Position Bias Interferes with Auditory Same/Different Abstract-Concept Learning by Dogs

by

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Abstract

Canine cognition is a growing area of research, however the domestic dog's ability to utilize a same/different abstract concept has yet to be explored. In Experiment 1, six domestic dogs (*Canis familiaris*) were trained on a same/different task using auditory stimuli, including human, animal, environment, and effects sounds. A novel apparatus for dogs was designed and constructed to allow nose poke responses to be recorded during automated sessions. Training sessions were administered daily and consisted of 24 trials (12 same, 12 different). Four of six dogs learned to respond in the task but did not reach same/different discrimination criterion. Experiment 2 continued acquisition training with four novel sounds used as the stimulus set. Center panel responding and a suspected spatial response bias led to experiment termination. Experiment 3 introduced a panel spacing manipulation and revealed that comparison responding was controlled by panel location. The study was halted and plans were made for solutions to the task limitations. The results and discussed future directions of these experiments add to the canine cognition literature and potentially lay the ground work for exploring abstract-concept learning in canines.

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Abstract concepts can be defined as "rules learned from particular instances, yet dissociated from any specific instance," (Bodily, Katz, & Wright, 2008). More thoroughly, abstract-concept learning involves the development of relational rules that are not tied to the absolute features of individual stimuli. For example, whereas grouping into the category "car" might involve perceptual features like the shapes of tires and windows, a relational rule is expanded to make judgments among multiple stimuli, such as "these two objects are different" or "this object matches the other." While a concept may be developed with the use of many stimuli and these stimuli may initially be judged based on perceptual features, the development of a relational rule will allow accurate judgments to be made when an individual is presented with novel, unfamiliar stimuli. This transcendence of individual features is what sets abstract-concept learning apart from other forms of learning. Abstract-concept learning is widely considered a marker of so-called higher-order cognition in animals. The ability to make relational judgments about novel stimuli, as readily as trained familiar stimuli, is considered the hallmark of abstract-concept learning across species (Katz, Wright, & Bodily, 2007). There has been an emphasis by comparative cognition researchers on the development of tasks to determine which species do or do not have such higher-order learning, and if they do possess it, to what extent. The resulting findings from these tasks are used to compare animals based on their cognitive abilities in comparison to other species. In the following sections I will describe previously used procedures and parameters for demonstrating abstract-concept learning in non-human animals, previous concept learning research with dogs, and the warrants for a new experimental procedure and apparatus for canine research.

Investigating Abstract-Concept Learning

Premack was the first to propose the imaginal code and the abstract code, two components of intelligence whose separation was said to distinguish higher-order learning from other forms of judgment making (Premack, 1983). While the imaginal code is based in perceptual features of objects, possession of the abstract code is required for making relational judgments when dealing with perceptual situations that lack commonality in absolute features. Premack hypothesized that while the imaginal code may be widespread across species, the abstract code is exclusive to humans and some non-human primates. In order to test for the abstract code, one seeks to show transfer to novel stimuli. That is, if an animal has learned to use perceptual features to make decisions about stimuli (i.e. the imaginal code), then when presented with novel stimuli, that animal will not transfer learning. However, if an animal is using relational rules to make judgments about stimuli (i.e. the abstract code), then they will transfer learning to novel stimuli. In the latter case, abstract-concept learning may be demonstrated.

While Premack's hypothesis regarding the exclusivity of the abstract code was initially on firm ground, studies failing to demonstrate abstract-concept learning in non-humans began to question Premack's claims via developing more effective procedures. Zentall and Hogan (1974), for instance, challenged the notion that pigeons were incapable of learning the same/different concept by training groups of birds on either a matching or oddity task. When a number of birds in each group were shifted to the opposite task, transfer learning with novel stimuli was shown to be higher in birds that remained in their original task. This was repeated with brightness matching and oddity, emphasizing the feasibility of an abstract-concept learning task with avians.

Wright, Cook, Rivera, Sands, and Delius (1988) further progressed abstract-concept learning research with a study emphasizing the number of training stimuli. As would be expected, it took much longer for pigeons to reach criterion under a trial-unique condition with

152 stimuli than for pigeons trained with two stimuli. However, transfer testing showed that the trial-unique group responded to novel stimuli with the same accuracy as familiar trained stimuli, while the group trained with two stimuli responded to novel stimuli at chance levels. Thus, set size was shown to be vital component of experimental design when attempting to demonstrate abstract-concept learning in non-human animals.

The ability of non-human animals to form and use abstract concepts has continually progressed, often with a focus on the parameters necessary for demonstrating this type of learning rather than the assertion of the ability itself (e.g. Wright, 1997; Oden, Thomson, & Premack, 1988). It has now been established that abstract-concept learning can be shown in a variety of non-human species when studies use adequate stimulus set sizes, responses, and testing methods (Roberts, 1998).

Given the interest of using abstract-concept learning for cross-species comparisons, a large variety of species has been researched. Aside from investigating the foundation for this type of learning in humans (Roberts, 1998), non-human animal studies have highlighted abstract-concept learning in other primates such as chimpanzees (Thompson, Oden, & Boysen, 1997), baboons (Bovet & Vauclair, 2001), capuchin monkeys (Wright, Rivera, Katz, & Bachevalier, 2003), and rhesus monkeys (Katz, Wright, & Bachevalier, 2002). Non-primate species of interest have included parrots (Pepperberg, 1987), pigeons (Katz & Wright, 2006), honeybees (Giurfa, Zhang, Jenett, Menzel, & Srinivasan, 2001), and sea lions (Kastak & Shusterman, 1994). Direct comparisons across species are best made when using the same task. For example, Wright and Katz (2006) trained pigeons, rhesus monkeys, and capuchin monkeys on a same/different task with an expanding set size, which allowed direct performance comparisons to be made across the three species for each set. The factors known to be important to establish such direct comparisons are discussed next.

Procedures for testing abstract-concept learning. The ability to learn an abstract concept can be demonstrated through a variety of tasks, such as judgments of same and different, matching, nonmatching, and operations such as addition and subtraction (Katz et al., 2007). When developing such tasks for training and testing with non-human species, it becomes vital to assess the adequacy of a procedure in detecting and demonstrating relational rule use in the selected species. That is, if the task features are irrelevant or inaccessible in some degree to the subjects, then the lack of abstract-concept learning may not be due to a deficit in intelligence, but rather to a faulty experimental design (Katz et al., 2007). Therefore, it becomes necessary that methodology be carefully thought out when attempting to incorporate new species into the body of abstract-concept learning research.

Tasks involving same/different judgments are common in both humans and animals (e.g. Katz & Wright, 2006). The utility of this task as demonstrative of abstract-concept learning is that the judgments of same and different are made based on the relationship between two items, rather than bound to the physical features or “attributes of objects in the real world,” (Domjan, 2010). In humans, subjects may be presented with pairs of stimuli and asked to define the relationship between those stimuli as “same” or “different”. These subjects tend to show mastery of the task quickly, responding seamlessly to familiar and unfamiliar pairings alike (Roberts, 1998). In animals, subjects may be trained to press certain levers or contact certain locations on a computer screen to indicate “same” and “different” judgments. As with humans, high levels of accuracy can be achieved on such tasks when appropriate procedures are implemented.

The matching-to-sample task is also common in investigating abstract-concept learning (e.g. Wright et al., 1988; Bodily, Katz, & Wright, 2008). Generally, these tasks consist of the presentation of a sample stimulus followed, after a defined response, by two comparison stimuli, one of which is different from the sample and one of which is the same. Animals are trained to respond to the comparison stimulus that matches the sample stimulus. Thus, the animals are trained to match and can be transferred to novel stimuli to test the matching concept. Alternatively, subjects may be trained to respond to the stimulus that does not match the sample stimulus in a non-matching to sample (also known as oddity-from-sample) task (e.g. Zentall & Hogan, 1974). In such cases, subject are tested for the non-matching (or difference) concept, instead of the matching concept seen in matching-to-sample.

Many studies on non-human animal learning have been founded on the use of go/no-go tasks (e.g Scholtyssek et al., 2013; Petrides, 1986; Lind & Moustgaard, 2005). In the go/no-go task, one stimulus category is paired with an overt "go" response to be made within a set period of time, whereas an opposing category is paired with restraint of response during that time (Shenoy & Yu, 2012). While go/no-go tasks do demonstrate matching, they may not demonstrate full abstract-concept learning. This is because the lack of response in the no-go condition can have multiple meanings. A withheld response may in fact mean that the subject intends to respond in that form, but may also represent uncertainty, lack of concept, or lack of attention. In addition, response latencies will increase when novel stimuli are introduced, and such changes in processing speed could lead to a loss of sensitivity of the measure, as "no-go" responses may be recorded when in fact the subject is still processing the stimuli.

Parameters

When developing a procedure to test for abstract-concept learning, there are a number of parameters that should be considered for part of the experimental design whenever possible. These include requirement of both an observing and differential response to ensure attention and effortful responding, stimulus source contact and reinforcement aligned with response location to promote learning, and a sufficiently large set size to promote use of relational rules. These parameters are discussed as they form the backdrop for the rational for developing experiments in abstract-concept learning for dogs.

Set Size. The importance of the training set size for abstract-concept learning has been established across a number of species. Katz and Wright (2006), for example, demonstrated set size as vital to the ability of pigeons to learn abstract concepts. Stimulus set size ranged from eight items to 1024 items in this same/different study. As the number of items in the training set increased, performance on transfer trials with novel stimuli increased from chance levels at the smallest set to equivalent-to-training levels at the largest set size. These findings indicated that, at large set sizes, pigeons demonstrate full concept learning and use of relational rules. Additionally, it was shown that while pigeons do require more exemplars, their learning was similar to that of previously studied abstract-concept learning by rhesus monkeys and capuchin monkeys (Katz & Wright, 2006). Thus, this cross-species confirmation of set size as an integral part of learning provides justification for the intended use of a set size expansion in the current design. It can be expected that dogs will show a gradual increase in relational rule use as the number of items in an auditory stimulus set increases from few to many.

Observing Response. The amount of contact that a subject has with the stimulus source in the task has been shown to influence learning. Given past research, we are led to believe that dogs may acquire a concept more readily and rapidly with the implementation of a stimulus source contact requirement. Stollnitz (1965), Wright (1997), and Katz et al. (2002) all showed the benefit that contact with the stimulus provides in learning. Stollnitz (1965) emphasized the importance of the observing response by noting that that observing response serves as “a link in a chain leading to the response on which reinforcement is based,” (p. 249). Wright (1997) used a 3-item matching-to-sample task with subject groups formed based on required observing responses. The four groups were comprised of response requirements of 0, 1, 10, and 20 pecks before presentation of comparison stimuli. It was found that while the group that was not required to make an observing response performed at chance during transfer testing, the group that was required to peck the sample 20 times showed full abstract-concept learning. In regard to acquisition, Katz et al. (2002) used an observing response requirement with rhesus monkeys. In their same-different task, one group of monkeys was required to make a 10-touch observing response while the other group was not required to make any response. The 10-response group showed significantly more rapid acquisition and accuracy on the same/different task than the no-response group.

Given the importance of the observing response in past literature, it seems likely that it is a crucial component for dog to learn an abstract concept. If a subject is forced to attend and respond to a sample stimulus in order to receive the comparison, it would be expected that learning would be facilitated. Therefore, it was expected that dogs would show enhanced acquisition when a nose-poke observing response was required.

Sound Source Location. Harrison, Iverson, and Pratt (1977) established the importance of sound source location in training. Four rhesus monkeys were trained under three conditions of sound and response adjacency. After presentation of a sound, the monkeys were rewarded for responding to a correct key based on the requirement of one of three conditions. Under one condition, a sound was emitted through a key and that key served as the correct response location. In another, the sound was emitted from one key but the correct response was to be made to the opposite key. In a third condition, the correct response location was to be determined by the key closest to the location of the sound. In this study, the researchers found that the monkeys learned at a rapid rate when the training stimulus was presented at the same location as responses were made. Alternately, when the stimulus location and response location were not adjacent, performance was degraded. Thus, sound source location is a key parameter to be considered in experimental design. In the present study, close proximity of sample and response was expected to facilitate learning in dogs.

Criteria for the Demonstration of Abstract-Concept Learning.

In order to demonstrate abstract-concept learning in any species, certain criteria must be met both procedurally and in results. Katz et al. (2007) established a cross-species standard for demonstration of abstract-concept learning by a variety of tasks. The first criterion that must be met is the novelty of transfer stimuli during testing. That is, when testing subjects on an abstract concept, the stimuli used during test trials must be unfamiliar and previously unexperienced by the subjects. These stimuli should not be perceptually similar to prior training stimuli and should not be paired with those stimuli, as such conditions could confound responding based on relational rules. Additionally, transfer stimuli should not be repeated within a transfer session. On the surface, it seems clear that once a stimulus has been presented more than once, it becomes familiar and thus would not test for transfer to novelty. In addition to this, repetition of a transfer stimulus within a testing session could allow for rapid learning. Another criterion requires that, in order to demonstrate full abstract-concept learning, performance during transfer testing should be equivalent to the performance level that was achieved during training. This is true because partial transfer may suggest use of strategies other than abstract concepts (e.g.

generalization). Lastly, transfer trials should be reinforced like training trials to prevent within-session learning or extinction (Katz et al., 2007). These criteria allow for secure demonstration of abstract-concept learning and assist in comparing higher order abilities across species.

Abstract-Concept Learning in Dogs

Dogs are perfectly suited to studies of abstract-concept learning due not only to their keen cognitive abilities, but also to their trainability and social nature alongside humans. Dog cognition provides a vast but thriving area of research within comparative psychology, and although evidence abounds for social cognition and other forms of learning, abstract-concept learning literature is sparse in the field. This absence is unnecessary, and a comparative literature that has investigated monkeys, pigeons, and humans, to name a few, will benefit greatly from the incorporation of dog research.

The index of Dog Behaviour, Evolution, and Cognition (Miklósi, 2009) does not include abstract-concept learning as an entry. However, two past studies are of note. The earlier study by Pietrzykowska & Soltysik (1975) tested the transfer of the same/different discrimination using auditory stimuli. The study was conducted subsequent to the finding that four dogs did not transfer the same/different task across sensory modalities of auditory and vision. Two tones (200 Hz and 1200 Hz) were drawn from the original study and combined with the sounds of a metronome and a bell in order to test the same/different discrimination with the previously trained dogs. In this case in which the auditory modality was of focus, the dogs transferred to novel discriminations and were therefore considered to have acquired and used the same/different concept.

Though Pietrzykowska and Soltysik (1975) made claims for abstract-concept learning demonstration, several parameters were lacking in their design and leave the authors' conclusion unsatisfactory. In addressing the established criteria, the authors did conduct a study using an auditory same/different task. However, they did not require a differential response. In this task, dogs only made responses for “different” stimuli scenarios. This means that the dogs were trained to respond to difference, but were not trained in a true discrimination between sameness and differentness. Because responses were only given to one of the two conditions, “same” non-responses may have been due to lack of attention, confusion, or lack of acquisition of the task rather than discrimination. In addition, upon transfer to novel stimuli in Experiment 1, one of the two transfer stimuli had been previously trained; and in Experiment 2, the novel stimulus created an orienting response which drew each dog’s attention to the novel sound, irrespective of the same/different relationship. Therefore, while Pietrzykowska and Soltysik (1975) did use an auditory same/different task and did show equivalent-to-acquisition transfer performance, they failed to meet the criteria necessary for a true demonstration abstract-concept learning in an auditory task with domestic dogs because they intermixed training and testing stimuli in the same trial and the dogs may have been responding to novelty of the test stimulus or the familiarity of the training stimulus rather than utilizing an abstract same-different rule.

A later study by Kowalska (1997) examined the utility of training dogs on an auditory delayed matching-to-sample task using trial-unique stimuli. Three dogs were used in the task, in which they were presented with a sample stimulus followed by two alternating tones, one of which matched the sample stimulus and one of which was different. The dogs were trained to press a bar located beneath the speaker playing the matching comparison stimulus and to withhold any response to the speaker playing the non-matching sound. Three-hundred twenty auditory stimuli were used and the dogs were trained to an acquisition criterion of 90%. The results of the study indicated that the dogs learned the delayed matching-to-sample task with success.

When holding the research done by Kowalska (1997) to the established criteria, we find that several areas are lacking in regard to abstract-concept learning. First, while the study is posed as demonstrative of abstract-concept learning, the author used an auditory delayed matching-to-sample task and no differential response was required. This is a limitation because a lack of responding can mean several things. That is, a non-response that was recorded as a discriminative choice may have actually been due to lack of attention, confusion, or lack of acquisition of the task. Critically, true transfer testing was not conducted in this research, as the author notes that the task was facilitated when novel stimuli were introduced. Therefore, equivalent-to-acquisition transfer performance was not measured and the conclusions were limited by the likelihood that learning was taking place during testing. And while novel stimuli were used, stimuli were not trial unique as the testing sessions repeated. Therefore, while Kowalska (1997) did use novel transfer stimuli, the necessary criteria for demonstrating abstract-concept learning an auditory same/different task were not met.

Based on the above noted criteria for abstract-concept learning, these prior studies fell short on their claims of abstraction in dogs. In the present research, we sought to address the considerations that are lacking from these past studies in order to demonstrate abstract-concept learning in dogs via use of an auditory same/different task.

Testing Abstract-Concept Learning in Dogs

In order to design a test for abstract-concept learning in dogs, several key parameters were addressed: modality, set size, observing response, and performance criteria. These parameters were drawn from the past literature and to achieve the main goal there is a focus on the integration of optimal experimental conditions for demonstration of abstract-concept learning.

Modality. Experimental procedures should take into account the modalities to which a species is specialized or with which it exhibits optimal performance. That is, the experimenter must ask whether the task features being used are appropriate for the species. In the case of domestic dogs, previously used concept learning tasks have been based on use of the visual and auditory modalities. Dogs have significantly lower visual acuity than humans, and thus they see fewer fine details than humans. Additionally, dog are dichromats and therefore see less color variation with less intensity than humans. On the other hand, domestic dogs have very fine-tuned hearing abilities. They can hear a greater range of frequencies than humans and can do so at farther distances (Lindsay, 1999). Thus, it seemed natural that the auditory modality would be more suitable for task design than the visual modality.

Set Size. The task itself must consist of an appropriate number of stimuli for concept learning to take place. Therefore, the auditory set size was selected carefully. Again, a standard had not been set for auditory stimuli set size with domestic dogs, and we based the appropriate stimulus set size according to past literature with other non-human species, particularly Katz and Wright (2006). Given that this study gradually increased the number of items in the set, replicating this expansion was expected to allow for a measure of the rate at which dogs learn the task – either item-specifically or relationally – at any given set size. Additionally, the contact with the stimuli in the set is of importance, and observing responses were required throughout the task.

Observing Response. In Wright et al. (1990), the researchers implemented an auditory task of same/different concept learning with two rhesus monkeys and showed significant demonstration of abstract-concept learning. The researchers used a training set of 38 auditory stimuli that included non-natural sounds such as a door buzzer and cuckoo clock as well as natural sounds such as a monkey coo and a cage rattle. During training, a sound source contact requirement, sound localization, and trial-unique stimuli were implemented to enhanced acquisition of the task. During preliminary training, monkeys received food reward for touch responses to a speaker when sounds were emitted. This sound-source contact was also required during sound localization training, in which the monkeys were rewarded for responding to the one speaker (of three) from which a sound was played. This touch response requirement continued through each trial during task training and testing. Additionally, trial-unique stimuli were used throughout training, beginning with the 38-item set. These stimuli were scrambled for each acquisition phase and therefore created unique sound pairs for each. When monkeys did not perform to criterion for a given acquisition phase, a fading procedure was implemented, by which the incorrect choice was gradually faded out and the correct speaker for touch response became more apparent. Upon transfer to 138 novel stimuli, the rhesus monkeys trained under this set of parameters successfully demonstrated the abstract concept of same/different.

The importance of the observing response was emphasized in Katz et al. (2007) by noting that while pigeons need not be trained with a large stimulus set when a high observing response requirement is in place, transfer performance is unsuccessful without an observing response. Further, rhesus monkeys have shown more rapid learning with an observing response requirement. Thus, it could be expected that an observing response requirement would be useful across species and would facilitate abstract-concept learning in the domestic dog.

Performance Criteria. Ultimately, we attempted to make the criteria set forth by Katz et al. (2007) attainable in the present research. That is, the experiment aimed to demonstrate the use of the same/different abstract concept with auditory stimuli through initial training and acquisition of a sufficient training set, as well as through transfer testing. Transfer testing was to be designed such that if an abstract concept has been formed, it would be successfully demonstrated when a subject was presented with novel auditory stimuli. If the criteria outlined by Katz et al. (2007) were met, we would conclude that abstract-concept learning through the use of a same/different auditory task had been demonstrated in domestic dogs.

There were many benefits at hand with the design of a new experiment, and also benefits with the use of established design features and protocols. While we implemented many new experimental components, we also drew on past designs, particularly those used in Wright et al. (1990) and Wright and Katz (2006). These designs proved effective in demonstrating abstract-concept learning in primates and avians and were therefore likely ideal for dog research. Combined with previously demonstrated effectiveness, the use of a similar task was expected to allow comparisons to be made across species.

Designing a New Apparatus

There were several expected benefits with the design and use of a new apparatus. For the present research, we used a custom-built apparatus that targeted the physical attributes of the domestic dog as well as promoted abstract-concept learning through sound source location (Harrison, Iverson, & Pratt, 1977) and contact areas (Stollnitz, 1965). Wright et al. (1990) emphasized the importance of stimulus contact, and the apparatus for this experiment allowed for recorded contact with the sample and comparison speakers throughout the task.

The new apparatus also eliminated several potential confounds. First, the physical challenges that may be presented by ready-made apparatuses designed for other species were eliminated, as this design is suited specifically for domestic dogs. That is, the apparatus makes use of appropriate speaker elevation for nose-poke responding for medium- to large-breed dogs as well as delivers treat reinforcers to bowls below the speakers, allowing dogs to receive food similarly to the way they would at home. Additionally, the risk of experimenter cueing must be addressed, as domestic dogs have evolved socially with humans and are well attuned to subtle cues that we may or may not be aware we are giving (Miklósi, Polgárdi, Topál, & Csányi, 1998; Hare, Brown, Williamson, & Tomasello, 2002). This potential confound was eliminated by the full automation of the task program as well as the enclosed nature of the apparatus.

Finally, adaptability was a large benefit of the new apparatus design. The panels of the structure were made separable in order to change distance and angles between speakers as well as to be made functional in a variety of experimental environments. The wiring of the apparatus was configured for easy breakdown and reassembly. Additionally, the reinforcement dispenser was designed such that a variety of treats and varying reinforcement durations may be used.

Experiment 1: Same/Different Acquisition

As old and new research met, a single question was posed. When placed in an auditory same/different task, will domestic dogs demonstrate abstract-concept learning? We hypothesized that, when trained to an appropriate acquisition criterion, domestic dogs would learn and then transfer to novel stimuli. The present study aimed to provide the benefit of additional knowledge and methodology for abstract-concept learning within the comparative cognition field. There has long been a perceived gap between humans and non-human animals in regard to higher-order learning. By furthering research investigating non-human animal abilities to engage in higher-order learning through the use of abstract concepts, this gap may be further filled with evidence for animal cognitive abilities.

This study sought also to benefit the present body of research with dogs specifically. The research area of dog cognition is rich with studies targeting topics such as social intelligence and natural concept learning within the visual modality, but fewer studies have been done using the auditory modality and abstract-concept learning. The present research offers a chance to enrich what we as researchers understand about dog cognition and also allows for a new avenue of investigation into the abilities of the dog mind. Additionally, the research provides an apparatus design that may be uniquely appropriate for training and testing with domestic dogs. As the research with this species continues to grow, such a design could serve to ease experimental design as well as provide a common ground on which comparisons can be made.

In the present experiment, dogs were trained on a four-item auditory same/different task. Upon reaching criterion, transfer testing was to be conducted, after which the set size would be doubled until equivalent-to-baseline transfer performance was shown and abstract-concept learning was demonstrated. It was hypothesized that dogs would use item-specific learning under the four-item condition, with memorization of stimuli during acquisition leading to criterion performance but subsequent failed transfer. As set sizes were doubled, it was hypothesized that item-specific learning and memorization would give way to relational rule use and abstract-concept learning as indicated by full transfer to novel stimuli.

Method

Subjects. Six adult domestic dogs (*Canis familiaris*) were used in the study. Subject information can be found in Table 1. Dogs were selected based on age, size, residence location, prior training, and hearing ability. They were between one and six years of age at the onset of the study in order to control for similarities in development and potential attention and/or response detriments due to puppyhood or aging (Milgram, Head, Weiner, & Thomas, 1994). Dogs weighing between 30-pounds and 110-pounds and between 20” and 30” height at the shoulders were selected to ensure appropriate physical compatibility for the apparatus. As the task required attention to commands, prior basic obedience training was necessary, and subjects were proficient with commands such as “sit” and “stay”. Finally, the dogs were tested for hearing ability to ensure that results would not be confounded due to hearing loss.

The present research took place at Auburn Veterinary Hospital in Auburn, AL, and was conducted with dogs owned by clinic employees. The dogs used in this study were selected according to the health and behavior criteria described above as well as with consideration to temperament and motivation. Selected dogs had updated vaccinations and confirmation of health by Dr. Mary Smith of Auburn Veterinary Hospital. Dogs were assessed for aggressive or fearful tendencies. Aggressive or fearful tendencies included, but were not limited to, cowering or growling at the presentation of unfamiliar sights or sounds and aggressive posturing or fearful posturing toward the researcher or other individuals involved in assessment. Dogs exhibiting these tendencies were not included in the study.

Additionally, dogs were assessed for food motivation through the use of treat reinforcers for basic commands such as “sit”. Dogs that were not motivated by treat reinforcers were not included in the study. Finally, dogs were assessed for hearing ability. Dogs that demonstrated any hearing difficulties were not included in the study. Dog owners were given a subject information sheet to serve as a record of each dog’s health/personality history as well as a client consent form. The subject information sheet included history questions such as, “Does your dog have any allergies we should be aware of?” as well as preference questions such as, “What type of treat does your dog enjoy most?” The client consent form explained the experimental protocol and informed dog owners of the risks and benefits involved in study participation.

Were a dog to seem unmotivated to respond during multiple sessions of the experiment, the owner was asked to keep a daily food and health log. This log was kept because a lack of responding could have been due to declining health or lack of reinforcer motivation caused by overfeeding. If a dog were to become aggressive or fearful toward the researcher or in the experiment room, the dog was to be dismissed from the study. Any dogs exhibiting chronic physical ailments or a consistent lack of attention to the task were to be dismissed from the study. A dog could drop out of the study at the owner's discretion. Any medical action to be taken for a dog was to be determined at the owner's own discretion and under the owner's responsibility and care. Were a dog to drop out of or be removed from the study, the data already obtained was to be analyzed and included in study data where appropriate. No replacement subjects were used.

Apparatus. The apparatus was designed and constructed in collaboration with a student in the Samuel Ginn College of Engineering's Electrical Engineering Masters program. Figure 1 provides an image of the completed apparatus. The apparatus consisted of three panels: center, left, and right sample/response panels. Each panel was identical in construction (36-in high x 24-in wide x 10.5-in deep). A 5.25- in speaker (Auvio #4000334) was located in the center of the horizontal plane, beginning 7-in below the top of the panel and ending 19-in above the bottom of the panel. Nose-poke responses were made between photoresistors within an acrylic half-circle with a radius of 3-in. Finally, a reinforcement dispenser (Zevro, model GAT100) dropped treat rewards through vacuum hosing (approx. 18-in long) into a food bowl. Each food bowl (6.5-in diameter) protruded 4-in from the front of the panel. Sounds were delivered via Pioneer stereo receiver (model SX-201). Sample sounds were presented via the left channel through the front panel speaker and comparison sounds were presented via the right channel through the left and right speakers. The three panels of the apparatus were designed such that they were easily made mobile. This mobility allowed for experimental changes in distance and angle as well as ease in shifting environments. In any case, the apparatus was located within an otherwise empty room during training and testing. This eliminated potential confounds brought about by environmental distractors. Additionally, a divider separated the experimenter and subject to further eliminate distractors. The edges of the panels were positioned flush with one another, leaving no space between panels. The left and right panels were each positioned at a 135° angle with the center panel.

Stimuli. The sounds played in this experiment included audio clips that were 1 to 3 seconds in length and played through speakers installed in the apparatus. A set of four stimuli were selected for the initial training set. These stimuli made up four sound categories: animal sounds, environment sounds, human sounds, and effects sounds. These sounds were chosen to ensure that dogs did not generalize across stimuli due to similarity but were rather exposed to multiple distinct sounds. Further, sounds within each category were chosen considering each dog's life experience, eliminating sounds that could be fear- or aggression- inducing or already associated with behavioral contingencies. Table 2 outlines the 4 audio clips used as initial training stimuli

Experimental Control. . Software designed by the College of Engineering student allowed for session creation, modification, and saving. Screenshots of the software can be seen in Figure 2. The same/different Visual Basic program ran on a Dell Optiplex 745 PC.

Design. Prior to pretraining, a preliminary phase served to habituate each dog to the experimenter, the research room and apparatus, and the treat reinforcer. During this time, the dog received treats for exploring new areas of the apparatus and research room and for approaching the experimenter.

***Pretraining*.** During pretraining, each dog was hand-trained to sit in the center of the apparatus using verbal commands, hand posturing, and treat reinforcers. During this training, a treat reinforcer was given on intervals progressing from five seconds to thirty seconds. Once this behavior was adequately mastered, the dog was then trained to sit in the center of the apparatus and then respond to a sound from the front speaker (via nose-poke response) before returning to the central position. The nose-poke response was defined as the dog approaching the speaker and breaking the photo beam using the snout. This was initially trained by hand- guiding the dog with a treat to touch the speaker. Once the dog demonstrated sufficient responding to the front speaker, the side speaker responses were trained. Side speaker responses were trained by reinforcing the correct chain of sitting in the center, responding to the front speaker, returning to the center, and responding to a sound from a side speaker.

Training. Once the pretraining phase was completed, each dog moved on to the training phase. Each training session consisted of 24 trials (12 same, 12 different). Auditory sample and comparison stimuli were selected from the four item stimulus set in order to create 3 repetitions of each of four same trials and one instance the 12 different trials. Trial order was randomized within each session with the requirement that no trial type was presented more than 4 times in a row.

Figure 3 shows a schematic of both a same and different trial used in training. At the beginning of each trial, a sample stimulus was looped from the front speaker until a nose-poke response was made to that speaker. Once the sample response had been made, the looping of a comparison stimulus from both the left and right speakers began simultaneously. If the two auditory stimuli that were played were the same, then a nose-poke response to the left speaker was recorded as correct and treats were delivered. If the auditory stimuli that were played were different from the sample, then a nose-poke response to the right speaker was recorded as correct and treats were delivered. Same/different response configurations were counterbalanced across subjects. Correct responses progressed the session to the next trial. However, if an incorrect response was made (nose-poke to the left speaker when auditory stimuli were different, or nose-poke response to the right speaker when auditory stimuli were same) then no treats were given and a correction procedure of a one-time trial repetition was carried out. If no response was made to the sample or if no response was made to the comparison after a response was made to the sample, the trial timed out after 20 s, was marked as an abort, and was repeated one time per the correction procedure. Between trials, an inter-trial interval of 15 s occurred. During this time, the dog returned to the start position. As needed, the dog was instructed by the experimenter to return to this position.

A session was considered complete when 24 trials (not including repetition trials) were completed. Training sessions occurred daily and lasted between 15 and 45 minutes for each dog. If a dog was unable to complete a training session in the allotted time, the session was continued at the start of the next training day. Training sessions were conducted daily, Monday-Friday. Sessions were conducted from January through July of 2014.

Results and Discussion

Training was halted after 3 months due to apparatus failure. As described previously, the apparatus was made up of 3 panels, with each holding a motorized reward dispenser, a speaker, and a nose poke sensor. The motorized reward dispenser on the right panel began malfunctioning 3 months into the project, as correct-response nose pokes were detected but did not activate the motor to provide food reward. Manual food reward began at this point by responding to correct-response nose pokes (as indicated by the same/different program screen) with placement of food reward into the bowl via the back of the panel. This controlled for experimenter influence, but still led to degraded experimental quality due to a timing delay that was inconsistent with the motorized reward system. Temporary fixes were made to the sensors by trimming the acrylic casing, but the temporary nature of the repairs and continued malfunction led to termination of the initial acquisition phase of the study.

Figure 4 shows individual accuracy based on trials completed across sessions for each dog up to the point of apparatus failure. Butterz completed 30 sessions during Experiment 1, with accuracy peaking near the 80% criterion at session 15 but remaining below criterion for the remaining sessions. Butterz' number of completed trials increased from low responding during the first 3 sessions to full (24-trial) and near-full responding for the majority of remaining sessions. Wee-Zee completed 17 sessions during the experiment. Her accuracy approached criterion up to session 7, after which her performance declined and remained below criterion. Wee-Zee's number of trials completed increased across sessions but never reached full responding. Champ showed fairly consistent performance across 11 sessions, with trials completed and session accuracy remaining below criteria. Diesel also remained below criteria for both accuracy and responding across 9 sessions. Finally, Hannibal and Haelo showed inadequate responding, defined by fewer than 4 responses per day for 10 days, and were removed from the study. As shown in Figure 4, two sessions were attempted across the 10-day period, with only 19 total responses made by Haelo and 10 responses made by Hannibal. While the four other dogs did not reach the acquisition criteria during this time, they did demonstrate appropriate response behaviors. Statistical analyses were run for these four dogs and support the descriptions above.

Butterz. Butterz learned to complete trials in the task over 30 sessions, however she did not acquire the same/different discrimination. A simple linear regression of acquisition performance (accuracy x session) showed that session did not reliably predict accuracy (β =-0.3010, p = 0.2032), indicating that Butterz was not acquiring the task at the point of apparatus failure. However, session number did predict the number of trials completed (β = 0.28165, $p < 0.01$), indicating that responding improved over time.

Wee-Zee. Wee-Zee learned to complete trials across 17 sessions, but she did not acquire the same/different discrimination. A simple linear regression of acquisition performance (accuracy x session) revealed that session did not reliably predict accuracy (β = 0.1481, p = 0.1183), indicating that Wee-Zee was not acquiring the task at the point of apparatus failure. However, session number did predict the number of trials completed (β = 0.6991, $p < 0.01$), indicating that responding improved over time.

Champ. Champ learned to complete trials across 11 sessions, however he did not acquire the same/different discrimination. A simple linear regression of Champ's acquisition performance (accuracy x session) indicated that session did not predict accuracy (β = 1.7259, p = 0.0790), indicating that he was not acquiring the task at the point of apparatus failure. Additionally, session was not a predictor of trials completed (β = 0.1055, p = 0.6928) during acquisition, indicating that responding did not change significantly over time.

Diesel. Although Diesel learned to complete trials across nine sessions, he did not acquire the same/different discrimination. A simple linear regression of acquisition accuracy (accuracy x session) showed that session did not predict accuracy (β = 1.5170, p = 0.2169), indicating that

Diesel was not improving on the task at the point of apparatus failure. Additionally, session was not a predictor of trials completed ($\beta = 0.3336$, $p = 0.2605$) for trials completed during acquisition indicated that responding did not improve significantly over time.

In summary, Experiment 1 served to introduce the dogs to the same/different task and showed some potential for acquisition of the discrimination, as some dogs learned to respond appropriately. However, due to apparatus failure, the experiment was halted before any of the six dogs reached criterion. Additionally, two dogs, Hannibal and Haelo, were removed from the study due to insufficient responding. At the termination of Experiment 1, plans were made to begin Experiment 2 when the apparatus was repaired, and the experiment would be conducted with the four remaining dogs, Butterz, Wee-Zee, Champ, and Diesel.

Experiment 2: Second Acquisition with Novel Stimuli

The second acquisition phase began when the apparatus was repaired and deemed appropriate for running sessions. Again, the attempt was to demonstrate auditory same/different abstract-concept learning. Though Experiment 1 was halted, the design and rationale remained the same in Experiment 2. Novel stimuli were used to help eliminate residual effects of apparatus malfunction and any incorrect contingencies that may have been established during that time. At the start of Experiment 2, the dogs had been off the task for 3 months. It was hypothesized that the dogs would return quickly to their baseline training performance and subsequently approach acquisition criterion. Item-specific learning was expected for the four-item set, but as set sizes were doubled, it was hypothesized that item-specific learning would give way to abstract-concept learning and full transfer.

Method

Subjects. At the time the apparatus was deemed functional, Diesel and Champ had been removed from the study due to owner relocation. Butterz and Wee-Zee remained in the study and served as the subjects for Experiment 2.

Stimuli. Four novel stimuli were used for Experiment 2, detailed in Table 3. As in Experiment 1, the stimuli were selected from four sound categories: animal sounds, environment sounds, human sounds, and effects sounds.

Design. The same training methodology and design parameters that were used in Experiment 1 were used in Experiment 2, with the exception that the dogs did not require habituation or pretraining phases.

Results and Discussion

Experiment 2 was halted after one month due to concerns about task strategies. That is, it seemed that the two dogs were responding to the comparison sound based on their relative proximity to the left and right panels. Additionally, it seemed that the dogs frequently made accidental responses to the center panel upon comparison, driving their accuracy down without learning of the same/different discrimination. Center panel responses were made allowable by the software code and changes to disable these responses were not possible during the course of the experiment. In order to target discriminative choices and the potential side bias, center panel responses have been removed for the graphs and analyses in this experiment.

During this second acquisition phase, Butterz performed near chance (50% as defined by 2 response locations) for both first-attempt and correction trials, as shown in panels A and B of Figure 5. She responded to all trials but did not show discrimination between panels, though she did respond to the left panel more than the right panel, as shown in panel C. Consequently, Butterz's accuracy on same trials was higher than on different trials (panel D). Wee-Zee performed at same/different chance (50%) for both first-attempt and correction trials, although accuracy was more variable for correction trials, as shown in panels A and B of Figure 6. Panels C and D show that Wee-Zee's response behaviors were more balanced than Butterz', with similar frequencies and accuracies for left/right panels and same/different trials, respectively. Of note, Wee-Zee did not respond to all trials and often got distracted by outside noise. Additionally, she seemingly became frustrated by the task, as demonstrated by barking and pawing at the food bowls. Statistical analyses run for these two dogs support these descriptions.

Butterz. As in Experiment 1, session was not found to be a predictor of accuracy (β = -0.2641, p = 0.6449). Likewise, session was not found to be a predictor of trials completed (β = 0.1571, p = 0.3420). A Wilcoxon signed-ranks test for response panel location was significant (Z = -3.411, p < 0.01), indicating that Butterz responded to the left panel significantly more than the right panel and that she could have developed a side bias during training. Consequently, there was also a significant effect of trial type, $t(26) = 9.86$, $p < .01$, with higher accuracy for same trials (M = 74.402) than for different trials (M = 22.78).

Wee-Zee. As in Experiment 1, session was not found to be a predictor of accuracy (β = 0.3933, p = 0.4438). Likewise, session was not found to be a predictor of trials completed (β = -0.1786, p = 0.2037). A Wilcoxon signed-ranks test for response panel location was not significant (Z = -1.230, p = 0.2190), indicating that Wee-Zee did not respond to the left or right panel significantly more than the other. Similarly, there was no significant effect of trial type, $t(26) = 1.11$, p = 0.2752, with no significant difference between same trial and different trial accuracy.

Motivation and Strategies. In summary, although Butterz and Wee-Zee responded in the task they did not demonstrate same/different learning. Concerns were raised in Experiment 2 regarding their panel bias and motivation. That is, it seemed that the dogs' choice was based on their proximity to the left or right panel. Specifically, the dogs often positioned themselves slightly to the right or left of the center speaker in order to give a nose-poke response to the center panel upon sample presentation. Upon comparison presentation, the dogs appeared to respond to whichever panel was closer to their sample-response position. In conjunction with this concern, inconsistent acquisition performance increases were seen, emphasizing the possibility that the dogs were using strategies unrelated to the task. Further, the problem created by allowed center panel responses created a major flaw in the functionality of the same/different training task and likely worsened behavioral inconsistency by deviating from the discrimination. Therefore, Experiment 2 was terminated. As observations of the dogs' in-session behaviors suggested that a proximity bias was a likely cause of inconsistent performance plans were made to test the suspected proximity response strategy via panel spacing.

Experiment 3: Spatial Manipulation

Experiment 1 and Experiment 2 data were obtained with even spacing between panels. Observationally, choice behavior appeared to be mediated by spatial proximity of the dog to the left and right choice locations. Even though the dogs returned to the center of the apparatus at the beginning of each trial, they stood slightly to the left or right of the sample response location. To test whether the dogs' response choices were being governed by proximity to the left or right choice locations upon comparison, the two dogs completed a series of sessions in which the panels were spaced at varying distances and degrees of difference. It was hypothesized that panel location would determine responding. That is, it was expected that when one comparison panel was closer to the dog, the majority of responses would be made to that panel, regardless of correct response location dictated by sameness/differentness.

Method

Subjects. Butterz and Wee-Zee remained in the study and served as the subjects for Experiment 3.

Stimuli. The same four stimuli that were used in Experiment 2 were used for Experiment 3. These stimuli represented four sound categories: animal sounds, environment sounds, human sounds, and effects sounds.

Design. The same training methodology and design parameters that were used in Experiment 2 were used in Experiment 3, with one exception. The dogs did not require habituation or pretraining phases, and training sessions were continued like those in Experiment 2. However, the position of the three panels changed repeatedly during this experiment.

Panel Spacing. During Butterz' first spatial manipulation session, the left (same) panel was moved 12 inches to the left of its original position, creating a gap between the left panel and the center (sample) and right (different) panels, which were still connected. During the second spatial manipulation for Butterz, the left panel was moved an additional 12 inches to the left of its original position (24 inches), creating a large gap between the left panel and center and right panels. During the third session, the left panel was returned to its original position and the right panel was moved 12 inches to the right of its original position, creating a gap between the right panel and the left and center panels, which were connected. Finally, three sessions were completed during which the left and right panels were moved 12 inches to the left and right of the center panel, respectively. This created an even gap between each panel.

During Wee-Zee's first spatial manipulation session, the left (different) panel was moved 12 inches to the left of its original position, creating a gap between the left panel and the center (sample) and right (same) panels, which were still connected. During the second session, the right panel was moved 12 inches to the right of its original position, creating a gap between the right panel and the left and center panels, which were connected. Finally, three sessions were completed during which the left and right panels were moved 12 inches to the left and right of the center panel, respectively. This created an even gap between each panel.

Results and Discussion

Butterz. Spatial manipulation results for Butterz are shown in Figure 7. Panels A and B show that she responded to most, if not all, trials and corrections in each session and her accuracy remained below criterion. As seen in panel C, an apparent bias to the left panel is muted in the first session but is eliminated in the second session where it becomes apparent that spacing is controlling responding. This bias seems to return during the fourth, fifth, and sixth sessions, during which the left panel is closer to the sample panel (third session) and in the same proximity of the sample panel as the right panel (fourth, fifth, and sixth sessions). Consequently, panel D of Figure 7 shows changes in same/different accuracy that follow the panel spacing manipulations. Tabulations of Butterz' left and right panel responses for the last 3 sessions of Experiment 2 and each of the spatial manipulations can be seen in Table 4. The percentages of responses made to the left and right panels under each condition followed responding to the closer panel and further confirm the hypothesis that responding was controlled by panel proximity.

Wee-Zee. Spatial manipulation results for Wee-Zee are shown in Figure 8. Panels A and B show that she responded to many, and in one case all, trials and corrections in each session and her accuracy remained below criterion. As seen in panel C, Wee-Zee's performance was very clearly controlled by panel spacing. During the first session, with the left panel moved away, no left panel responses were made while all right panel responses were made. This response behavior switched when the right panel was placed at a distance, and all left panel responses were made with no right panel responses. Wee-Zee's responding was less skewed for the third, fourth, and fifth sessions, during which the left panel was place in the same proximity of the sample panel as the right panel. Following these response patterns, panel D of Figure 8 shows changes in same/different accuracy that follow the panel spacing manipulations. Tabulations of Wee-Zee's responses for the last 3 sessions of Experiment 2 and each of the spatial manipulations are shown in Table 5. The percentages of responses made to the left and right panels under each condition follow the closer panel and confirm the hypothesis that responding was controlled by panel proximity.

Video Coding. The results of the spatial manipulation experiment suggest that Butterz and Wee-Zee had learned to respond to whichever sound was closer, or louder, to them. To confirm this, video was recorded of each dog completing a session under the equal spacing setup, with each panel spaced 12 inches apart. The footage showed that the dogs would often position themselves to either the left or right of the center panel speaker during sample presentation and response, and would subsequently move toward the comparison speaker that was closest to them during comparison. Therefore, video was coded by tallying the number of responses made to the panel closest to the dog at the time of comparison presentation. As shown in Table 6, the video scoring revealed a vast majority of responses to the closer panel, confirming the idea that location controlled responding.

In summary, Experiment 3 served as a follow-up to Experiments 1 and 2 in order to test the hypothesis that responding was controlled by panel proximity. A spacing manipulation was used that placed the response panels at varying distances from the center sample panel. As expected, responses were consistently made to the panel that was located closer to the dog upon comparison presentation. Therefore, it was concluded that relative proximity to each response panel controlled responding in the same/different task.

General Discussion

The present study sought to demonstrate abstract-concept learning in domestic dogs via an auditory same/different task. In Experiment 1, the apparatus and same/different task were introduced. Six dogs were trained on the task, and two were removed due to lack of responding. Experiment 1 and task acquisition continued until an apparatus failure prevented the continuation of training sessions and the experiment was halted until repairs were made. Experiment 2 began when apparatus repairs were completed and sessions could be resumed. Training was conducted with the same parameters as Experiment 1, with the exception that four novel sounds were used as the stimulus set. Experiment 2 continued until inappropriate response behaviors and strategies became apparent. Center panel responding and a suspected panel proximity strategy led to the termination of Experiment 2. Experiment 3 introduced a panel spacing manipulation under which proximity strategy could be tested. It was found the comparison responding was indeed controlled by a dog's relative proximity to the response panels. At the conclusion of Experiment 3, the study was halted and plans were made for a future study to eliminate the problems raised in Experiments 1, 2, and 3.

Though anticipated results were not observed, the present research provides insights as to why that was the case. Future directions to improve performance are discussed below. Overall, a new apparatus, experimental design, and behavioral training methodology were developed and hold the promise for experimental success.

Problems and Solutions

As detailed in Experiments 1, 2, and 3, several problems arose over time with the experimental setup. The apparatus and software coding malfunctioned frequently and also failed to target the specific parameters of the experiment in full. These problems were exacerbated by a training location that lacked resources and flexibility to make changes and corrections to the apparatus and code. Therefore, the following problems will be addressed and corrected in a future experiment.

Training Location. The space used in the present study (shed at Auburn Veterinary Hospital) was cramped, noisy, inflexible, and lacking internet and sufficient power connections. Due to this, software and apparatus updates were made nearly impossible. After training with Butterz and Wee-Zee was terminated, the apparatus was disassembled and moved to a detached garage, where a more suitable laboratory space will be developed. At the new location, a larger training space will be used and will be organized to allow for a variety of apparatus configurations. Sound proofing will be used to eliminate outside noise and encourage attention to the relevant task sounds. Finally, an internet connection will be set up to allow real-time software changes and transmission of data.

Apparatus. During the three experiments, several concerns were raised regarding the design and functionality of the apparatus. Concerns included the efficiency and accessibility of the food reward system, as well as the functionality of the software coding.

Reward Dispensers. The reward dispensers were unable to support more than one trial's food reward allotment at a time, prevent the training sessions from being fully automated. The reward dispensers will be replaced with metal, rather than plastic, moving parts in order to support the weight of a full training session's allotment of food reward.

Reward Tubing, Food Bowls, and Access Point. The apparatus delivered food through a rigid vacuum hosing and into the back of a food bowl located behind the panel, through which the food flowed underneath the panel to the front portion of the bowl. Because the hosing forced the food straight down and the bowl was not elevated at an angle, some of the food reward was often left behind the access point. This led the dogs to try to reach their snouts through the opening in the panel to the back of the bowl, and presented a distraction as well as a possibility for skin irritation. To remedy this problem, flexible hosing will be used to move the food reward from the dispenser to the food bowl. This hosing will stop several inches above the access point and will drop food into an angled chute connected to the food bowl. This will ensure that no food is left behind the panel and that the dog is able to access it immediately and easily.

Software Coding. The software as designed did not adequately fit the flexibility and task needs of individual dogs. For example, Butterz demonstrated a tendency to respond to the center panel on comparison. The software did not allow center panel responses to be disabled for comparison. Other coding issues arose in terms of saving results, streamlining training sessions and stimuli, and within-session parameter flexibility. Thus, the software will be revised, if not replaced completely, with a focus on these parameters before another experiment is conducted. Additionally, the new location will ensure that updates can be made fluidly, efficiently, and in real time, as needed when new training demands are presented.

Implications

The present study provides a step toward additional knowledge and methodology for abstract-concept learning within the comparative cognition field. There has long been a perceived gap between humans and non-human animals in regard to higher-order learning. By furthering research investigating non-human animal abilities to engage in higher-order learning through the use of abstract concepts, this gap may be further filled with evidence for animal cognitive abilities.

Continued research from this project has the potential to benefit the present body of research with dogs. This area is rich with studies targeting topics such as social intelligence and general concept learning within the visual modality, but fewer studies have been done using the auditory modality and abstract concepts. This research offers a chance to enrich what we as researchers understand about dog cognition and also allows for a new avenue of investigation into the abilities of the dog mind. Additionally, this research provides a new apparatus design that is uniquely appropriate for training and testing with domestic dogs. As the research with this species continues to grow, such a design could serve as an aid in future experimental design as well as provide a common ground on which comparisons can be made.

Conclusions

In closing, the present study utilized past abstract-concept learning methodology and findings to design an apparatus and experimentation suitable for dogs. The data obtained during this experiment will guide future examination of dog cognition via auditory abstract-concept learning. Additionally, apparatus refinements will ensure functional data acquisition.

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Appendix A

Table 1

Subject information as provided by owners.

Subject	Butterz	Champ	Diesel	Haelo	Hannibal	Wee-Zee
Age	2 years	2 years	1 year	2 years	3 years	1 year
Sex	Female	Male	Male	Female	Male	Female
Breed	Labrador Retriever	Labrador Retriever	Pitbull Mix	Cane Corso	Rottweiler	Standard Poodle
Color	Yellow	Black	Brindle/White	Brindle	Black/Tan	Black
Fixed	No	No	No	No	No	No
Weight	55 lbs		49 lbs	105 lbs	106 lbs	35 lbs
Height (at shoulders)	21"	24"		27"	27"	22"
Daily Activities	Backyard play with other dogs	Daycare	Daycare, Playtime with sibling	Short runs in yard	Daycare ~2x/wk	Daycare, Outside play, Some retrieving
Training	Sit, Down, Stay, Fetch	Basic Commands	Sit, Shake (both paws), Lay	Basic Commands	Commands in English & Thai	Sit & Stay, Retrieving, Pick up objects
Daily Feeding	Iams 7:00 A/P		Pedigree Dry Sensitive 8:30A, 6:30P	3 cups A/P	2.5 cups A/P	Iams 7:00A/P
Favorite Treats	Any, No greens/fruit		Any, Pup-peroni, Hills Prescription Hypoallergenic	Beggin' Strips, T-Bonez, Milk Bones, Chewy treats	Any dog treat	Any, No greens/fruit
Past Injuries / Sensitive Areas	Right knee, Sits with leg out	None	None	None	Gimpy gait, not painful	None
Medications	None	None	None	None	None	None
Allergies	None	None	Grain/Food	None	None	None
Fear/ Aggression Inducers	Large objects approaching	Can be shy	None	Can be shy with newcomers	Can be shy but warms up	Barks at threatening dogs
Destructive behaviors when alone	None	None	None	None	None	Tear up toys, get in garbage/litter
Frightened by Noise?	Will jump at sudden noise with movement	No	Sometimes if loud	No	No	No

Figure 1. The apparatus design featured three separate panels. Each panel held a speaker, a response sensor overlaying the speaker, and a reinforcement dispenser. The dog began and ended each trial at a central location between the panels. A divider separated the dog and experimenter.

Table 2

The stimuli used in Experiment 1: Initial Acquisition.

Category	Stimulus
Animal Sounds	Birds chirping
Environment Sounds	Bell Tower
Human Sounds	Crowd Cheering
Sound Effects	Boing

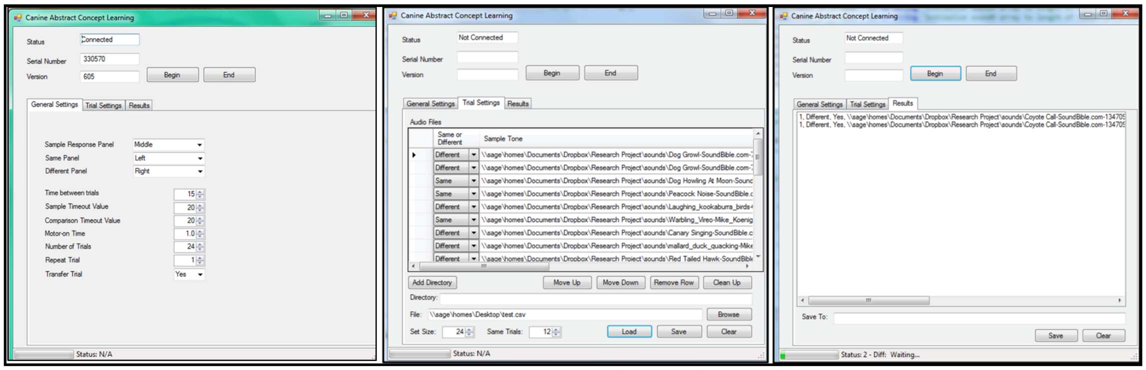


Figure 2. The software was designed to allow for unique sessions with customizable parameters. Session parameters such as panel selection, intertrial intervals, timeout times, sample and comparison times, number of trials, and number of correction trials could be modified on the main 'Session Settings' screen. Individual session information was available under 'Trial Settings', where previously created sessions could be loaded and trial types and order could be modified. Completed trial information was available on the 'Results' screen, from which point it could be saved as .csv files for later analysis.

Table 3

The stimuli used during Experiment 2: Second Acquisition.

Category	Stimulus
Animal Sounds	Seagulls
Environment Sounds	Papers Shuffling
Human Sounds	Crowd Cheering
Sound Effects	Womp-womp-womp

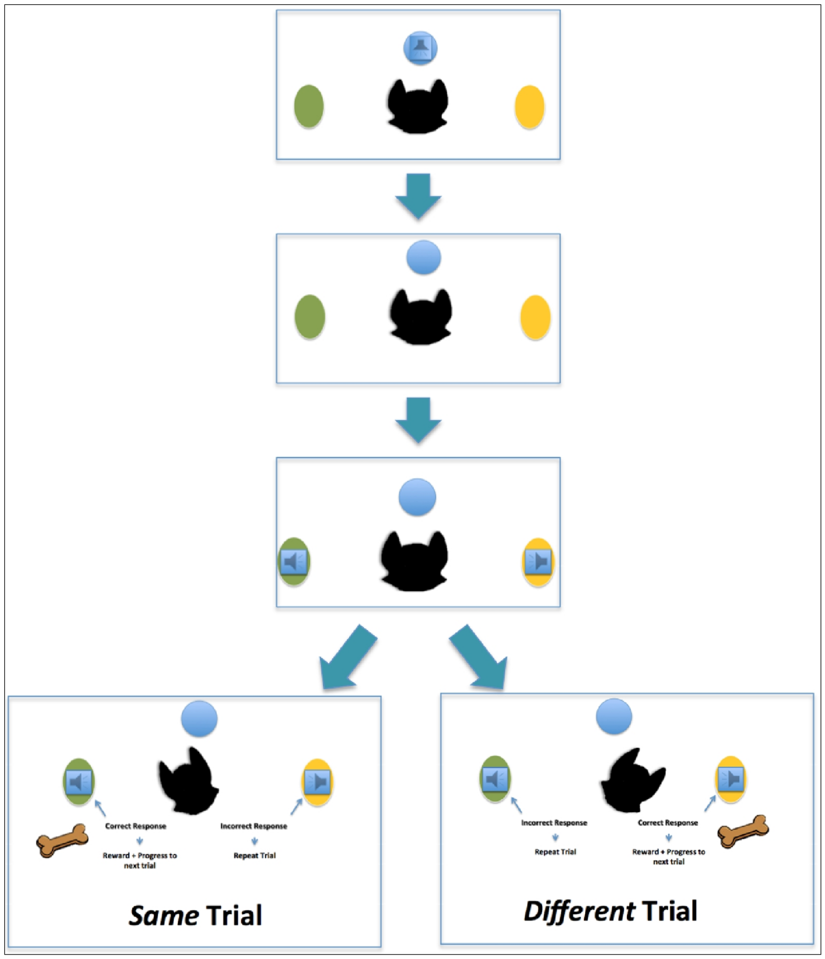


Figure 3. The procedure for a single training trial. For a “same” trial, a nose-poke response to the left speaker were recorded as correct, whereas a nose-poke response to the right speaker was recorded as correct for a “different” trial. This contingency was counterbalanced across subjects.

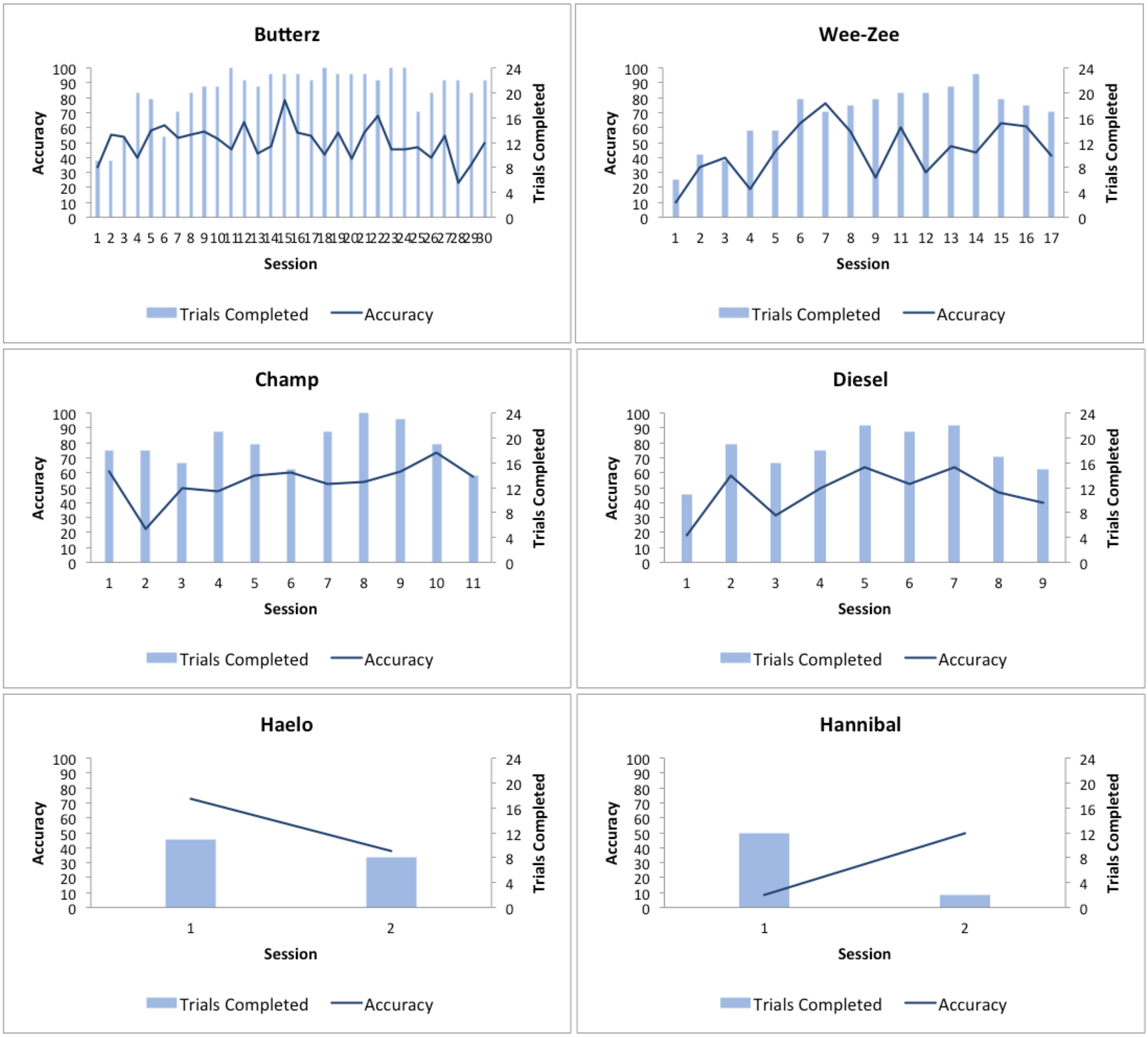


Figure 4. Individual initial acquisition data for each dog. Trial accuracy (line) is plotted alongside the number of trials completed (bars) per session.

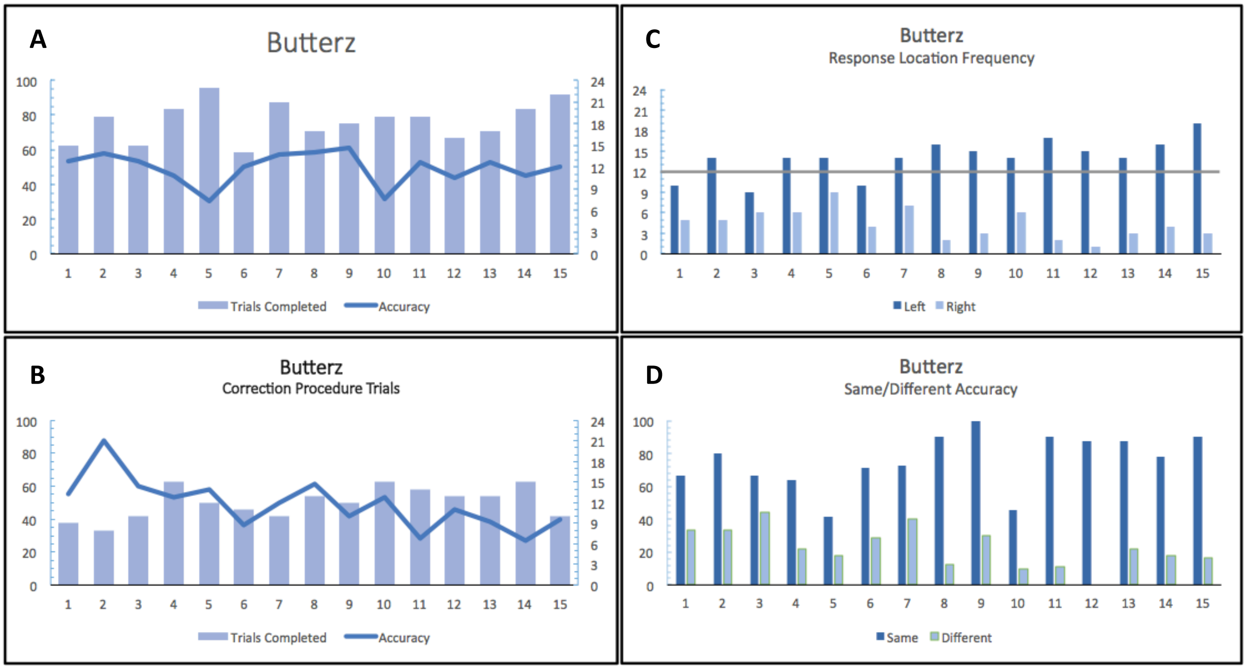


Figure 5. Butterz' second acquisition performance. Panel A shows overall accuracy (line) and number of trials completed (bars). Panel B shows accuracy and completion of correction trials. Panel C shows the number of responses made to the left and right panels. Panel D shows accuracy on same and different trials.

Figure 6. Wee-Zee's second acquisition performance. Panel A shows overall accuracy (line) and number of trials completed (bars). Panel B shows accuracy and completion of correction trials. Panel C shows the number of responses made to the left and right panels. Panel D shows accuracy on same and different trials.

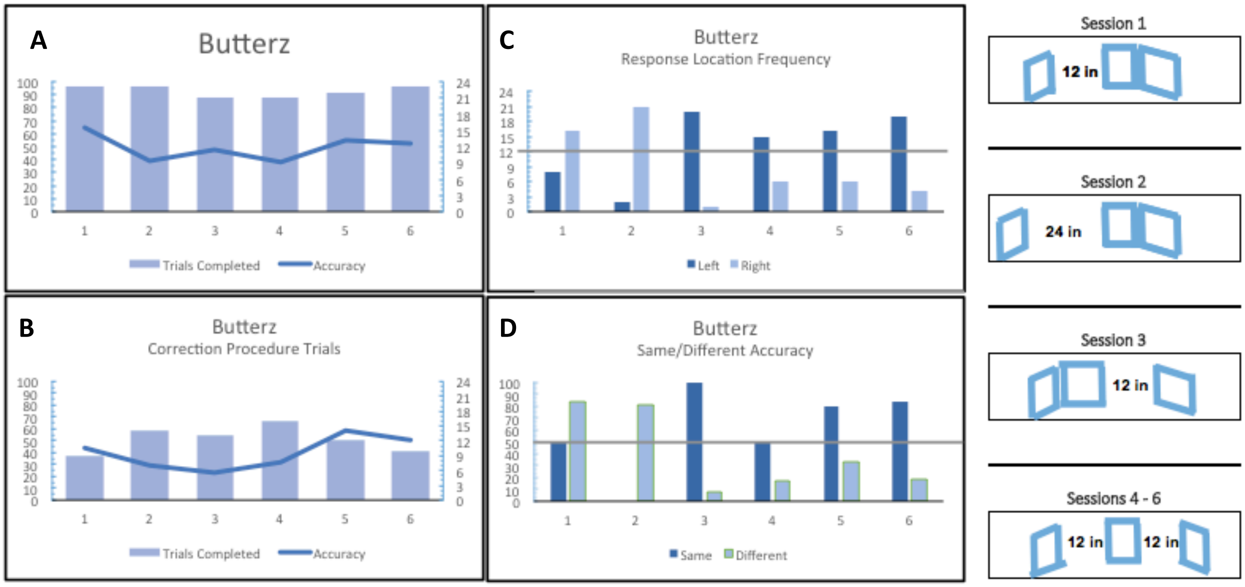


Figure 7. Butterz' performance on six spatial manipulation sessions. Panel A shows overall accuracy (line) and number of trials completed (bars). Panel B shows accuracy and completion of correction trials. Panel C shows the number of responses made to the left and right panels. Panel D shows accuracy on same and different trials.

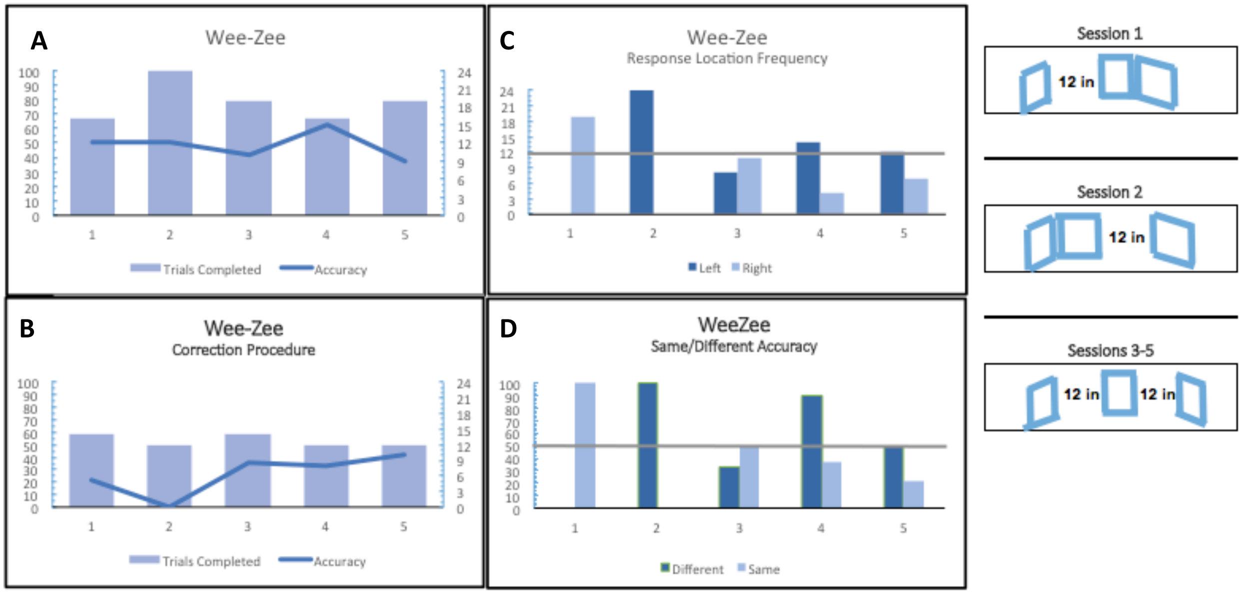


Figure 8. Wee-Zee's performance on five spatial manipulation sessions. Panel A shows overall accuracy (line) and number of trials completed (bars). Panel B shows accuracy and completion of correction trials. Panel C shows the number of responses made to the left and right panels. Panel D shows accuracy on same and different trials.

Table 4

Tabulation of Butterz' Responses for Spatial Manipulation. Left, right, and total responses are displayed, along with the percentage of each response type per session. The spatial manipulation used in each session is included to the right.

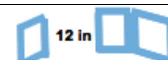
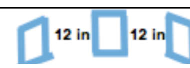
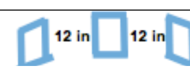
Session	Left Responses	Right Responses	Total Responses	Spacing
13 (Experiment 2)	14 82.35%	3 17.65%	17 100.00%	
14 (Experiment 2)	16 80.00%	4 20.00%	20 100.00%	
15 (Experiment 2)	19 86.36%	3 13.64%	22 100.00%	
1	8 33.33%	16 66.67%	24 100.00%	
2	2 8.70%	21 91.30%	23 100.00%	
3	20 95.24%	1 4.76%	21 100.00%	
4	15 71.43%	6 28.57%	21 100.00%	
5	16 72.73%	6 27.27%	22 100.00%	
6	19 82.61%	4 17.39%	23 100.00%	

Table 5

Tabulation of Wee-Zee's Responses for Spatial Manipulation. Left, right, and total responses are displayed, along with the percentage of each response type per session. The spatial manipulation used in each session is included to the right.

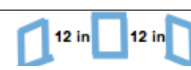
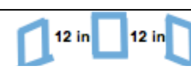
Session	Left Responses	Right Responses	Total Responses	Spacing
13 (Experiment 2)	11 57.90%	8 42.10%	19 100.00%	
14 (Experiment 2)	8 57.14%	6 42.86%	14 100.00%	
15 (Experiment 2)	14 63.64%	8 36.36%	22 100.00%	
1	0 0.00%	19 100.00%	19 100.00%	
2	24 100.00%	0 0.00%	24 100.00%	
3	8 42.11%	11 57.89%	19 100.00%	
4	14 77.78%	4 22.22%	18 100.00%	
5	12 63.16%	7 36.84%	19 100.00%	

Table 6

Video coding for Experiment 3. Responses were tallied for completed trials (including correction trials) according to whether the dog responded to the closest panel upon comparison presentation

Dog	Responses to Closer Panel	Responses to Farther Panel
Butterz	30	2
Wee-Zee	23	1