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COLLEGE OF GRADUATE STUDIES AND RESEARCH

AN ENGAGING ENVIRONMENT: IMPROVING NONHUMAN PRIMATE  
ENRICHMENT THROUGH CHOICE OF SOUND AMPLITUDE USING  
BROADBAND NOISE

By

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**THESIS APPROVAL PAGE**

This is to certify that the thesis prepared by Bradley M. Burgan Senior, entitled An engaging environment: Improving nonhuman primate enrichment through choice of sound amplitude using broadband noise, has been approved by the thesis committee as satisfactorily completing the thesis requirements for the degree Master of Arts.

  
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## ABSTRACT

### AN ENGAGING ENVIRONMENT: IMPROVING NONHUMAN PRIMATE ENRICHMENT THROUGH CHOICE OF SOUND AMPLITUDE USING BROADBAND NOISE

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Certain types of music may be more effective than others in promoting the welfare of animals. A fundamental understanding of simple properties of sound is needed to determine how music affects animal welfare. Two experiments were conducted using nonhuman primates to investigate choices to variations in amplitude using broadband noise. The first experiment examined subject's preferences for seventy decibels of pink noise or no-sound. The results revealed that five of seven subjects preferred no-sound. Experiment two tested whether avoidance and escape responding were sensitive to changes in amplitude from zero to eighty decibels. The results showed that subjects engaged in escape responding equally to all amplitudes. Overall, these findings suggest that broadband noise up to eighty decibels does not function as a reinforcing or aversive stimuli. The methods used herein could be adapted to a larger set of experimental questions, to determine more effective environmental enrichment strategies.

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## **An engaging environment: Improving nonhuman primate enrichment through choice of sound amplitude using broadband noise**

Historically, the Animal Welfare Act was instituted to make sure all animal researchers provided an adequate environment for nonhuman primates (NHPs); an environment that fosters physiological and psychological well-being. Originally, refinement of the way animals were handled, housed, and fed were of primary focus. Since the revision of the Animal Welfare Act of 1991, great strides have been implemented in promoting species-typical behavior. Standard environmental enrichment now includes perches, swings, access to toys that can be manipulated, increased foraging times, and social contact with both conspecifics and researchers. However, researchers will often go to greater lengths in improving the welfare of their subjects. For example, some studies have looked into ways to stimulate different sensory modalities (Clark, 2011; Koda, et al. 2013; Line, Clarke, Markowitz, & Ellman, 1990; Wells, 2009). One such way is through the use of auditory stimulation. Over the years, research of the effects of music in laboratory settings has had mixed results. Some of these studies have found that music can promote species-typical behavior, reduce aggression, and decrease physiological symptoms of distress (i.e. increased heart rate, high blood pressure, high cortisol levels) (Kawakami, Tomonaga, and Suzuki, 2002; Lemmer, 2008). In contrast, other studies have found that music has no effect at all, and that some NHPs-- if given the choice-- may prefer silence (Hinds, Raimond, and Perceli, 2005; McDermott, and Hauser, 2007). Two possible reasons for these mixed results may be due to lack of scientific rigor in choosing the music that is presented within these studies and the inherent subjective nature in determining an animal's preference. An environmental enrichment study that is



scientifically and methodologically rigorous should provide one or more measures of preference (e.g., choice proportion (percent allocated) between two or more alternatives, choice latency), in ways that reduce or eliminate experimental biases and potential confounding variables.

Wells (2009) speculated in a review on auditory enrichment that musical choice is often based upon the experimenter's preference or other non-experimental factors. One study described that soft rock was chosen because it was the only radio station that had good reception in the laboratory (Line, Clarke, Markowitz, & Ellman, 1990).

Despite the fact that animals often have little control over musical choice, studies have repeatedly shown that certain types of music promote species-typical behaviors better than others. For instance, a literature review has shown that cows, ponies, and hens, respectively, go to the milking parlor, feed, and head bob more often if exposed to country music rather than other genres (Wells, 2009). Another study has shown that Mozart rather than Ligeti reduces blood pressure and heart rate circadian rhythms in both normotensive and hypertensive rats (Lemmer, 2008). These studies suggest that certain properties of music may be more effective than others in promoting the welfare of animals. However, due to a general lack of scientific rigor in choosing the music that is presented within these studies, it is hard to separate which properties of music are most beneficial.

Music is a complex arrangement of many simpler properties, such as pitch, harmony, melody, and tempo (McDermott & Hauser, 2005). How these properties act individually and in conjunction to one another to affect preference in NHPs is not well

understood. Before any attempt is made to understand how music affects preference, a fundamental understanding of the underlying, simpler properties is warranted.

One such study, decided to stray away from the complexities of music and use a sound that is not confounded by other variables (i.e. fluctuations in pitch, tempo, harmony). Kawakami, Tomonaga, and Suzuki (2002) found that 85 decibels (dB) of white noise played during blood collection had calming effects in Japanese macaques. Eight subjects were tested twice under both experimental and control conditions for physiological and behavioral measures of stress. The physiological measures entailed comparing pre and post salivary and blood cortisol levels. Behaviorally, stress was measured by coding facial and vocal expressions on a 2-point scale at 5 s intervals. Two coders independently scored a 1 for facial distress/0 for no facial distress, and 1 for cry/0 for no sound. The results from their study revealed no significant difference between groups for physiological measures but there was a significant difference in the behavioral measures, wherein subjects exposed to the white noise had significantly attenuated behavioral signs of distress. This study is important for two reasons. One, it shows that simpler properties of sound such as a broadband frequencies (e.g., white noise) can reduce stress in captive animals. Two, by having both a sound and no sound condition, this study ensured that all subjects were equally exposed to both alternatives. However, the results from this study should be interpreted cautiously due to inherent flaws in the experimental design. First, as in other studies, white noise was played passively to the subjects, therefore the NHPs were not actively choosing sound. Thus, true preference (i.e., choice) could not be behaviorally assessed. Second, it was unclear if the two conditions were counterbalanced in any way. Thus, order effects alone could have

affected the outcome and interpretation in the absence of necessary controls and analysis. Specifically, any increase or decrease in observed stress responses should have been analyzed as a function of experience to the blood sampling procedure and personnel. Third, if the coders were listening for cries then they would have heard (and known) when any white noise was being presented, making them aware of the experimental condition and possibly affecting their judgment.

To sum up Kawakami, Tomonaga, and Suzuki's (2002) study, when white noise was played passively during blood collection it improved these NHPs' psychological wellbeing. However, due to the aforementioned confounds, these results should be interpreted cautiously. To expand upon these initial results and better determine the putative enriching qualities of broadband noise, a study is needed that directly provides for and measures preference for (or against) white noise when given repeated and controlled choices using a well-established preference assessment (concurrent choice) paradigm.

The next study added an element of active choice to the experimental design to determine if NHPs would listen or not listen to music. Line et al. (1990) gave five rhesus macaques the ability to manipulate a toggle device that would turn on or off a radio that was mounted to the front of their cage. The device also contained a toggle where the NHPs could work on a fixed-ratio schedule of ten responses to receive a 45mg banana-flavored food pellet. All NHPs learned the function of the device and were able to both work for pellets and turn on or off the radio at their own discretion (i.e. concurrent choice). For 20 weeks, the total amount of time that the radio played was recorded. Their results revealed a mean playing time of more than 12 hours per day. This study is

important, because it shows, that if given the opportunity monkeys will actively choose to listen to music, signaling the potential reinforcing value of auditory stimulation.

However, one major limitation to this study is that the experimenters failed to control for the presentation of sounds emitted from the radio. The soft rock radio station was chosen for its clear reception but it played not only music, but advertisements and other talking components were also presented to the subjects. Also, subjects turned their radios on at different time points, so all subjects experienced different sounds entirely. This paradigm was good because it gave NHPs the option to listen to the radio at their own discretion. However, because this paradigm did not control for the different properties of sound, it is difficult to determine the reinforcing nature of the sounds being presented. To separate the complexities of music and a radio broadcast, simpler properties of sound should be examined while still providing NHPs with the same opportunity to actively and repeatedly choose which sounds they want to listen to.

One such study was conducted by McDermott and Hauser (2004 & 2007), where they examined a NHP's preference to simpler properties of music like volume and tempo. Their methods consisted of placing cotton-top tamarins in the center of a v-maze where no sound was played (McDermott and Hauser, 2004). Then, when the NHPs crossed over into one branch of the maze, one sound would start to play, and when they crossed over to the other branch of the maze a different sound was presented. To ensure that monkeys traveled into both branches, pieces of food were placed at an equal distance in each branch. Sounds were presented on the same side for a number of sessions (n=2-4) and then switched sides for an equal number of sessions. Independent blind observers coded for length of time in each branch and computers recorded the total amount of time sounds

played. Preference, was operationally defined as a statistically significant difference between the time spent in one branch compared to the other. The researchers found that cotton-top tamarins spent more time on the side where soft white noise was played (60dB or 75dB) compared to loud white noise (90 dB or 85dB). After determining a volume that the animals preferred (75 dB), they tried to use this same methodology to examine preferences for tempo in marmosets (McDermott and Hauser, 2007). Ultimately, these researchers made the same mistake as earlier researchers and chose the musical selections themselves. One type of music was the sound of a flute playing a Russian lullaby to signify the slow-tempo condition, and the other was German techno representing the fast-tempo condition. Their results showed that the NHPs preferred the slow-tempo music to the fast-tempo music. However, as previously mentioned, there are distinct properties of music (McDermott and Hauser, 2005) and thus, by using two complete pieces of music, several different musical properties varied across the two compositions. To gain control over the several properties of sound found in the two compositions, the researchers isolated tempo by comparing beats per minute (bpm) in click tracks. The experimenters determined that the Russian lullaby was 60 bpm approximately and the German techno was 400 bpm approximately. So, using the same subjects in the same experimental design, a 400 bpm click track and a 60 bpm click track were compared to determine differences in preference. The results showed that the NHPs had a preference for the 60 bpm slower tempo click track. One important aspect of their study was the fact they gave the NHPs the ability to actively choose which type of sound was presented by simply moving from one end of the maze to the other. Another important aspect is that they were the first researchers to compare musical compositions based off of properties of sound.

Clearly, a Russian lullaby and a German techno song are at opposite ends of the spectrum in terms of tempo. The experimenters supported their musical choice study by comparing click tracks to control for other possible influences other than tempo. This study was designed with more scientific rigor than former studies, in which music or radio was *passively* played through speakers within the housing area (LAREF Discussions, 2006; Reinhardt and Reindhart, 2008, pp 103).

Since McDermott and Hauser's (2007) study, another team of researchers has examined the relation between characteristics of music and a NHP's preference. Koda et al. (2013) used a similar v-maze procedure and found that Old World monkeys, unlike humans, had no preference between consonant and dissonant sounds. Consonance is the harmonization of two or more notes in a chord whereas dissonance is the lack of such harmonization. Unlike, McDermott and Hauser's (2007) study where a fast tempo or loud noise may have been aversive (producing avoidance or escape by the NHPs), dissonant sounds did not seem to produce avoidance. Koda et al. (2013) speculated that NHPs may not have sensitivity for harmonic intervals and that this sensitivity may have occurred later in human evolution. While this hypothesis is plausible, caution should be used in interpreting Koda et al.'s results in light of the fact that *neither* consonant nor dissonant sounds produced control of the NHP's choice.

These studies are important for a few reasons. First, they demonstrated that NHPs may prefer certain types of sound. Second, these preferences appear sensitive to the more basic properties of sound (i.e., volume, tempo) compared to more complex musical characteristics (i.e., harmony). Most importantly, in several studies (Koda et al., 2013; Line et al., 1990; McDermott and Hauser, 2007) the NHPs were able to control sound

that was played in their environment rather than merely being subjected to a selected sound (as is currently standard laboratory practice at many institutes). All of these studies took great steps forward in determining the reinforcing nature of sound, the current studies will take it one step further by combining all these elements (i.e. simpler properties of sound, active manipulation) in an operant paradigm using two species of Old World monkeys: the African green vervet (*Chlorocebus aethiops sabeus*) and the cynomolgus or crab-eating macaque (*Macaca fascicularis*).

### **Current Study**

In our laboratory, we have implemented an operant paradigm where NHPs are actively engaged in a touch screen task that produces a food pellet reinforcer. This task was designed to build operant response chains using a variety of discriminative stimuli (touch screen squares of various colors). To ensure that subjects experienced all available sound alternatives while also maintaining an active element of choice between two sound alternatives, blocks of forced-choice and free-choice trial types were used. Free choice trials presented both choice alternatives at the same time (e.g., 0 dB versus 70 dB). Forced-choice trials presented only one of the alternatives (e.g., 70 dB) pseudorandomly and for an equal number of times for each of the two alternatives (0 and 70 dB). Food pellets were used to reinforce choice responding equally on either alternative (to prevent choice bias) and to produce high levels of choice responding throughout sessions that often exceeded 2 hours. This paradigm ensures contact with the various sound alternatives and provides repeated and concurrent assessments of choice when sound outcomes vary only along a single decibel level. This basic paradigm has been used extensively to quantitatively assess behavioral preference (choice) along a variety of

dimensions (reinforcer type; reinforcer magnitude; reinforcer delay) in a variety of species (rat, pigeon, and monkey) (Battalio, Kagel, MacDonald, 1985; Mazur, 1985; Nader, Woolverton, 1991). These procedures ensure sufficient and counterbalanced contact with all sound options, greatly enhancing one's confidence in the preferences exhibited, if any. These procedures are also completely automated, greatly reducing potential for experimental biases that may be introduced by investigative personnel. The present studies will try to build upon the results of McDermott and Hauser (2004) by using our operant paradigm to determine preference for volume (amplitude; dB measured from a sound level meter). This paradigm will take an originally passive form of putative enrichment (i.e. playing music over a loud speaker) and turn it into an active engagement. Enrichment that entails active engagement (i.e. toys, mirrors, foraging devices, social contact) has been proven to be the most beneficial in promoting species-typical behavior (Lutz and Novak, 2005). By allowing NHPs to actively engage in this operant paradigm we will be stimulating learning, choice, different sensory modalities (i.e. hearing, seeing, touching) and also providing an excellent analog of natural food foraging patterns, wherein morsels of food are procured across a protracted period each day (e.g., 10 hours or more) (Milton, 1981).

Also, a fuller understanding of NHPs' preferences toward amplitude (and possible species differences) would likely lead to better implementations when choosing music or other auditory stimulation to passively play in a housing environment. For example, if these results are replicated we can definitively say that sounds should be played at a low volume, or perhaps not at all. Furthermore, instituting these novel forms of enrichment may assist in future research endeavors by promoting psychological well-being, and



potentially providing insight into the origins and development of human musical preferences.

### **Experiment 1**

This study was conducted to investigate NHPs' choices to variations in amplitude using broadband noise. Data from this study will be used to further develop active and passive forms of auditory enrichment in the laboratory environment. The purpose of this study was to have NHPs actively manipulate sound and no sound outcomes to determine which outcomes were more reinforcing (i.e., preferred) and, by extension, functioned as the most enriching. These findings could then be used to enhance animal welfare for these and other species of laboratory primates.

### **Method**

#### **Subjects**

Six male African green monkeys (*Chlorocebus sabaeus*), and two cynomolgus macaques (*Macaca fascicularis*), one male and one female, were used in the study. The six male African greens were, SG8, SG13, SG4, SG3, SG19, and SG9. The two cynomolgus macaques were SG55 (female) and SG88 (male). All subjects had previous experience using the touch screen and working for food pellets. Sessions were generally conducted Monday through Friday and lasted four hours maximum. The cynomolgus macaques started their session at 9:30 and ended at approximately 13:30. The African green monkeys started their session at 10:30 and ended at approximately 14:30.

#### **Food Reinforcer Selection and Diet**

Two weeks before the experiment started, a preference test was conducted for the African green monkeys. The preference test consisted of presenting five varieties of

pellets: banana, orange, grape, lime, and sugar pellets. A laboratory technician presented two Dixie cups containing ten pellets each of two different pellet types. The dependent measures used to determine preference were the amount of pellets consumed, time taken to consume the pellets, cup first chosen, and cup finished first. All the Dixie cup pairings were randomly ordered after determining all 15 possible combinations. Across all subjects, no measures of preference were significantly different from one another. Sugar pellets were chosen for the reason that no difference was noted in preference and because African greens have been known to scavenge raw sugar cane in parts of the Caribbean islands. The two cynomolgus macaques had recently concluded a study wherein touchscreen responses produced banana pellets (Bio-Serv F0035), thus their pellets were not changed for this study. The banana pellets are a good alternative to the sugar pellets because they offer the same caloric equivalency (and basic nutritional value) that the subjects receive in their normal primate chow. In addition to pellets all subjects received daily allotments of biscuits (Certified Primate Diet 5048, Purina Mills, Inc., St. Louis, MO) and fresh fruit/or vegetables. On work days, animals were fed nothing until the behavioral test began and choices were made, producing a 190 mg food pellet. Up to 120 pellets could be earned in each daily session. Then a measured amount of chow was given at least 30 minutes after the conclusion of the session. This amount was the amount necessary to maintain motivation and body weight. On non-work days, monkeys were fed a divided and calorically equivalent workday chow ration at approximately 7:00 and 13:00.

## **Apparatus**

The apparatus used was a 15-inch LCD touch screen encased in an aluminum panel that mounted directly to the front of each NHP's home cage. Two Dell computer speakers model number A215 were secured inside of mouse cages and mounted to the top of the aluminum panel (See Figure. 21). A 60-s pink noise sound track was generated using the audio software, Audacity (2.0.4). The 70 dB sound level was achieved by manually adjusting the speaker volume on each panel. To ensure that the sound level presented was of the appropriate volume, an Extech Instruments sound level meter, model number 407732, was used. The sound level meter was tested and determined to be within tolerance by the MRICD medical maintenance team. Sound calibration consisted of placing the sound level meter in three different orientations to the cage: the center, the front, and the back. During sound calibration the sound meter was hung from the top of the cage using a swivel arm that was made for a video camera. Next, the panel was mounted to the front of the cage with the cage door open. Then, 60 seconds of pink noise was played while a laboratory technician manually adjusted the speaker volume until the sound level meter read 70 dB. Once, the 70 dB sound level was achieved at the center of the cage, this process was conducted again at both the front and back of the cage. Sound loses amplitude as distance increases; as such, the sound levels were approximately 70 dB plus or minus 3 dB at the front and back of the cage, respectively. Sound calibrations were conducted on every panel prior to the start of the experiment and periodically throughout the experiment. During testing, the cage door was secured in the open position so that the NHP would have full access to manipulate the LCD touch screen. A

custom-written program using Visual Basic subroutines controlled and recorded all experimental events with 0.01 s precision on a Dell notebook PC.

### **Procedure**

The first condition tested whether subjects had a preference for 70 dB pink noise or no sound (0 dB). Prior to the start of every session, a two-minute delay ensued to allow the laboratory technicians enough time to exit the room. Each session consisted of 144 trials, and each trial consisted of four phases: Initial Link, Choice Link, Terminal Link, and variable inter-trial interval (ITI).

The initial link served as a cue to signal the start of every trial and gauge attention and motivation by measuring initial link response latency and proportion of initial links with a response. The initial link presented a 4.33375 cm gray square at the center of the screen for a maximum of 30 seconds (See Figure.16). If the initial link stimulus was pressed then the subject would immediately enter the second phase of the trial. If the initial link stimulus was not pressed then the subject would enter the second phase of the trial, after thirty seconds had elapsed.

The second phase of the trial was the choice phase, during which either one or two distinct stimuli were presented to the subjects. One choice stimulus was a gold rectangle that filled the upper top portion of the screen and the other choice stimulus was an aqua rectangle that filled the lower portion of the touch screen. The two choice stimuli served as discriminative cues to signify each sound variable (e.g. 70 dB or 0 dB). A choice was made by touching one of the choice stimuli. Once a choice was made, a 190 mg food pellet was delivered through the hopper door and the color of the touch screen changed to black for three seconds. The 3 s delay was used to prevent the development of

a reinforcer-sound contingency by presenting the pellet several seconds prior to the onset of the sound and sound-correlated stimulus, thereby reducing the likelihood of respondent (Pavlovian) conditioning. Specifically, if the sound had been presented just prior to pellet delivery and consumption, the sound could have become a conditional stimulus (CS) for the pellet (the unconditional stimulus, US), resulting in short-delay CS-US conditioning and potentially establishing the sound stimulus as a conditioned reinforcer. Following the 3 s delay, the terminal link phase was presented for a duration of 60 s. If no choice was made within the 60 s choice period then a food pellet was not delivered and the terminal link phase of the trial was presented. During the terminal link phase, either 70 dB of sound or no sound (0 dB) was played for 60 s over the speaker system. The touch screen was filled with the color of the choice made (e.g. aqua) for the entire duration of the terminal-link phase (i.e., 60 s). After 60 s of sound presentation, the touch screen went black signaling the start of a 90-s variable interval inter-trial interval (VI90 ITI), which lasted between 30 s and 90 s. After the VI90 ITI, the start of new trial always began with the presentation of the initial link stimulus. The purpose of the variable ITI was to ensure that the cessation of sound did not reliably and promptly precede the start of the next trial, and thereby become a discriminative stimulus and conditioned reinforcer through its close association with the next opportunity to earn a food pellet.

Each choice phase consisted of either forced-choice or free-choice trial types. During a forced-choice trial only one choice stimulus was presented, either aqua or gold. During a free-choice trial both stimuli were presented simultaneously. The different trial types were separated into blocks of four trials. A forced-choice trial block was always presented as the first block at the start of every session. During a forced-choice trial

block, each choice stimulus (and its associated sound) was presented twice and in a pseudorandom sequence. The importance of the forced-choice trial types is that its presence ensures that the subject is being exposed to both available stimulus-sound outcomes. After a block of forced-choice trials, the subject entered a free-choice trial block. Each free-choice block presented four choice trials. If one sound was preferred in that block (i.e., three or four choices made to the same stimulus), then a forced-choice trial block occurred following the last free choice trial. If there was no preference for either sound option within a given free-choice block, then no forced-choice trials followed that given free-choice block. Potentially, a total of 36 trial blocks can be completed in a session totaling 144 trials. However, the potential number of trials could have been much less than that (i.e., 76 trials), if no preference was consistently observed in each free-choice trial block, thereby greatly reducing the number of forced-choice trials presented. Nevertheless, this arrangement ensured contact with all choice alternatives at the outset and throughout each session and assessed sound preference on a total of 72 free-choice trials per session.

After two sessions, it was noted that animals were not finishing the program in the allotted 4 h timeframe. Therefore, the total amount of trial blocks was reduced from 36 to 30, totaling 120 trials (60 forced-choice and 60 free-choice). A second concern was that only low levels of touchscreen responding occurred during the choice phase of many trials. Therefore, to increase choice responding to exceed a 90% criterion, the choice stimuli were changed to resemble the size of the initial link stimulus. To clarify, instead of the choice stimuli filling the top half and lower half portions of the screen, the stimuli were reduced in size to resemble the same dimensions as the initial link stimulus, a shape

with which the subjects had greater experience in previous behavioral tests including delayed match-to-sample and a simple reaction time task (Myers and Hamilton, 2011). In addition, the choice stimuli were now centered at the top half and lower half of the touch screen (See Figure. 17). It was predicted that these changes would engender greater stimulus generalization and higher levels of choice-stimulus responding. The African green monkeys started the experiment 28 days before the two cynomolgus macaques. As a result, the cynomolgus macaques started the experiment with the newly adjusted parameters (i.e., reduced dimensions and centralized locations of the choice stimuli, and reduced number of trials per session).

Session-level data were examined daily for each monkey to assess preference and to see if software or mechanical errors were occurring. A clear preference was said to have occurred if a subject made greater than eighty percent of free-choice responses for a specific choice stimulus for three or more consecutive sessions. After such a preference was observed, the locations of the choice stimuli were counterbalanced and moved to the opposite position. For example, if the aqua stimulus was previously at the bottom location and the gold stimulus was at the top, they then switched positions. The locations of the choice stimuli alternated in ABAB format. Therefore, position reversals were presented twice to each subject.

Daily analysis of session data indicated that four out of the eight monkeys (SG55, SG3, SG8, and SG4) showed a clear preference for a choice stimulus (sound outcome) and maintained that preference after each position reversal, in “Program 1: Top and Bottom.” However, it was also observed that three of the other four monkeys did not maintain their choice preference after a reversal. These monkeys were responding to a

choice stimulus' location irrespective of its color or auditory outcome. Therefore a new program was designed ("Program 1: Left and Right") with the same overall experimental design, with the exception that the locations of the choice stimuli were now side by side in the center of the screen.(See Figure. 18). The three subjects studied under "Program 1: Left and Right" were SG88, SG19, and SG9.

### **Data Analysis**

For each trial within a session, several dependent measures were recorded and analyzed. These custom-written software generated two separate comma-delimited data files: a trial-by-trial and session summary data file and a time-event code file which recorded the exact moment of every recorded event and its pre-determined event code for more detailed analyses, should they be needed. In principle, only the trial-by-trial session summary was required for most analyses. Primarily, the mean Sound Choice and Position Choice during all free-choice trials per session were the dependent measures calculated and analyzed across sessions. Sound Choice was coded as a 1 for 70 dB and a 0 was coded for 0 dB. For Position Choice, 1 signified either the top or right-side stimulus, and 0 indicated the bottom or left-side stimulus.

Other dependent measures included trial number, trial type (forced or free-choice), sound type (0 dB or 70 dB), choice latency, choice response failures (i.e., "no choice" responses), initial-link response latency, total trial duration, ITI duration, elapsed cumulative session time, the 24:00:00 time (computer clock time (e.g., 09:54:32), pellet delivery, terminal link touches, initial- and choice-link off-stimulus touches, and x/y coordinates of screen touches. Dependent measures such as initial link touches and latency between choices indicated how well choice responding is under stimulus control



and whether or not responding is well motivated. All other measures serve as secondary measures to help the experimenter recognize possible mechanical or software errors that may have occurred during the session (e.g., clogged pellet dispenser, a touch screen not correctly recording touches).

## Results

Data for total choices made within a session were analyzed by creating a proportion score (total number of a particular choice type that occurred divided by total number of choice opportunities). For each session, two proportion scores were determined by separately averaging the Sound Choice and Position Choice dependent measures. These proportion scores represent the overall preference for a particular sound outcome or choice stimulus location. A session average score of 1 for Sound Choice would indicate that 100% of responses were for the higher volume sound choice (i.e., exclusive preference for the 70 dB sound). Whereas, a session average score of 0 for Sound Choice would indicate that 100% of responses were for the lower volume (e.g., exclusive preference for the 0 dB sound; no sound). If the preference score was .50 for Sound Choice, then it would indicate that the subject had no preference because the subject equally chose both alternatives (i.e., indifference). Similarly, the preference score for Position Choice was 1 for the top or right-side stimulus, depending on the specific program, and 0 for the bottom or left-side stimulus, again depending on the specific program. Figures (1-7) shows each subject's preferences scores for specific choice stimuli across all sessions in Experiment 1. Data from the first 10 sessions for SG55 were thrown out due to hardware and software errors. Only data from Program 1: Top and Bottom were analyzed for SG88 and SG19 because there were not enough data from

Program 1: Left and Right to compare across conditions. Also, due to mechanical errors, the first four sessions from SG88 were omitted. SG88 was still given two Presentations of both conditions, however SG88 started on Condition B instead of A (i.e., BABA).

The number of sessions required for each subject to develop a clear preference in each condition for Position Choice and Sound Choice differed greatly. Generally, the criteria for and stable responding (preference scores) in each condition were defined as at least three number of sessions per condition and approximately equal preferences scores for three to four consecutive sessions. Thus, only the last three sessions were averaged and analyzed for every condition to best represent terminal condition data and provide approximately 200 free-choice trials to assess preference in each condition. Despite this rule, SG9 had only two sessions in the first condition of the second presentation, as a result only 120 free-choice trials were analyzed for this condition. The results indicated that the average preference score ( $n=7$ ) for the Sound Choice condition was 0.179 ( $SD=.342$ ). This result suggests that when given the choice these subjects preferred no sound rather than 70 dB pink noise.

In a separate analysis, both Condition and Presentation were examined in relation to each subjects' Sound Choice. Conditions A and B indicate the reversals of the Sound-Choice location, where A is the initial Sound-Choice location and B is the second Sound-Choice location. Presentation was the order of conditions; because each condition was repeated twice, conditions could either be the first presentation (i.e., the initial exposure) or the second presentation (i.e., the replication). A 2 x 2 repeated measure ANOVA was conducted to assess if Sound Choice differed across the Condition and Presentation within-subject factors. The results indicated there was no main effect for Condition,  $F$

(1,6)=3.468,  $p=.256$ , or Presentation,  $F(1,6)=.924$ ,  $p=.373$ , and there was no significant interaction. These results indicate that sound choice did not change from condition A to condition B and also, sound choice did not change between the first and second presentation. These results indicate that the subjects' preference for no sound (versus 70 dB pink noise) developed early and remained stable throughout the entire duration of the study.

In another analysis, both Condition and Presentation were examined in relation to Position Choice. A 2 X 2 repeated measures ANOVA was conducted with Condition and Presentation as within-subject factors and Position Choice as the dependent variable. The results indicated that there was a main effect for Condition,  $F(1,6)=13.642$ ,  $p=.010$ ,  $d=2.082$ ,  $\eta=.72$ . There was no main effect of Presentation  $F(1,6)=.153$ ,  $p=.709$  and no significant interactions were observed. These results indicate that Position Choice is changing between conditions. This result shows that preference tracked the no-sound alternative even when the location of that alternative was changed between conditions (See Figure.1). Thus, this result provides strong support for the fact that subjects preferred no sound over 70 dB pink noise because choice response location tracked this outcome across repeated reversals of the location-outcome relation.

Table 1 shows the mean proportion scores as well as the standard deviations for all subjects. This table shows that five out of seven subjects overwhelmingly preferred the no sound option after both Condition and Presentation changes. However, SG19 and SG88's mean proportion scores were 0.517 and 0.5, respectively. These mean scores indicate that the subjects had no preference for Sound Choice after both Condition and Presentation changes. SG19 and SG88's figures indicate that these subjects had a

preference for the bottom positioned choice stimulus, regardless of its auditory outcome. This finding suggests that, despite repeated contact with the difference in sound choice outcome, no preference in choice responding developed for these subjects (i.e., indifference to the sound outcome). It should be noted that one subject's data were excluded from data analysis (SG13) because stable preference could not be attained within each condition.

### **Discussion**

The purpose of this study was to investigate NHPs choice responding to variations in sound amplitude using broadband noise. Experiment 1 tested whether NHPs could use computer and touch screen technologies to actively manipulate discriminative cues that led to either sound or no sound outcomes. It was predicted that these data would provide information regarding preference similarities between individuals and monkey species. Data analysis indicated that all subjects developed a preference during the first session and that the preference remained after three position reversals. More importantly, average preference scores indicated that when given the choice between 70 dB of pink noise and no sound, both African green monkeys and cynomolgus macaques preferred to listen to no sound. These results reflect and build upon previous research that has investigated NHPs' auditory preference of broadband noise. For example, McDermott and Hauser's (2004) study showed that when cotton-top tamarins were exposed to 60 dB and 90 dB of broadband noise they preferred 60 dB. The results from the current study were similar in that subjects preferred the quieter of the two alternatives. However, the current study differed in a number of ways; the most fundamental differences being the experimental design and dB level. First, in the current study all subjects were exposed to two sound

locations that reversed three times compared to only one reversal in McDermott and Hauser's (2004) study. Second, forced-choice trials were used to ensure that subjects had equal experience to both alternatives whereas in McDermott and Hauser's (2004) study the experimenters placed food in both branches of the maze to ensure exposure to both sounds. Most importantly, the experimental design in the current study allowed for hundreds of concurrent choices to be made thus allowing a better assessment of preference to be made. Lastly, this study utilized a touch screen interface that positively reinforced choice responding compared to a v-maze where escaping loud volumes was negatively reinforcing. In McDermott and Hauser's (2004) study the experimenters intended for their 90 dB sound to be aversive (i.e., functions as a negative reinforcer). If it is aversive, postponement, prevention, or escape from the 90 dB sound should reinforce whatever response produces that outcome. So, if the subject escaped and or avoided a 90 dB sound presentation, then it would indicate that they preferred not to listen to that sound. However, one of the major flaws to this interpretation is simply because the subject's preferred not to listen to one stimulus, it does not necessarily mean that the alternative was a reinforcer or a source of enrichment—it may have been preferred simply because this sound option (60 dB) may have been less aversive than the 90 dB sound.

The existing literature indicates that certain properties of broadband noise have calming effects on NHPs (Kawakami, Tomonaga, and Suzuki, 2002). This experiment was designed so that a 70dB exposure to sound would not dissuade the subjects from responding in subsequent trials. Before the start of this experiment, it was determined that presenting broadband noise at 90 dB would be both detrimental to the subjects and the

purpose of this study. One of the main purposes of this study was to answer the question, “Will monkeys choose to listen to sound or not to listen?” More fundamentally the sole basis of this experiment was to design a program that would actively engage subjects into responding to a choice.

The current study was successful in both of these aspects. First, all subjects were actively engaged with a touch screen interface that provided them opportunities to receive food, increasing their foraging time by four hours, five days a week. Second, by implementing an operant procedure that rewarded choice, this study revealed that 5 out of 7 monkeys preferred the no sound alternative compared to 70 dB of pink noise. The fact that 5 out of 7 subjects preferred the null might indicate that 70 dB was an aversive auditory stimulus. However, the question remains, why did not SG88 and SG19 have a definitive preference for the null? One reason might be that that these subjects had position biases. As noted before, Figures 5 and 7 show that both of these subjects primarily chose the bottom choice stimulus despite repeated reversals of the location-outcome relation. To better assess preference, Program 1: Left and Right was implemented. However, in Program 1: Left and Right, these subjects quickly developed a bias for the left choice stimulus regardless of its auditory outcome (Not shown). One possibility is that these subjects did not have a preference for either of the sound outcomes, thus trivial factors such as stimulus location could then control choice responding. Of course, choices continue to occur because they produced food pellets, and correspondingly shorter response latencies further reduced Initial Link and Choice Link durations, increasing the number of trials per minute (thereby increasing reinforcer density, pellets/min, in the session as a whole). Another reason for apparent lack of

preference might be that the subjects did not discriminate the sound choice color alternatives or associate each to its respective auditory outcome. To better enhance the likelihood of establishing an effective association between the choice stimulus and its auditory outcome, during the terminal link phase the touch screen was filled entirely with the color of the chosen stimulus. Furthermore, these subjects had previous experience with a DMTS program that required subjects to associate colors to their respective outcomes. Therefore, it is unlikely that the subjects could not discriminate between sound and no sound options. The most likely cause for SG88 and SG19's lack of auditory preference was because neither outcome was differentially reinforcing, suggesting that if in general, the sound is kept to a moderate volume, then it is neither reinforcing nor aversive. Further investigation should examine if G19 and G88's indifference to Sound Choice will continue if there is an increase in amplitude. Also, for subjects who had previously preferred the null, it is important to determine at which point increases in amplitude become positively or negatively reinforcing. For example, will subjects who previously preferred the null, exhibit a greater proportion of escape-avoidance behavior at higher amplitudes than at lower ones? By using multiple amplitude levels (i.e., 0 dB, 60 dB, 70 dB and 80 dB), the mathematical function relating amplitude level of a sound to its reinforcing/aversive functions can be characterized.

## **Experiment 2**

Experiment 2 was designed to test the reinforcing/aversive function of broadband noise by determining if avoidance and escape responding would differ as a function of sound amplitude. When given a choice in Experiment 1, five out of seven subjects preferred the no sound alternative compared to 70 dB of pink noise. However, the other

two subjects exhibited no clear sound preference. One reason might be that 70 dB of pink noise was neither positively reinforcing nor aversive. The current study was designed to determine at which point increases in amplitude become reinforcing/aversive. By presenting pink noise at an array of amplitudes that range from silent to loud, the function relating changes in volume to the sound's reinforcing/aversive efficacy can be determined.

In the previous experiment, when a majority of the subjects equally experienced two choice outcomes in forced-choice trials, they developed a distinct preference in free-choice trials for the quieter of two alternatives. In Experiment 1, the importance of the forced-choice trial type was to ensure that subjects were being exposed to both alternatives. However, in free-choice trials the subjects had the opportunity to choose the stimulus and, thus, sound level they were exposed to. If subjects found one sound choice to be aversive they could have avoided that choice by choosing the opposite sound choice (i.e., the one preferred). In the present study, subjects were provided the opportunity to remove any sound presentation by either avoiding or escaping that presentation. To ensure that all subjects would experience all amplitudes, only forced-choice trial types were used. Importantly, for assessing escape behavior an opportunity to remove a sound was always available during every 60 s sound presentation. The addition of an avoidance or escape stimulus, also allowed a quantitative assessment of aversiveness to be made by calculating the total amount of avoidance and escape responding at each distinct sound level (0, 60, 70, and 80 dB). It was predicted that avoidance and escape responding would increase as a function of amplitude. The louder the sound, the more escape and



avoidance responses were predicted to occur, minimizing time spent in contact with the particular sound stimulus presented in each forced-choice trial.

## **Method**

### **Subjects**

The same subjects and caloric-regulation protocols were as in Experiment 1.

### **Apparatus**

The same apparatus and food pellets were used as in Experiment 1.

### **Sound Calibration**

Since, there were 4 separate volumes being presented within a session, volume calibration could not be accomplished by simply adjusting the speaker volume till the intended volume was reached. Instead, all computer speaker volumes, both the laptops volume and the mounted external speakers were adjusted to highest possible setting. Then, separate tracks for 0 dB, 60 dB, 70 dB, and 80 dB were generated in Audacity. Amplitude of each track was calibrated in similar fashion to Experiment 1, using the same sound level meter mounted in three different orientations to the cage. The respected generated amplitudes were 0 dB, 60 dB, 70 dB, and 80 dB. Each Sound Level was presented 30 times in a total of 120 trials. Each session had a 4 h time limit, if subjects did not complete the session in the allotted time, then a laboratory technician ended that session manually. All subjects ran approximately 5 days a week at the same designated times as in Experiment 1.

### **Avoidance Study**

Each trial in the Avoidance Study had four phases: Initial Link, Choice Link, Avoidance phase, and the ITI. The initial link looked and functioned the same as in

Experiment 1. The choice phase in the Avoidance Study differed in a number of ways compared to Experiment 1. For example, in the Avoidance Study there were only forced-choice trials, therefore, only one choice stimulus was ever presented. The choice stimulus was gold and it was located in the same place as the bottom stimulus in Program 1: Top and Bottom (See Figure.19). The subject responded by pressing the choice stimulus five times (i.e., Fixed-ratio 5 (FR5)). When the FR5 response requirement was completed, the subject received a 190 mg food pellet and the avoidance phase began 3 s later with one of the four pre-determined sound levels. If the subject did not respond to the choice stimulus within 60 seconds, the avoidance phase began without a food pellet delivery and 3 s delay to sound onset. The avoidance phase began with a gold filled screen with a 4.33 cm square magenta avoidance stimulus centered in the screen. During the first three seconds of the avoidance phase, no sound was played. After three seconds, one of four possible volumes (i.e. 0 dB, 60 dB, 70 dB, or 80 dB) was presented to the subjects. Each press of the avoidance stimulus removed the sound presentation for ten seconds. After 10 s the sound would return unless the 60 s avoidance phase was over or another response further postponed the sound. Once the 60 s avoidance phase was over the ITI began. Essentially, if the subject actively responded to the avoidance stimulus little to no sound exposure would occur. These dependent measures were designed to quantify the reinforcing efficacy of each sound level.

If the avoidance stimulus was pressed during sound presentation, the press was recorded as an Escape. If the avoidance stimulus was pressed before sound presentation (e.g. The first three seconds of the avoid phase) or while the sound presentation was in a ten second cessation period, the press was then recorded as an Avoid. The dependent

measures included in the data analysis were the total number of Escapes and Avoids for each trial. Daily analysis of session data revealed that all but SG55 ceased responding to the avoidance stimulus after one session. Then, total Escapes and Avoids were examined across all Sound Levels for each session. After three subsequent sessions, data revealed that all responding to the avoidance stimulus extinguished except for SG55, who continued to respond to the avoidance stimulus. SG55 was left on the Avoidance study for the remainder of Experiment 2 to determine if there was an Escape or Avoidance difference across Sound Levels (See Results). Since the parameters set forth in the Avoidance study did not engender sustained responding to the avoidance stimulus, it was decided to create a program that would increase responding. The Escape Sound Study was intended to measure the number of escapes across sound levels. However, the fundamental difference between the Avoidance study and the Escape Sound Study is that the subject could escape a sound presentation with one response, instead of actively responding.

### **Escape Sound Study**

The Escape Sound study consisted of two conditions. Each trial in Condition 1 contained three phases, the initial link, the choice phase, and the escape phase. The initial link was the same as in Experiment 1, it was a gray square located at the center of the touch screen. The properties of the initial link were the same as in Experiment 1: the second phase of the experiment was initiated following an initial-link response; if no initial-link response occurred within 30 s then the second phase of the experiment was initiated at the end of the 30 s interval. Similarly, the choice phase was like Experiment 1 as it contained a choice stimulus that when pressed would immediately deliver a pellet

and start the next phase. Also, if the choice stimulus was not pressed in 30 s then it would enter the next phase without delivering a pellet. The choice phase in the Escape Sound Study was similar to the Avoidance study in that only one choice stimulus was ever presented. However, the choice stimulus was an aqua square located at the same bottom location as the choice stimulus in Experiment 1, Program 1: Top and Bottom (See Figure. 20). To make a choice, the subject was required to press the choice stimulus five times (i.e., FR5). Once a choice was made, a 190 mg food pellet was delivered through the hopper door and the color of the touch screen changed to black for five seconds. After, five seconds the subject entered the Escape Phase. During the Escape Phase the screen was filled with the color aqua, and one of the four possible sounds was played. Also during this phase an escape stimulus was present. The escape stimulus was of the same dimensions and color (e.g. grey) as the initial link stimulus and it was in the same location (e.g. center of the touch screen), however, the escape stimulus had a distinctive black border to help increase its salience and promote responding (see Figure. 20). Most importantly, when the subject pressed the escape button, the sound would stop playing and the next trial would start immediately with the next initial link phase. If the escape stimulus was not pressed within 60 s the sound stimulus played for the entire 60 s duration before the next trial began.

The ITI was eliminated in Condition 1 because it was important for the subjects to learn the utility or function of the escape stimulus and also to regain responding to this stimulus after it had extinguished previously in the Avoidance study. Thus, by eliminating an ITI and terminating the sound period, the temporal contiguity between pressing the escape stimulus and the start of the next trial was increased and escape

responding could become strengthened by reduced delay to start of the next trial and the opportunity to earn another food pellet. Thus, escape responding could greatly increase the number of trials per minute, increasing the reinforcer density of the session as a whole.

Condition 2 was almost identical in design to Condition 1, with the exception of two differences. One difference is that the escape phase did not terminate upon an escape response. So, any responses to the escape stimulus were a function of removing the sound and its associated stimuli, not response-dependent changes in trial pacing (the effects of escape responding on reinforcer density). The second difference was the addition of a VI90, ITI phase. The purpose of a VI90 ITI was to dilute the temporal relation between sound cessation and the start of the next trial. Therefore, sound cessation does not become a discriminative stimulus signaling the start of the next trial. In condition 2, escape responses turned the touch screen black for the remainder of the escape phase and it would remain black for the VI90 ITI phase. If the subject did not press the escape stimulus, the escape phase lasted 60 s the sound and its correlated stimuli remained on throughout the escape phase before entering the ITI phase. Thus, escape responding did not alter trial pacing but controlled whether the sound and its visual stimuli were present during the terminal link.

The Escape Sound Study was designed in such a way that minimal effort was required to escape a sound presentation. In any circumstances if the subject pressed the escape stimulus, the sound would stop. Due to the minimal effort required, the subjects should have pressed the escape stimulus if the sound was aversive. This arrangement is the optimal way to obtain escape behavior, so if escape behavior did not occur then the

sounds were clearly not aversive. Moreover, Condition 1 was used in part to establish a high level of escape responding just prior to Condition 2, not only to help ensure contact with the changed escape contingency, but also to provide the best possible conditions for maintaining a high level of escape responding. The differential maintenance of escape responding in relation to different amplitudes would quantitatively establish the different reinforcing/aversive functions of the sound stimulus. Additionally, this transition from Condition 1 to Condition 2 allowed for the monitoring of extinction (a reduction in response frequency upon transition to a condition of non-reinforcement). Extinction of escape responding at certain volumes levels would provide compelling evidence that those sounds were not aversive.

### **Data Analysis**

The primary dependent measure was the average number of escapes for each sound level. Average number of escape response were calculated by taking the total number of escape responding within a sound level (e.g. 60 dB) and dividing it by the total number of trials completed for that volume. Session data were examined daily for each subject to monitor changes in escape responding. Daily analysis of session data revealed that SG19 and SG8 were not responding to the escape stimulus in Condition 1, however they were making a large number of off-stimulus touches (touches outside the escape stimulus perimeter). Therefore, to increase the probability of escape stimulus touching, the program was modified into the Large Escape Sound Program, which was identical to the Escape Sound Program with the exception that the escape stimulus was greatly increased in size (See Figure 20). The purpose of the larger escape stimulus was to increase the chances that the subject would touch it and encounter the response-escape

contingency. If successful, any changes in escape responding can be interpreted in the context of considerable experience between responding and its consequences for each subject.

Stable responding to the escape stimulus for three consecutive sessions were required for subjects to move on to Condition 2. In Condition 2 subjects ran on either Escape Sound Program or Large Escape Sound Program. SG 88 and SG19 ran on Large Escape Sound Program as to not introduce any new variability to the escape stimulus's dimensions. After examining daily session data in Condition 2, it was noted that SG88 was pressing the escape stimulus within 1 second after it was presented. Therefore, to ensure exposure to the sound stimulus, a new program was written: Escape Sound Program: Forced Exposure. This program adjusted access to the escape response contingency by programming the escape stimulus to not become available (or visible) until after the sound stimulus was presented for ten seconds, ensuring at least 10 s of exposure to the sound stimulus prior to emitting an escape response. The escape stimulus was still presented for a total of 60 s and the 10 s were not subtracted from this time.

## **Results**

### **Avoidance Study**

For all subjects in the Avoidance study, except SG55, avoidance responding extinguished after three sessions (See Table 2). SG55's data was analyzed separately for the purposes of assessing extinction and are not intended to be generalized in any way. Within each session, the Average number of avoids were calculated for each Sound Level. SG55 completed 13 sessions, these sessions were broken down into 4 sequential session blocks. The first session block contained four sessions, and the remaining three

blocks each contained three sessions. The average number of avoids for each sound level and from each session were averaged into session block averages.

A two-way repeated measures ANOVA was conducted to assess the Average Number of Avoidance Responses for Sound Level across Session Blocks. A Shapiro-Wilk test was conducted to assess for normality,  $p=.968$ . The results indicated a main effect for Session Block,  $F(3,9)=15.582$ ,  $p=.001$ . However, there was no main effect for Sound Level,  $F(3,9)=.808$ ,  $p=.521$ . These results show that the Average Number of Avoidance Responses differed across Session Blocks. A Bonferroni posthoc analysis revealed that the Average Number of Avoidance Responses for the first session block was significantly different from all the other session blocks. More specifically, Session block 1 had a higher Average Number of Avoidance Responses ( $M=2.419$ ) compared to Session blocks 2, 3, and 4 ( $M=1.71$ ,  $M=.595$ ,  $M=.924$ , respectively). Figure 8 shows the average Avoidance Responses for all sessions. Both the Session Block marginal means and Figure 8, reveal that the average number of Avoidance Responses decreased after the first session.

### **Escape Sound Study**

Figures 9-15 shows the Average Escape data from the last three sessions of condition 1 for each Sound Level, as well as the Average Escape data for all sessions in condition 2 for each Sound Level. Average Escape data was omitted if a subject failed to earn 30 or more food pellets in a session. SG4 had 5 sessions omitted from the analysis and SG3 had one session omitted. It is clear that in condition 1, there is no difference in escape responding per session across sound levels for any subject (Figures 9-15).



To further ascertain whether escape responding varied as a function of sound level, a dependent measure called Total Average Escape Responding was created for every Sound Level by taking the mean value of the Average Escape data from every session of the condition. A one-way repeated measures ANOVA was conducted to assess Total Average Escape Responding across different Sound Levels for all subjects in Condition 2. The results indicated that there was no significant effect for Total Average Escape Responding across Sound Levels  $F(1,6) = .609, p = .618$ . The results show that when subjects escaped, they escaped at all Sound Levels equally.

A 4 x 2 repeated measures ANOVA was conducted with Sound Level and Condition as within-subject factors and Total Average Escapes as the dependent variable. The results revealed a main effect for Condition-,  $F(1,6) = 9.013, p = .024$ . However, there was no main effect for Sound Level,  $F(1,6) = .567, p = .644$  and no significant interactions were observed. When examining Figures 9-15 it is evident that subjects were proportionately escaping more frequently in Condition 1 ( $M = 1.00$ ) compared to Condition 2 ( $M = .643$ ). However, there were no differences in Total Average Escapes as a function of Sound Level, indicating that all Sound Levels were escaped equally.

### **Discussion**

The purpose of Experiment 2 was to investigate NHPs' preferences for or against pink noise presented at various sound amplitudes (dB levels) by quantitatively indexing avoidance and escape behavior under two different response contingencies. The Avoidance Study tested whether subjects would actively avoid a sound presentation under free-operant conditions of sound escape and postponement (a temporal avoidance contingency; (Sidman, 1953)). It was predicted that escape/avoidance responding would

occur at the highest sound amplitudes but could not accurately predict what might occur at lower amplitudes. The results from this study showed that responding to the avoidance stimulus extinguished after one session for all subjects except SG55. SG55 remained on the avoidance program for 13 sessions. After 13 sessions data analysis revealed no difference in number of avoidance or escape responses as a function of sound level. That is, escape/avoidance responding occurred similarly across all decibel levels. The fact that SG55 escaped all sounds equally suggests that no sound level was more aversive or reinforcing than the others. For SG55, the results from Experiment 2 seemed to contradict the results from Experiment 1. For example, in Experiment 1 SG55's choices reflected that the subject preferred the null to 70 dB of pink noise however, in Experiment 2 no difference was noted in Average Avoids as a function of Sound Level. If SG55 preferred 0 dB, then why would this subject actively avoid 0 dB when it was presented? Surely, avoiding 0 dB would require more effort than simply letting the trial time out. Furthermore, there is no reinforcement associated with touching the avoidance stimulus when 0 dB is presented. One possibility is that touching the avoidance stimulus became such a conditioned reinforcer that it paid more often than not to touch it, rather than be exposed to loud volumes. In contrast, if touching the avoidance stimulus was such a strong reinforcer, it would be expected that the other subjects would have increased avoidance stimulus responses, but the other subjects did not, instead their responding extinguished. To add, SG55's average avoids decreased after the first session block, indicating that touching the avoidance stimulus may have not been such a conditioned reinforcer after all.

The remaining seven subjects were used in the Escape Sound Study. The Escape

Sound Study tested whether subjects would escape a sound presentation if the sound was aversive. The first condition was designed to restore responding to the escape stimulus since it was extinguished in the Avoidance study for these subjects. To increase responding to the escape stimulus, two temporal factors were eliminated from the experimental design, the ITI and the sound presentation time out period. When these factors were eliminated it made it so that one response to an escape stimulus would end the escape phase and start the next trial. In doing so, subjects were able to earn food pellets faster. The first condition was successful in that all subjects were now responding to the escape stimulus. However, subjects were responding at such a high rate that average escapes were equal across all sound levels. Since responding was at such a high rate to the escape stimulus it was apparent that subjects discovered the function of the escape stimulus. At this point the escape stimulus had two reinforcing functions: it started the next trial and it terminated the sound.

The second condition was designed so that the only reinforcing function of pressing the escape stimulus was to stop the sound presentation. Therefore, if subjects escaped a sound level it would suggest that escaping that sound level alone was sufficiently reinforcing. It was predicted that there would be an ordinal difference for average escapes with respect to increases in amplitude. However, the data analysis revealed no difference in average escapes across sound levels. Essentially, escape responding failed to be controlled by sound amplitude. These results differed from Experiment 1 where sound presentation determined free-choice responses in 5 out of 7 subjects. It is unclear, why these subjects' who previously preferred the null in Experiment 1, did not escape higher amplitude sounds with greater frequency in

Experiment 2. In Experiment 2, subjects were exposed to no less than 1320 trials. It is possible that these same sound levels were presented to the subjects so often that the sound levels lost their effect. Therefore, habituation may have been a reason why subjects escaped all sounds equally.

In an effort to assess the possibility of habituation, SG13, SG9, and SG88 were put on a pure tone program with the same experimental design as Escape Sound Study Condition 2. The pure tones were presented at the same amplitudes as in the Escape Sound Study and the frequency of the pure tone was 440 hertz (A4). The results from the Pure Tone Study were the same as the results from the Escape Sound Study in that all sound levels were escaped equally. The evidence from this study suggests that, subjects did not habituate to the pink noise therefore some other factor must have contributed to there being no difference in average escapes across sound levels.

Ultimately, the most plausible explanation as to why there was no difference in average escapes across different sound levels was because the auditory stimuli used were not aversive enough to exhibit stimulus control. To produce avoidance or escape learning there must be something aversive worth escaping. It was determined in Experiment 1 that when given a choice a majority of the subjects preferred the no sound option. It was proposed that subjects preferred the no sound alternative because 70 dB's of pink noise was aversive. It was expected that similar results would reveal themselves in Experiment 2, where animals would escape more often to 80 dB than they would to 0 dB, because 80 dB was thought to be more aversive. However, the results from Experiment 2 showed that subjects did not escape louder sounds more often than quieter sounds. Therefore, Experiment 2 was not successful in showing that subjects will escape higher amplitude

sounds in a greater proportion than lower amplitude sounds. It is possible that if the amplitude level were to increase to 90 dB than it may have garnered more control over escape responding. For example, McDermott and Hauser (2004) found that NHPs exposed to both 90 dB and 60 dB in their v-maze paradigm, spent more time in the branch that played 60 dB.

Although the evidence failed to support the hypothesis that subjects would escape in greater frequency to higher amplitude levels, this study was successful in providing evidence for the null hypothesis. For example, the fact that all subjects escaped all sound levels equally suggests that NHPs did not find amplitudes in the 0-80 dB to be reliably aversive. Therefore, this study was successful in terms of finding an amplitude range that NHPs do not find aversive.

### **General Discussion**

The paradigm outlined in these studies offers a novel way to determine auditory preference for simpler properties of sound. These studies extend upon previous literature because an amplitude preference was determined in Old World monkeys, using lower amplitude sounds in a paradigm that actively engaged subjects and rewarded choice (Koda et al., 2013; Line et al., 1990; McDermott and Hauser, 2007). To put in perspective, the various amplitudes used throughout this study were equivalent to a conversation in a restaurant (e.g. 60dB), a vacuum cleaner (e.g. 70dB), and a garbage disposal (e.g. 80dB) (Noise Comparisons, n.d.). In contrast, the amplitudes used in McDermott and Hauser's (2004) and Kawakami, Tomonaga, and Suzuki's (2002) studies were equivalent to a powered lawn mower (e.g. 90dB) and a food blender (e.g. 85dB). Although, the results from Kawakami, Tomonaga, and Suzuki's (2002) study

suggested that 85dB of white noise may have had beneficial effects to reduce stress. These results were interpreted cautiously and careful consideration was taken to not expose subjects to sounds louder than 83dB. One possible way to improve upon the current studies would be test NHPs individually. For example, all subjects were tested at the same time in a colony room. Although, NHPs were housed individually, there was noise contamination from cage to cage. Thus, subjects who were presented with 0dB may have also been exposed to 80dB of sound from their neighbor, thus possibly affecting choice and/or escape responding.

The primary purpose of the current experiments was to find the reinforcing and aversive qualities of volume using broadband noise. Experiment 1 and 2 are important because they show that if sound is kept to a moderate volume it neither reinforcing nor aversive. Determining a specific volume that NHPs prefer is the first step in elaborating the potential enriching constituent properties of music. For example, once a proper volume is determined, other properties of sound such as pitch and tempo can then be examined and compared by presenting them at this specific volume. The results from these studies suggest that some property found in music, other than amplitude, may have influence over preference. A fuller understanding of NHPs preference to pitch and tempo would likely lead to better implementations when choosing music to passively play in a housing environment. The experimental design outlined in these studies could be used in the future to determine preferences for various other forms of sensory stimuli (i.e., music, videos, lights, pictures, toys etc.). Ultimately, having determined these preferences then such sensory stimuli can be provided response dependently there by creating a dynamic and engaging environment.

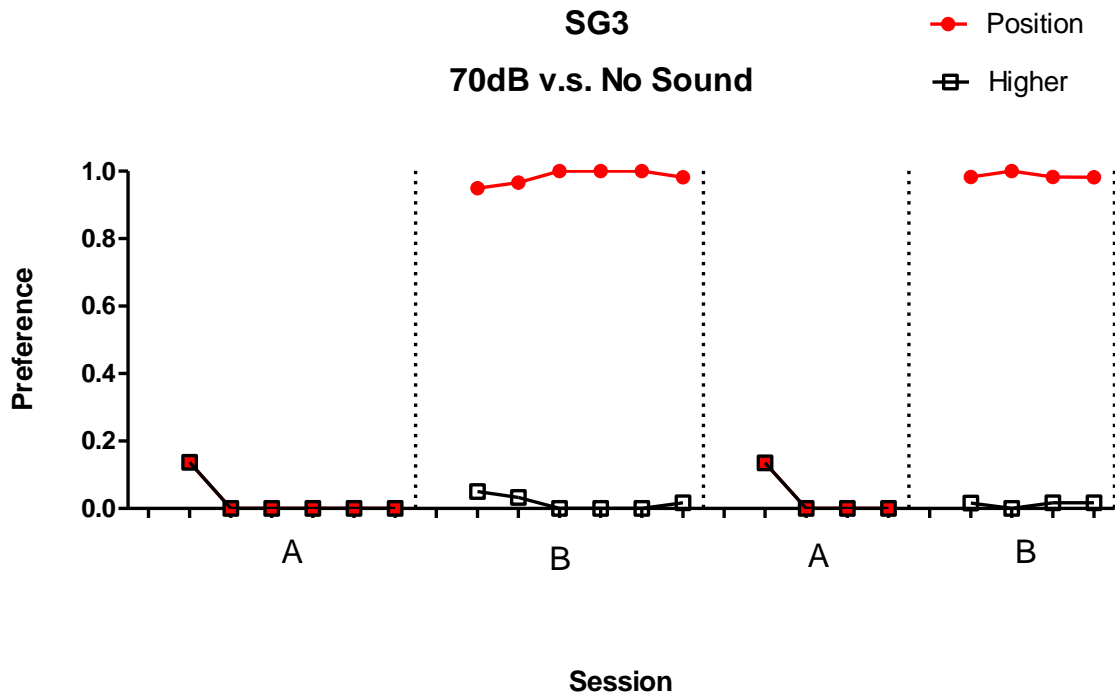
**Table 1.** The mean and standard deviations of Sound Choice for subjects in Conditions A and B.

<b>Subject</b>	<b>Mean A</b>	<b>Mean B</b>
SG3	0(0)	0.009(.009)
SG4	0.032(.064)	0.266(.098)
SG8	0.021(.032)	0.008(.02)
SG9	0.01(.014)	0.050(.021)
SG19	0.051(.062)	0.983(.021)
SG55	0.033(.028)	0.053(.032)
SG88	.011(.013)	0.988(.014)

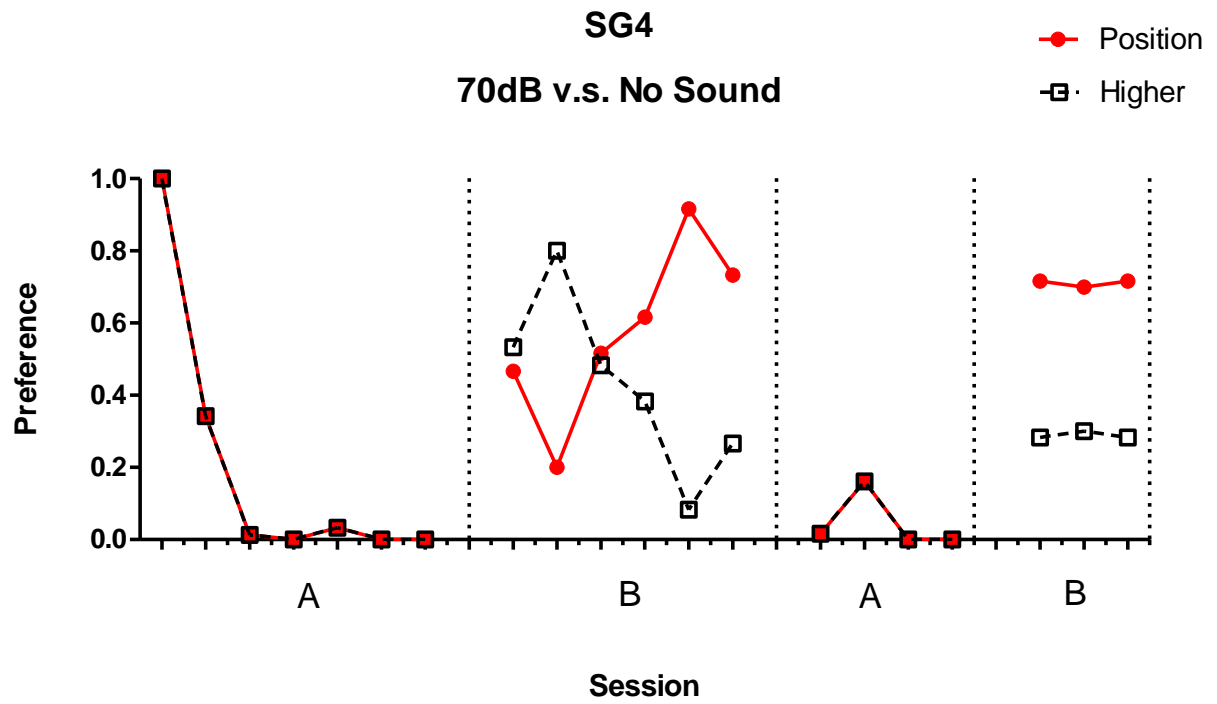
**Table 2.** Subjects' first and last session mean total of avoids and standard deviations for each sound level in Experiment Two: Avoidance Study. This table shows that responding for the avoidance stimulus extinguished by the last session.

<b>Session</b>	<b>0dB</b>	<b>60dB</b>	<b>70dB</b>	<b>80dB</b>
First	1.92(2.2)	2.04(2.53)	2.05(2.10)	1.85(2.49)
Last	.16(.37)	.16(.33)	.28(.77)	.19(.48)

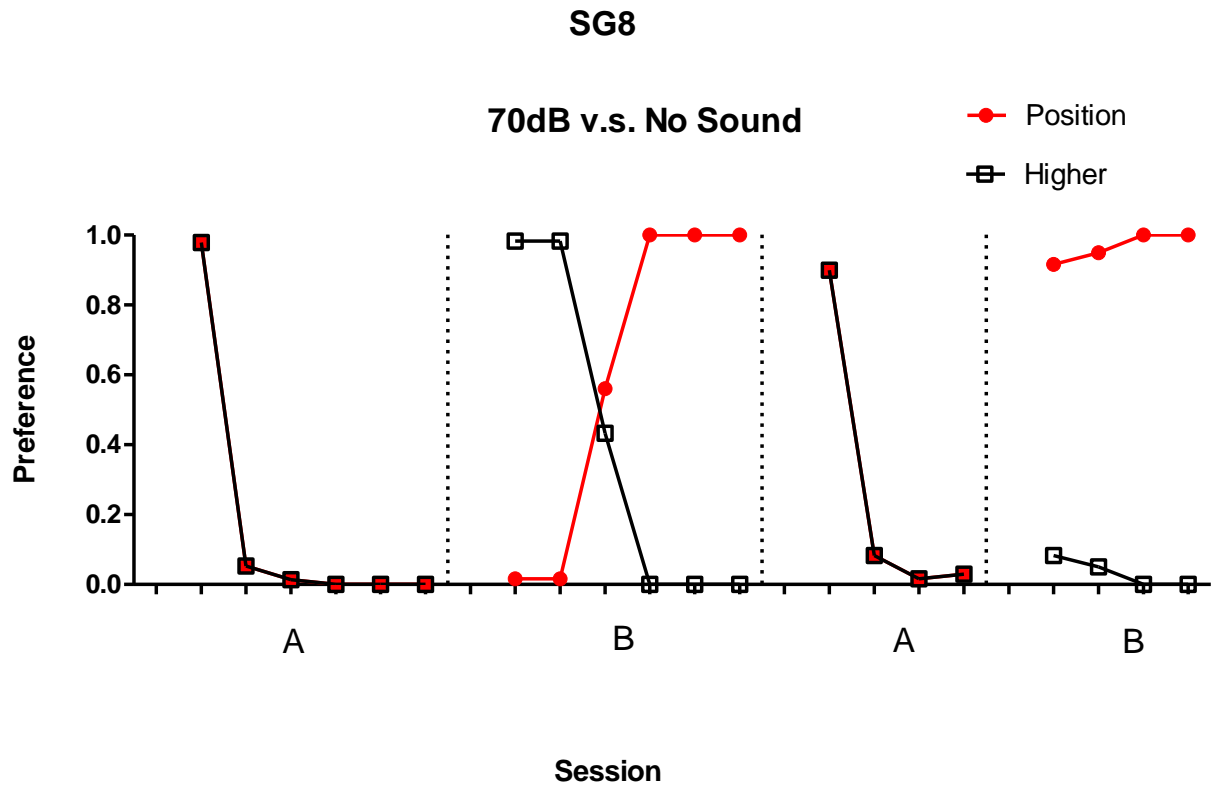




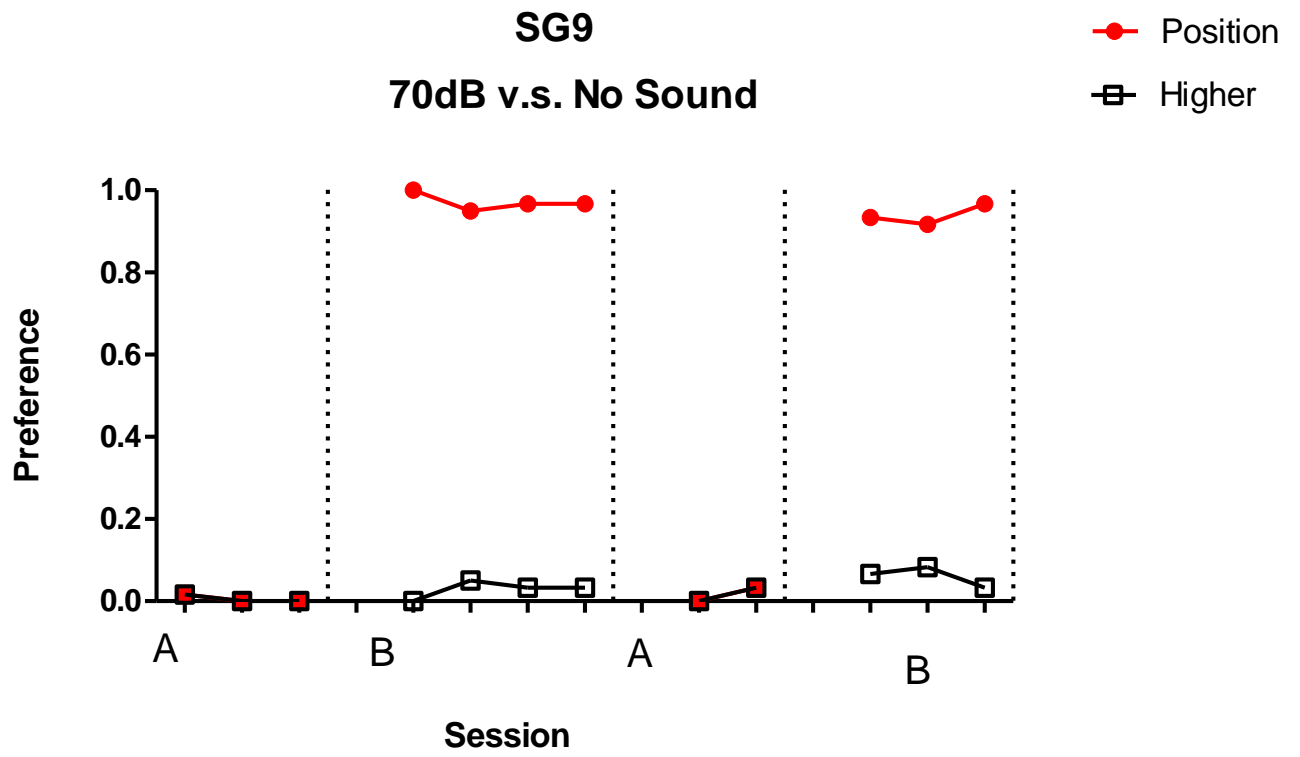
**Figure 1.** Preference scores for choices made during free-choice trials for every session of Experiment 1 for a subject. Preference scores are the proportions of choices made during a session. Higher represents the proportion of choices allocated to the stimulus associated with the 70dB sound, as indicated by the empty squares. Position represents the proportion of choices allocated to the uppermost or right most stimulus location, as indicated by red-filled circles. A dotted vertical line separates conditions and the letters A and B below the x-axis indicate the condition.



**Figure 2.** Description with figure 1.



**Figure 3.** Description with figure 1.



**Figure 4.** Description with figure 1.

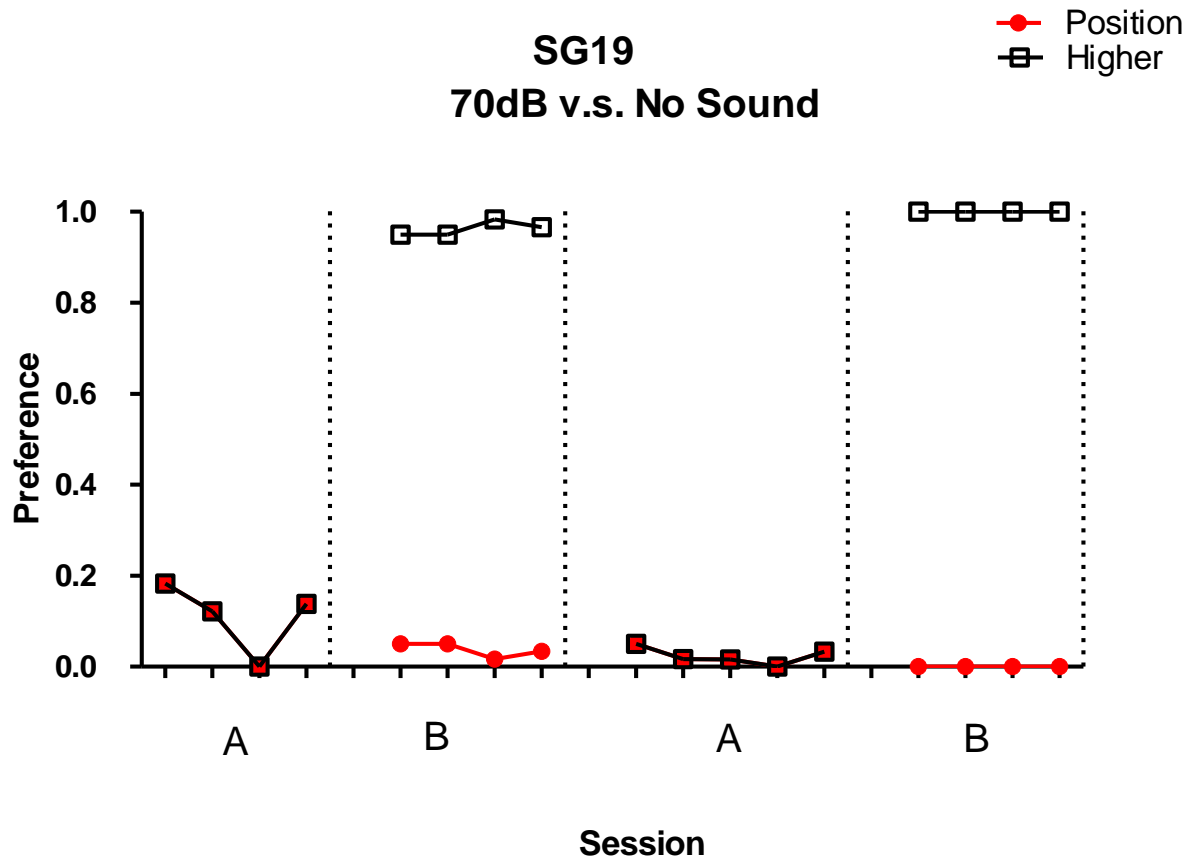
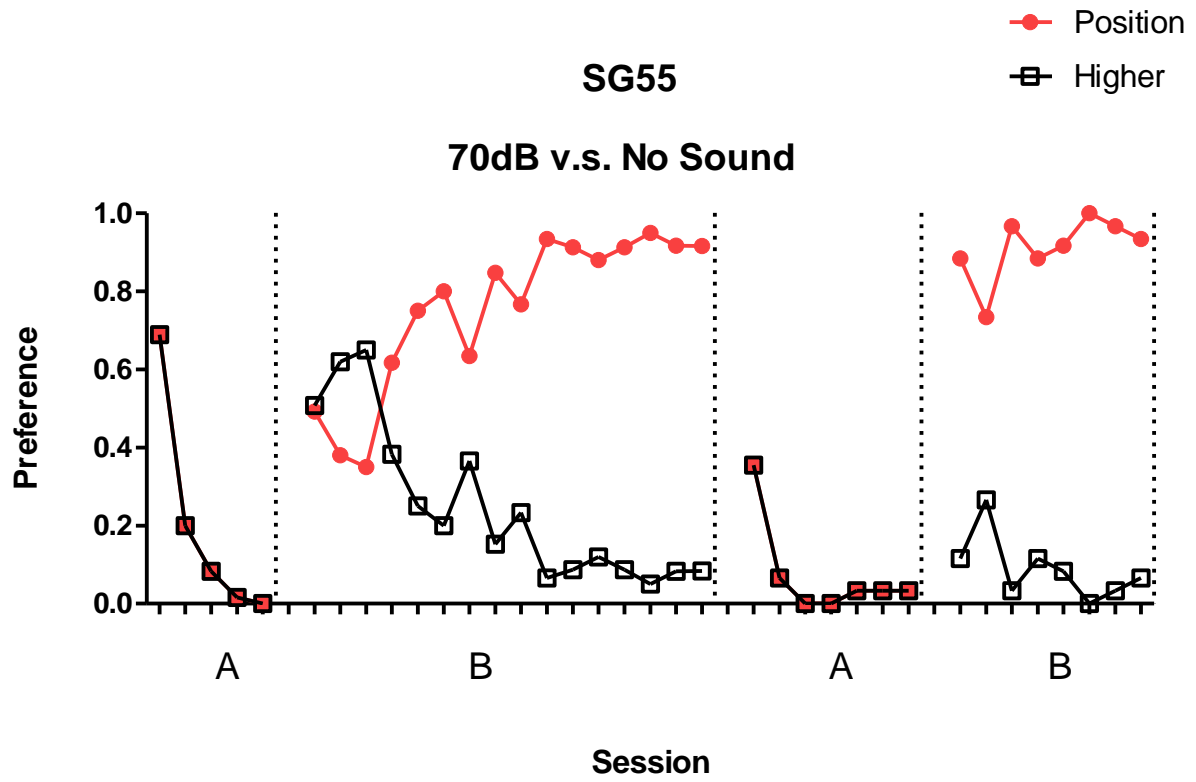


Figure 5. Description with figure 1.



**Figure 6.** Description with figure 1.

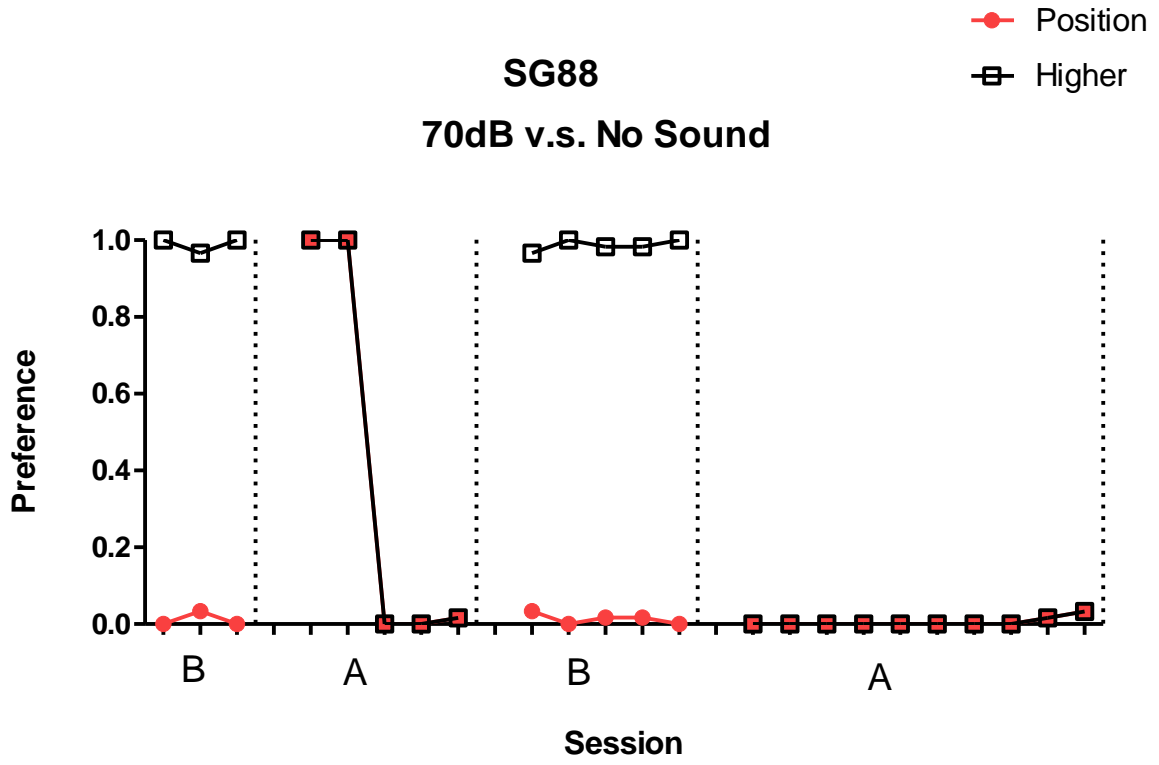
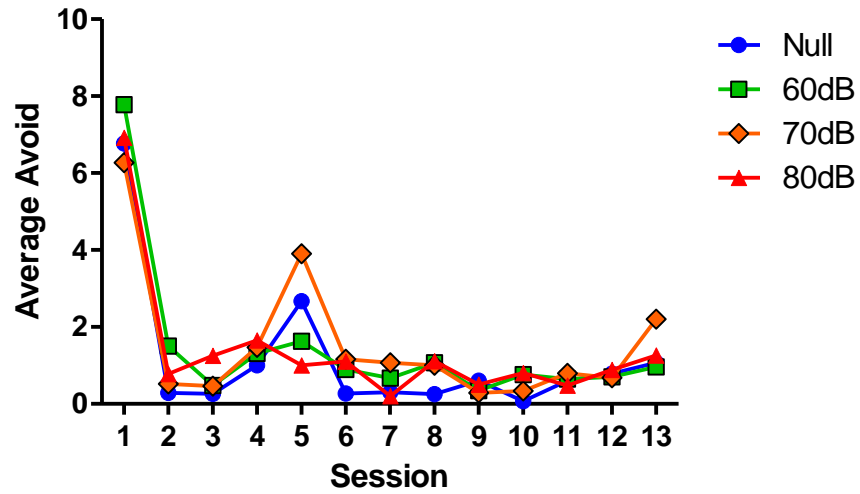


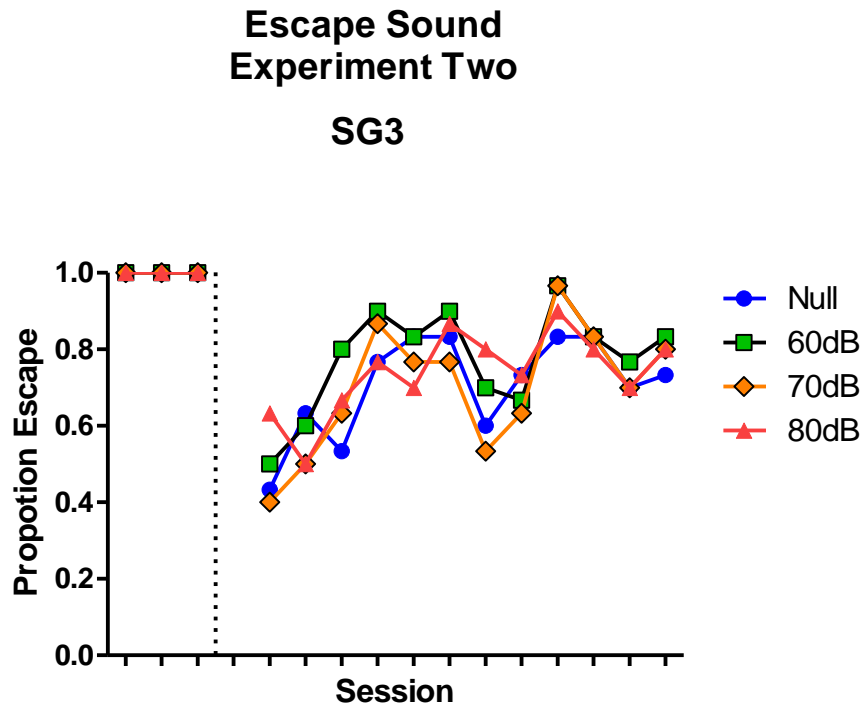
Figure 7. Description with figure 1.

**Avoid Sound  
Experiment Two  
SG55**

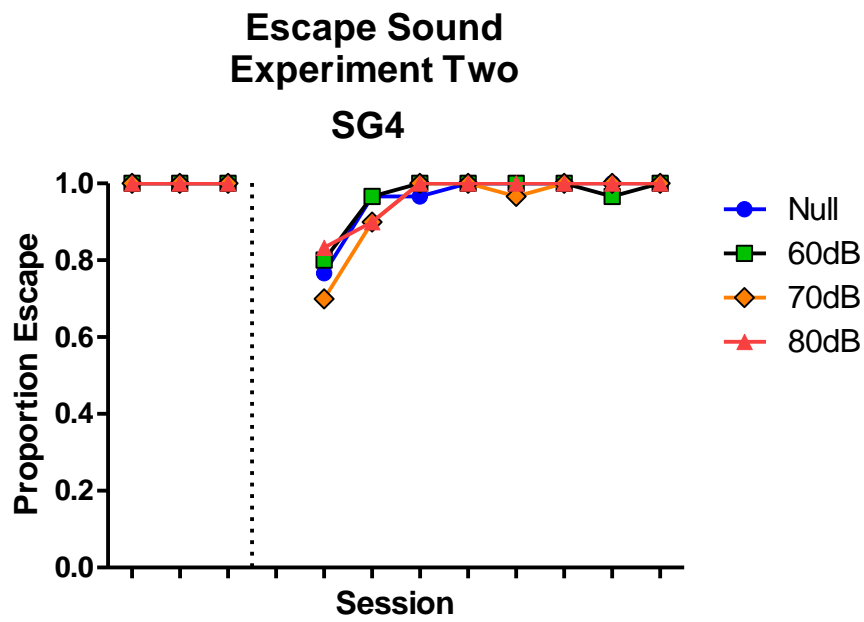


**Figure 8.** Average number of avoidance responses for each sound presentation. Data are presented as a function of sound level and session. The blue-filled circle represent null or 0dB. The green-filled square represents 60dB. The gold-filled diamond represents 70dB. The red-filled triangle represents 80dB.





**Figure 9.** The proportion of trials where an escape response occurred. Data are presented as a function of sound level and session. The blue-filled circle represent null or 0dB. The green-filled square represents 60dB. The gold-filled diamond represents 70dB. The red-filled triangle represents 80dB. Average escapes for Condition 1 and 2 are separated by a vertical dotted line.



**Figure 10.** Description with figure 9.

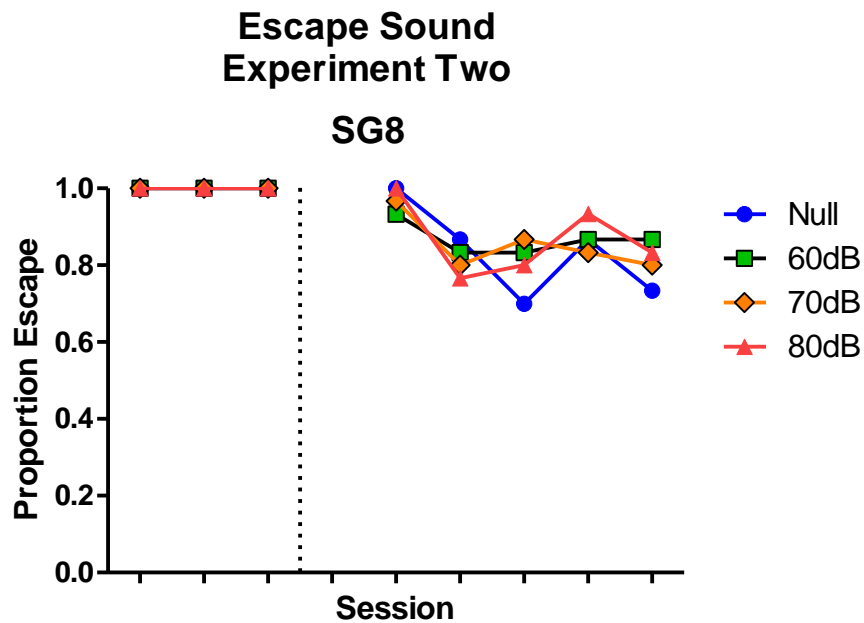
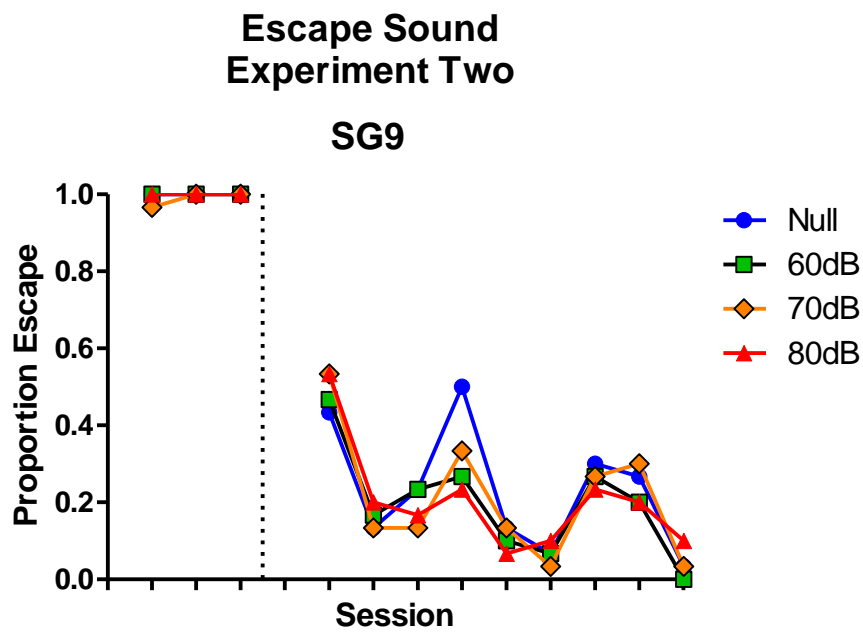


Figure 11. Description with figure 9.



**Figure 12.** Description with figure 9.

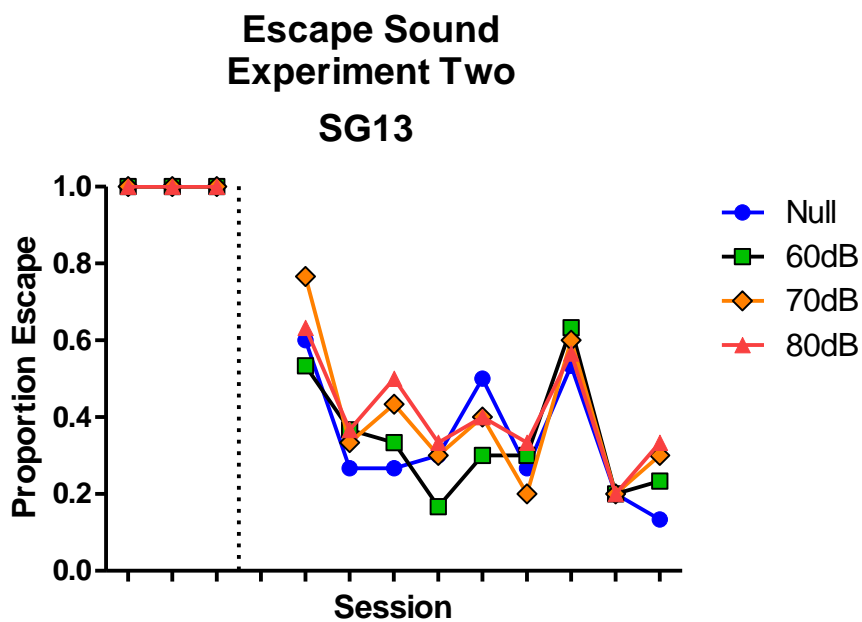


Figure 13. Description with figure 9.

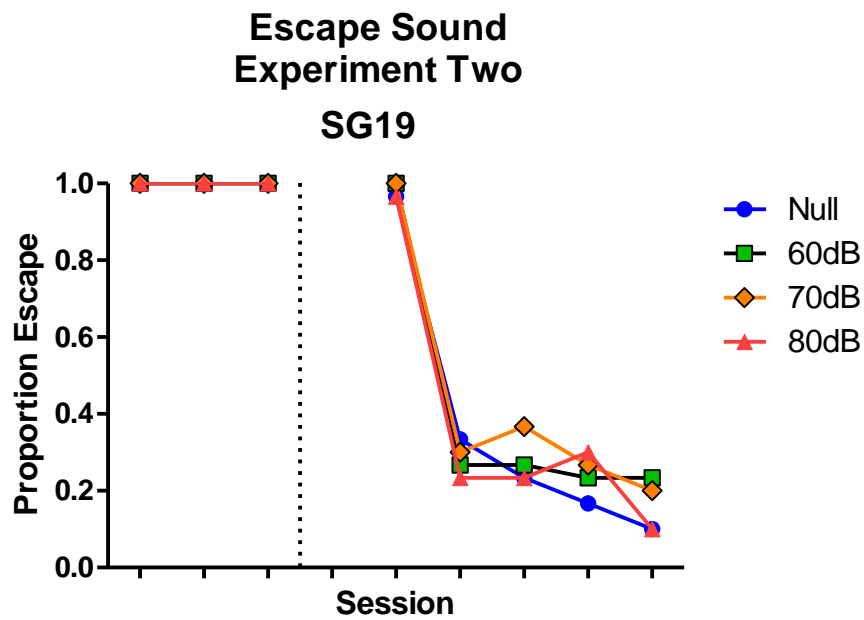


Figure 14. Description with figure 9.

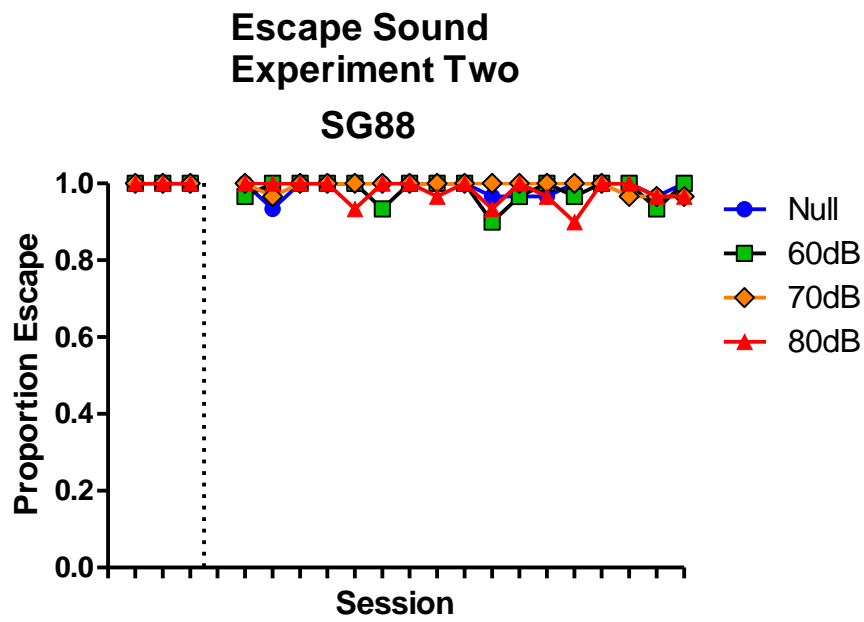
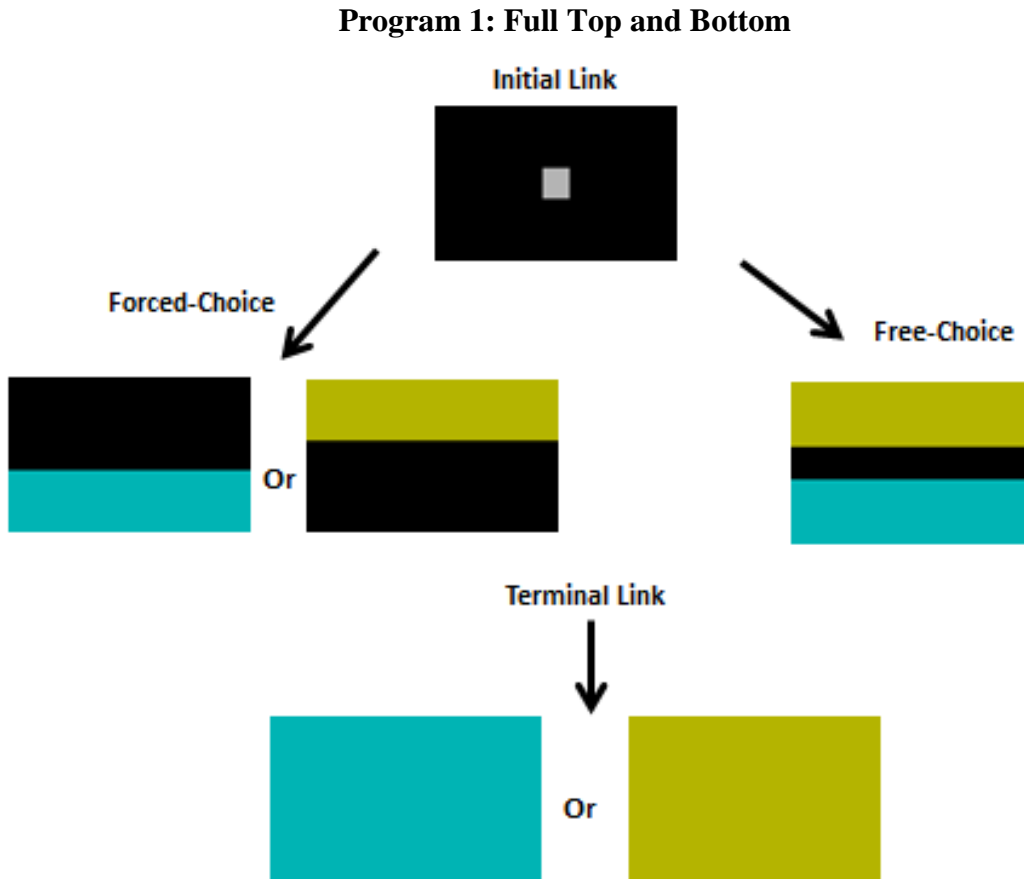
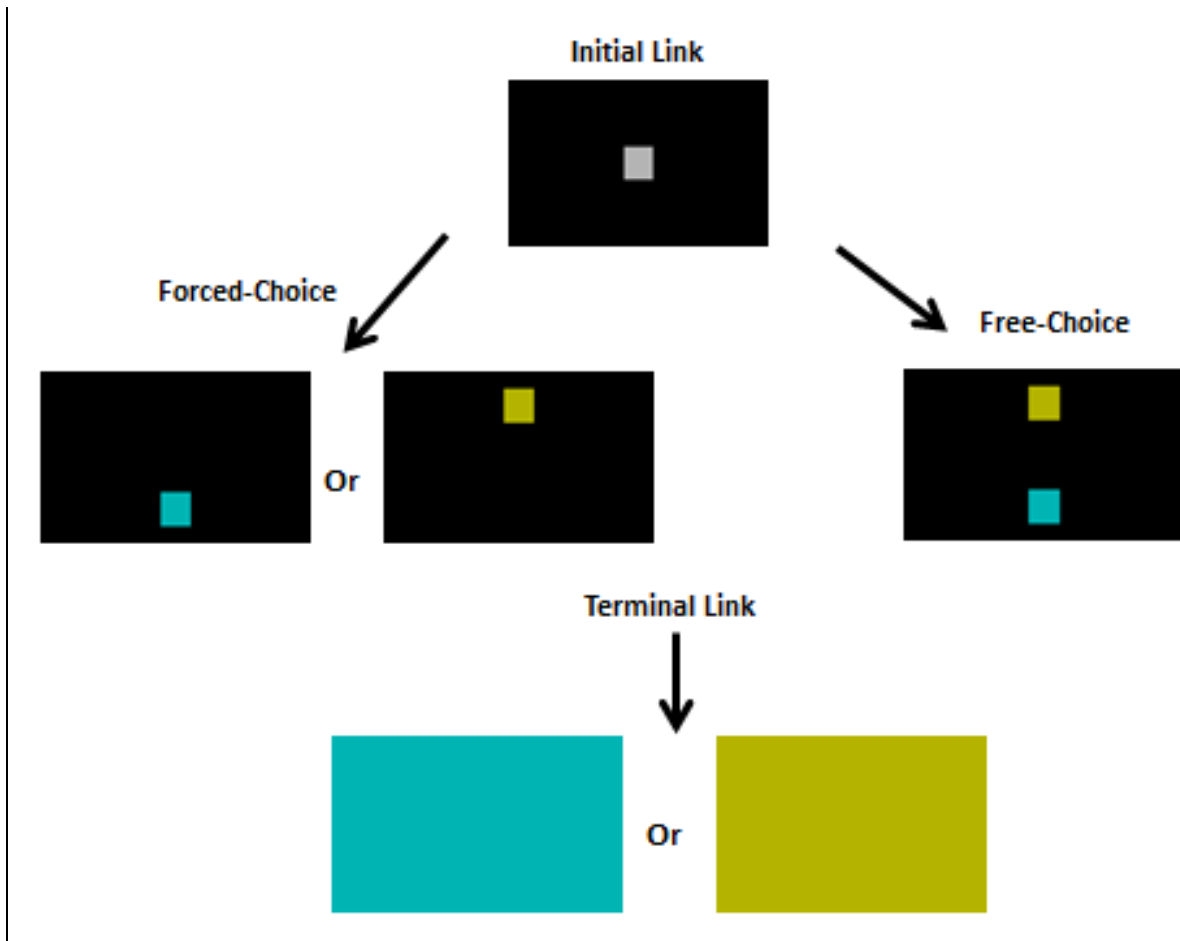


Figure 15. Description with figure 9.

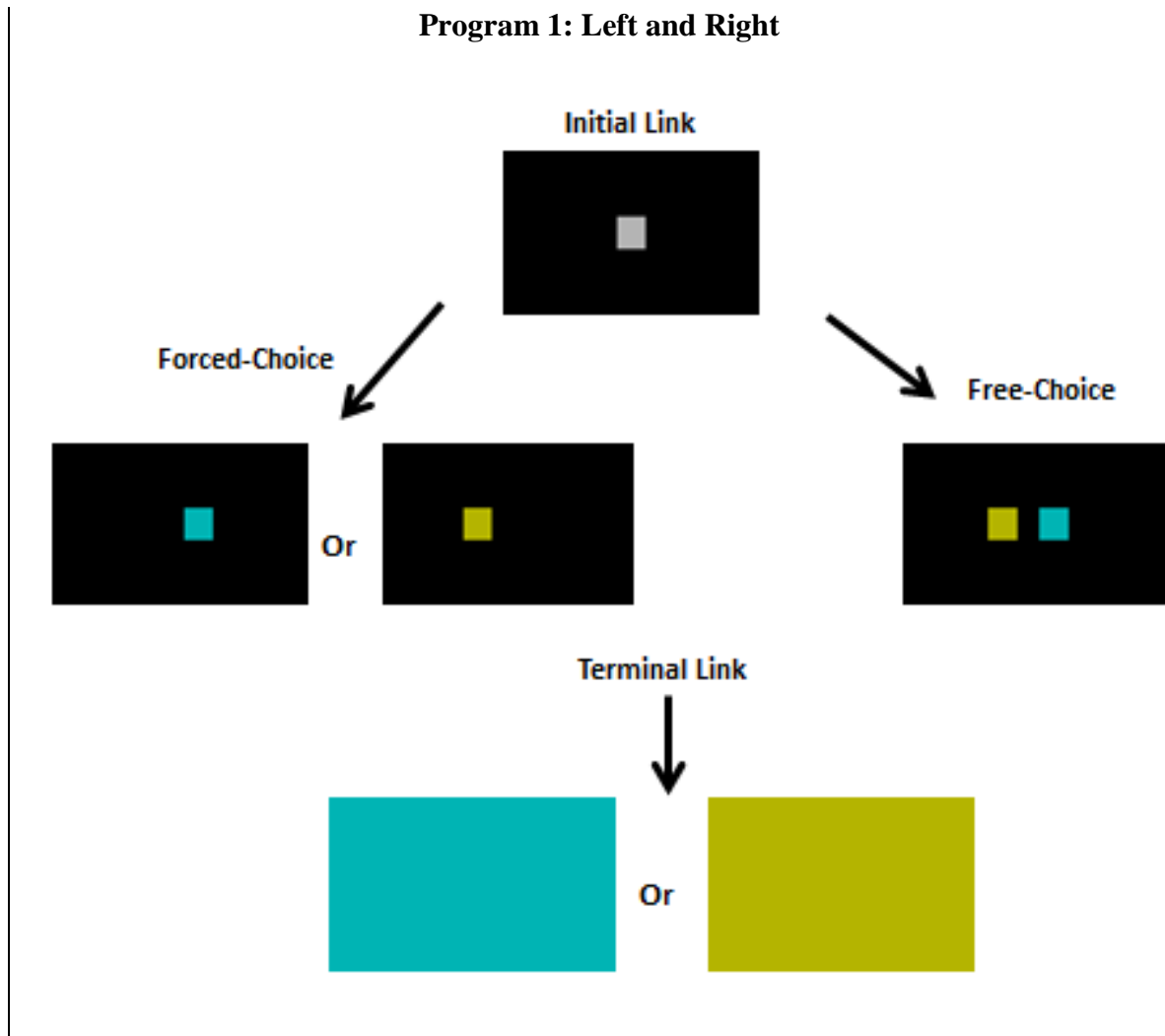


**Figure 16.** [Trial schematic](#) of sequential outcomes in Experiment 1's, experimental design. After, a 2-m pre-session delay, subjects are presented with the initial link that can be pressed to enter the next phase. During the choice phase subjects are either presented with forced choice or free-choice trial types. During a Forced-choice trial, subjects are either presented with an aqua or gold stimulus. During Free-choice trial subjects are presented with both choices. The terminal-link phase fills the screen with the choice outcome. Condition determines the location of the choice stimulus, aqua was at the bottom and gold was at the top in condition A and they reversed locations in Condition B.



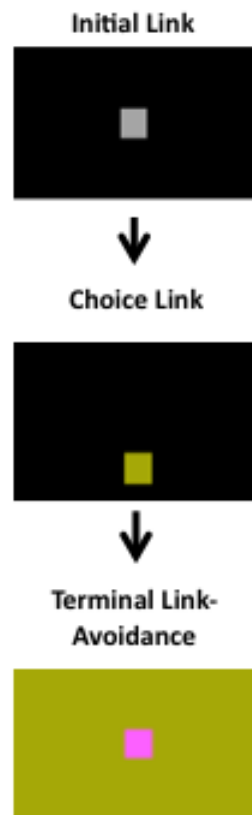
**Program 1: Top and Bottom**

**Figure 17.** Description with figure 16, with one exception, the choice stimuli have now been reduced in size.



**Figure 18.** Description with figure 16, with two exceptions, the choice stimuli have now been reduced in size and they are side by side.

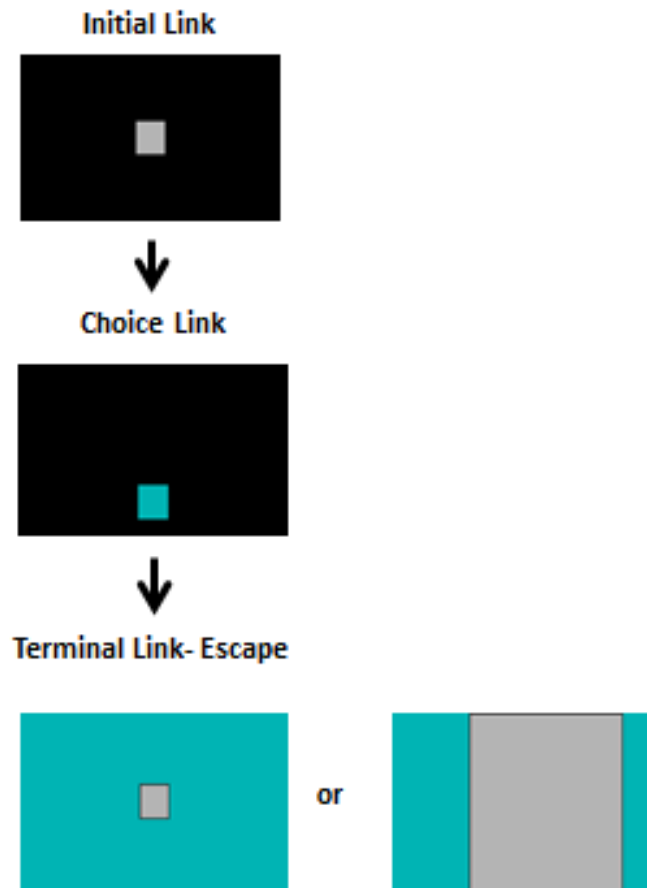
### The Avoidance Study



**Figure 19.** [Trial schematic](#) of sequential outcomes in Experiment 2's, Avoidance Study.

After a 2-m pre-session delay, subjects are presented with the initial link. Next, subjects are presented with a choice. Last, the subjects enter a 60-s terminal-link phase where they are exposed to one of four sound levels. Each press of the magenta stimulus interrupted sound presentation for ten seconds.

### The Escape Sound Study



**Figure 20.** [Trial schematic](#) of sequential outcomes in Experiment 2's, Escape Sound Study and Large Escape Sound Study. After, a 2-m pre-session delay subjects are presented with an initial link. Next, the subjects are presented with an aqua choice stimulus. Lastly, a 60-s terminal-link phase is presented where 1 of four sound levels is presented. One press to the escape stimulus will remove sound presentation for the remainder of the trial. SG19 and SG8 ran with the larger escape button seen on the right.



**Figure 21.** Picture of the apparatus used.

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### **Research Experience**

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### **Presentations**

- Golda C, Burgan B, Steinbaugh B, and Lenick N. 2013. Enhanced Spatial Cognition as a function of Cocoa Flavanol. Poster at Maryland Psychological Association of College Graduates conference, May, 2013.
- Burgan B. 2013. Acute Treatment Effect of Cocoa on Spatial Learning and Memory. Poster at the Towson Research Expo, April 14, 2013.
- Langston JL, Burgan BM, Makar JR, Myers TM, 2014. Development and Characterization of a Behavioral Assessment Platform for the Gottingen Minipig. Bioscience Convention May 20-24, 2014.

