1. After a delay of 100ms, state 3a (S3a) is entered. In this state the speaker is turned off and food flow remains the same as in states 1 and 2. This state can be left by the depression of either the one correct switch corresponding to this speaker/valve subsystem or the depression of any of the three incorrect switches. If the incorrect switch is pressed, food flow remains diverted to the reservoir, the speaker remains off, and a bit pattern specific to a failed trial for this subsystem is sent to the PC via the USB connector cable. The LabView program records that a failed trial has occurred for this speaker/valve subsystem. If the correct switch is pressed, the subsystem enters state 4 (S4). In state four, the speaker remains off and the flow of food to both the cat and to the reservoir are blocked. This state ensures that pressure in the tubing does not dissipate when switching between food flow to the reservoir and food flow to the cat. When this state is entered, a bit pattern indicating that the correct switch was pressed for this specific speaker/valve subsystem is sent to the PC. The LabView program records that a successful switch depression has occurred for this subsystem. After a delay of 100 ms the subsystem enters state 5(S5). In this state the speaker is off and the flow of food is diverted to the cat. After a delay of 2 seconds, the system returns to state 1 and waits for another command from the PC. No delay state with both pinch valves closed is necessary for the transition from state 5 to state 1. This is because if asynchronous switching of the valves occurs and there is a momentary loss in pressure for the tubing leading to the reservoir, this will in no way effect the delivery of food to the cat. There will be more than enough time between the return to state 1 and the entrance to a new state to ensure that the pressure is re-established in the tube leading to the reservoir before another drive command is given by the PC.

Speaker Driver Circuit

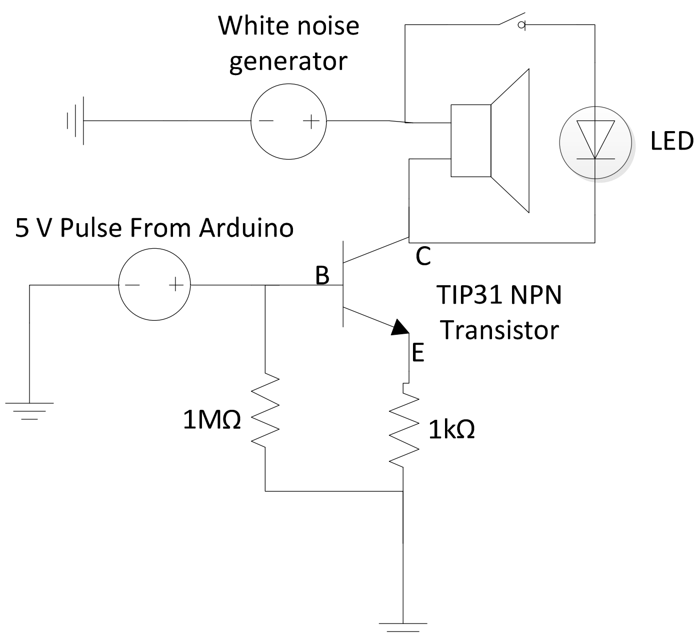

Figure 20: Circuit diagram for the speaker driver.

The four speakers are each controlled by separate transistor pull circuits. Figure 20 contains the circuit diagram for the speakers. A white noise generator is used to drive the positive input to the speaker. The negative terminal of the speaker is attached to the collector of an NPN transistor. The base (B) of an NPN transistor is connected to a pin on the Arduino. When the pin is set low (0V) there is no voltage difference between the base and emitter (E) of the transistor. In this state the transistor prevents current from flowing from the collector (C) to the emitter, and thus no current can flow through the speaker to ground. This means the speaker is turned off in this state. The 1 MΩ resistor ensures that if any stray voltage occurs on the wire leading to the base, it will be shunted to ground. This prevents false triggering of the transistor. When the Arduino pin is driven high (5V), a voltage difference is established between the base and the emitter. This allows current to flow from the collector to the emitter and thus allows the speaker to turn on. The 1 kΩ resistor prevents excessive current flow through the speaker and transistor when the transistor in set to the "on" state. An LED is mounted on the front of the speaker and connected in parallel with the speaker. A switch in series with this LED allows the option to have an LED light when the speaker is activated. If the above circuit is driven with a DC voltage rather than AC white noise, the LED will active without the speaker being activated.

Solenoid Driver Circuit

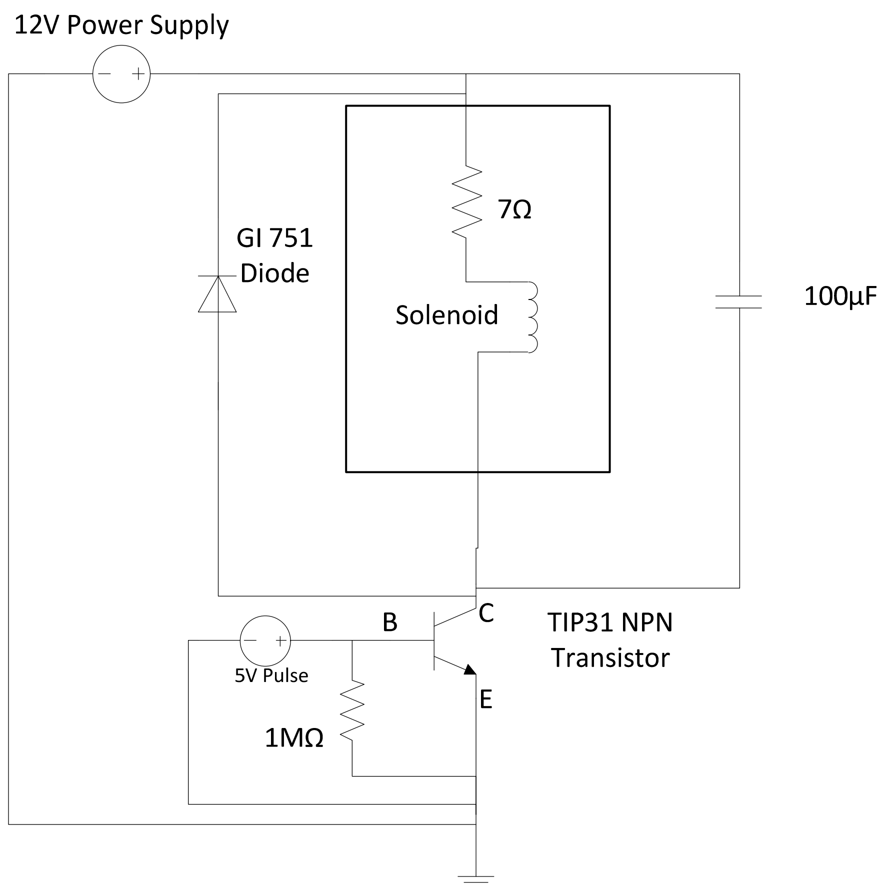

Figure 21: Solenoid driver circuit

The hold circuit shown in figure 21 is used to drive the solenoid pinch valves. A 12V power supply is used to power the solenoid. The solenoid is activated by an NPN transistor tied to a pin on the Arduino in the same manner described for the speaker circuit. A diode is connected in parallel with the solenoid to prevent excessive back current created when the solenoid shuts off from damaging circuit components. The capacitor connected in parallel with the solenoid is charged by the power supply when the transistor is turned off. When the transistor is activated, the capacitor provides the energy to initially drive the solenoid. Solenoids require a large current to initially activate and a low current to remain activated.

This capacitor provides the necessary current spike to activate the solenoid. After activation the current through the solenoid is reduced by the RC response of the circuit. This prevents excessive power use and the heating and damage of circuit components.

Testing

In order to specify and locate the correct parts for the assembly of the design several tests needed to be conducted on various aspects or elements.

- Unsure of whether or not a pump rated for low-viscosity fluids would function with a slurry of "reward", the team performed a density measurement on a 10 mL sample of the slurry and determined its density to be 1.012 g/ml. Comparing this to the density of water (1 g/ml), the team concluded that the Masterflex pump (figure 11) would be appropriate for the design.
- Unsure of which pinch valve would be appropriate for our tubing, the team measured the force required to "pinch shut" a segment of sample tubing provided by the client. This was done by placing the tubing on a scale and applying pressure vertically with a flathead screwdriver. Once the team verified that the tubing was closed to airflow, the total weight was recorded (~7lbs.) as a representation of the minimum force required in our criteria for selecting a valve.
- To ensure that the rigid spring action switch (figure 15) was easy enough for a feline subject to activate, the team visited the Yin lab and had one of the cats interface with the switch. In all cases, the cat was able to depress the lever arm of the switch.
- To determine the amperage required for the speakers the team attached one of the speakers to a waveform generator and concluded that each required 3 mA to operate.

Ethics

There ethical considerations for the design lie in the realm of humane treatment of animals in research as well as safety precautions to both the experiment's operator and feline subject.

- Bearing in mind potential harmful or toxic chemicals used in cleaning and manufacturing of components, the team selected and purchased only components that were certified to be safe for use with fluids for consumption. This includes the actual tubing, reservoir, and port manifold, which are composed of polybutylene and polyethylene.
- Conscious of the fact that an animal will be interfacing with this design, the team machined nearly all components to have rounded edges free of metal burrs or shards left over as a product from milling, cutting, drilling, etc.
- Anticipating improbable yet potential degradation of the design components, the team decided to operate speakers, switches, and valves with the lowest amount of amperage possible. In the event that current inadvertently passes through the semi-conductive slurry, the potential fallout to the cat as well as other hardware will thus be minimized.
- Future work will be done to ensure that each speaker's frequency response range does not deviate from the others used in the design.

Note: While the ethics regarding the actual implantation, operation, and maintenance of the cryoloop are certainly worth serious consideration, the team did not include them in any design considerations. It is assumed that the client is both knowledgeable and in compliance with all relevant protocols and laws regarding the use of animals for medical research.

Future Work

While the design is complete, the team acknowledges that there is always addition work that can be done to improve any design. Under different time constraints the team would have implemented a handful of design modifications to better meet the client's needs.

- In order to rule out the possibility of deviations in the speaker frequency generating bias in the feline subject, the speakers should be tested over their complete frequency spectrum to ensure their mutual fidelity.
- The pinch valve used on the return line is made from a normally closed solenoid. However, the design dictates that this particular valve remain open during much of the operation (whenever all other valves are closed). Constantly energizing the solenoid's coil in this fashion could lead to the generation of excess heat. It should be replaced with a normally open valve instead.

In addition to these modifications, the client indicated that he might have the desire to run this experiment with an additional four speakers. The open slotted track, adjustable flow pump, and 10-port manifold were all chosen with this prospect in mind. All that would be required in this circumstance would be to fabricate and assemble the four additional posts and modify the code to incorporate them as well.

Budget

Preliminary discussions of budget with the client were held at the beginning of the semester. The client's research is fairly well endowed and he expressed that money wasn't a huge limiting factor in the design; the client simply wanted a design that *worked*. Below is a list of parts purchased for the design project.

Item #	Description	Part #	Distributor	Quantity	Price
1	Peristaltic Pump	EW-07523-80	Cole Parmer	1	$1,710.00
2	Masterflex Pump Head	EW-07518-00	Cole Parmer	1	$ 178.00
3	5/16'' Masterflex Precision Tygon Tubing 50'	EW-06419-25	ColeParmer	1	$ 76.00
4	1/2'' Masterflex Precision Tygon Tubing 50'	EW-06419-18	Cole Parmer	1	$ 117.00
5	Rigid-Lever snap acting Limit Switch	7090K37	McMaster Carr	5	$ 7.88
6	10 Port Tube Manifold (1/2'' IN 5/16'' OUT)	52045K207	McMaster Carr	1	$ 25.31
9	Pinch Valve	98305-10	Cole Parmer	5	$77
10	5/16'' Port Plug	51055K81	McMaster Carr	1	$ 7.69
11	Arduino Mega Microcontroller	DEV-09949	SparkFun Electronics	1	$ 64.95
12	Stock Aluminum, bolts, nuts, washers, etc.	-	COE Student Shop	-	$ 107.35
	*all diameters are OD				
				Total	$2,709.70
-	Speaker	MDT20	Morel	4	-

The major purchase was a peristaltic pump, which is the driving force behind the reward system. The client already uses this pump for another experiment, and he requested specifically that the team implement a new one into the design. The pinch valves comprised another large portion of spending. However, there is not a very large selection of pinch valves on the market that meet the team's criteria and compared to others, the one purchased is somewhat cheaper. Efforts were made to cut costs by using a wooden slotted track instead of a track fabricated from aluminum.

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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 toward the speaker that it heart the sound from and activate the 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:

1. Design must be fully automated during the length of each individual replicate.
2. The speaker that is turned on for each replicate must be randomly generated.
3. After each replicate the system must be quickly reset itself for a second replicate without the need for human assistance.
4. Each speaker must be adjustable in its location around the arena and the arena should accommodate the use of more than four speakers, if necessary.
5. Speaker heights must be adjustable to account for different cat heights.
6. The entire system must allow manual cleaning at the end of an experiment.
7. System must be constructed of materials that do not interfere with a magnetic field to be used in the experiment.

Design Requirements:

1. **Physical and Operational Characteristics**
    a. *Performance Requirements*: The system must be fully automated for the length of each replicate and must reset after automatically after each replicate. The speakers need to sound on the same frequency. The system must be able to handle between 100 to 200 replicates in one test session.
    b. *Safety*: The cat cannot sustain any injury from the use of the system. The switches the cat must trigger to receive a food reward cannot exceed the amount of force a human can exert without difficulty with the pointer finger. The food being dispensed to the cat must be free of contamination and safe for consumption. The speaker noise level shouldn't exceed 100 db.
    c. *Accuracy and Reliability*: The system should have a high level of accuracy and consistency. Each speaker should fire for the same time length, between 0.1 and 0.2 seconds, the time delay between switch activation and food reward dispersal should be approximately 0.1 second and be delivered for 2 seconds for each speaker. The system should not disperse a food reward to the wrong speaker or when the wrong switch is activated.
    d. *Life in Service*: The system must accommodate 100-200 replicates in a trial session and should function for the estimated life of the experiment, approximately 2 years. The parts used should be easily replaceable in case of breakage.

e. *Shelf Life*: The only concern for shelf life is the slurry cat food. The food must be able to be replaced and the food lines flushed daily
f. *Operating Environment:* The arena will function on an approximately 3 foot platform inside of a roughly 6 ft. by 6 ft. by 6 ft. room sound proof room. The speakers are to be oriented 33 in from the center of the platform which is encompassed by a 5 ft. cube creating the magnetic field.
g. *Ergonomic*s: The system must be programmed to run on its own and need minimal human intervention. The speaker setup needs to be easily interchangeable to create variances in speaker frequency for each speaker.
h. *Size*: All speakers must sit on a radius 33 in from the center of the platform. The speaker should be between 10 in to 12 in in height with the switch located directly in front of it.
i. *Weight*: The system should be easily interchangeable and each speaker system should weigh no more than 5 lbs.
j. *Materials*: The tubing feeding the food reward must be pliable and safe for food transmission. All materials used should be non-ferromagnetic so as not to disrupt the magnetic field being used and must be able to be manually cleaned.
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 clean and all parts used should be consistent.

2. Production Characteristics:

a. *Quantity*: One device is needed with four separate speaker setups constructed.
b. *Target Product Cost*: Current budget is $4000.00 for all materials including specific client requested peristaltic pump

3. Miscellaneous:

a. *Standard and Specification*: The system must fit within the constrained space and be able to deliver the reared upon the cat activating the correct switch
b. *Customer*: The device must meet all client requirements and be operable by someone who did not design it.
c. *Patient-Related Concerns*: The food being provided to the cat must be fit for consumption, activating the switch should be within a reasonable level for a cat using its nose, and the arena must give the cat ample room for maneuver.
d. *Competition*: Stephen Lomber of the University of Western Ontario created a similar device in 1999 that required extensive human input. We are not working to improve the device and make it more automated to reduce human impact on the experiment. Dr. Lomber is working in conjunction with Dr. Yin.