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An Analysis of Canine Processing of Stimulus Compounds Varying in Light and Sound Intensity

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Varying in Light and Sound Intensity

by

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Abstract

Although the study of canine cognition is in vogue, at present there is little known about how domestic dogs (*canis familiaris*) categorize information. A touch-screen testing system was used to which a dog was trained to respond differentially to two light-sound compounds – a bright light/soft sound and a dim light/loud sound. Reinforcement was contingent upon touch at a different screen location for each compound. In order to examine how the elements of such light-sound compounds are processed the dog was tested with combinations of additional light and sound intensities. It was found that the dog used the information provided by both stimulus dimensions in a manner that maximized the probability of a correct choice. This research is relevant to the understanding of information processing, specifically attention, categorization and generalization.

An Analysis of Canine Processing of Stimulus Compounds Varying in Light and Sound Intensity

Every living being is a product of its environment. Sensations are the perception or awareness of stimuli through the senses. Perception is the organization and interpretation of sensory information that make it possible to understand the environment. It involves both the recognition of environmental stimuli and the actions in response to such stimuli. Through these psychological processes information is acquired about the aspects of our environment that are critical to survival. However, the way that the environment is perceived varies greatly depending on the types of stimuli that are sensed as well as the person or other living creature who experiences the stimuli.

The sensory information provided to animals is always changing because the environment itself is always changing. It is interesting to see how living creatures may interpret (perceive) ever-changing sensations and how they may use this information to survive, reproduce and evolve. Many scientists believe that a parallel exists between the external (physical) world and internal (sensations) world of all living organisms. Gustav Fechner (1860) was instrumental in developing methods to study the connection between the physical and phenomenal worlds. One of these methods, the “method of single stimuli” (Woodworth & Schlosberg, 1954) has proven to be ideal in training non-human animals in identifying and categorizing simple and complex stimuli (Chase, 1997); Heinemann, Avin, Sullivan & Chase, 1969; Chase & Heinemann, 1972). Important information about the environment often takes the form of a compound, for example, an approaching barking dog is both seen and heard. In this study, compound stimuli were used in an experiment in order to learn how such information is processed. Information from compound stimuli may provide additional information, which the organism can use to make useful decisions about its environment. The information obtained from the compound stimuli may be used in such a way so as to maximize the probability of making a correct choice in an imperfect world.

Understanding dog perception is of particular importance since it gives us insight into what in the environment the dog is sensitive to. According to Miklosi (2007), perception "involves regular sampling of the environment for significant stimuli (scanning), and is affected by mental representations, which focus the process of information gathering (attention and filtering), which also guide the process of recognition" (p. 138). If we can understand how animals combine information from multiple sensory modalities, we can better understand how such stimuli affect their behavior. Such information may also be relevant to pre-verbal and non-verbal children. Much of behavior is non-verbal. In short, by studying these processes in animals that do not have language, we can better understand the process, which is important to understand sensory information processing.

Dog conditioning

In order to understand how a dog perceives its world, one must develop a means of communication. One way of accomplishing this is through techniques used by dog trainers. Training a dog to do a specific task can be difficult and complex. There is a wide range of training methods used to train dogs. A brief review of the most frequently used training techniques follows with an emphasis on those techniques used in the current study. The focus on the shaping by the method of successive approximation as developed by B.F. Skinner (Skinner, 1958).

Generally dogs are trained using a mixture of classical and operant conditioning techniques (Blackwell, Bolster, Richards, Loftus, & Casey, 2012). It is vitally important to motivate the dog to want to do the task. Usually in laboratory settings this is done through a variety of methods including deprivation, the use of aversive stimuli (such as removal of a painful stimulus such as an electrical shock), or through providing a high value reward (Peterson, 2004). The use of aversive stimuli can cause unintended consequences such as anxiety or depression in the animal and therefore is the least desirable type of stimulus when working with animals (Pryor & Ramirez, 2014). In family pets this could not only negatively affect the study but it could also alter the handler's relationship with his dog and/or cause lasting behavioral problems. Using minimal deprivation (such as training right before a regularly scheduled meal) or a provision of a high-value reward should be the first choice of modality to motivate a dog in an experimental setting (Pryor & Ramirez, 2014).

Another factor that should be considered is the past training and current knowledge of the dog. The dog will learn more quickly if he has previous knowledge of the task that can be built upon to reach the final behavioral task. In the current study, the subject already had prior knowledge of several obedience commands that led to touching a tablet computer. These already established skills were chained together with new skills in order to shape the dog's behavior into performing the experimental task.

One of the most important tasks when training new behaviors is to establish a temporal contingency between the cued task and the reinforcer. Miklosi (2007) explains that "in order to reveal a behavioural change dogs are often put through a learning procedure which is aimed at building an association between the (presumed) perception of an event and a change in behaviour (p. 138)". This learning procedure moves more quickly when the new task is seen by the dog as an extension of a previously learned task.

There are species-specific limitations that must be considered when training any animal. These differences have an evolutionary basis and different species react to stimuli in a way that is based on behavioral adaptations to the environment. It is now known that dogs are especially adept at attending to human social cues. They tend to choose to respond to human cues, such as pointing to a container with food, over any olfactory, visual or auditory cues. (Stafford, 2006). Cunningham & Ramos (2014) explain that "social signaling is cognitively complex as it requires an understanding of meaning by both signaler and receiver for it to be a useful method of communication". Following human social cues appears to be beneficial to dogs in that it is a means to exploit others' knowledge of environmental resources. Much work has been done studying the behavior of dogs as it relates to human behavior (Blackwell, Bolster, Richards, Loftus, & Casey, 2012). Yet still relatively little has been studied about dog behavior outside of social learning and human cueing.

Dog training

Experts believe that the domestication of dogs probably started about 10,000 years ago (Pryor & Ramirez, 2014). Operant conditioning is the principle upon which most modern animal training is built. However, in order to successfully train any animal, we must pay specific attention to the contiguity of the stimulus, response and reward. A dog will associate the target behavior, the behavior that is being trained, with the cue and the reward if they are followed in quick succession. However, if the reward is given too long after the target behavior has happened, it no longer works to reinforce the desired behavior (Pryor & Ramirez, 2014).

Timing is of the utmost importance and can be challenging for even the most skilled trainer. Therefore, a secondary reinforcer may be used as a bridging stimulus to shorten the amount of time between the cue given and the reward (Pryor & Ramirez, 2014). Any discrete stimulus can be used as a bridging stimulus, but most often a trainer will use a clicker, bell, whistle, tone, light, word or hand gesture. In order to "charge" a bridging stimulus, such as a click, with positive value, one must first establish a close association between it and the reward (Pryor & Ramirez, 2014). The click and food reward should happen in rapid succession. This should be repeated a number of times so that the association becomes established in the dog's mind. After this, the click will signify the coming reward. This will establish a secondary reward, as opposed to a primary reward such as food (Coren, 2004). The secondary reward, such as the click, can then work as a "marker" for the desired behavior (Pryor, Hagg, & O'Reilly, 1969). When the desired behavior is seen by the trainer, he or she will mark the behavior with a click and the dog will know that the food reward will soon arrive. Finally, the trainer can add a cue to the training session. The cue is the signal (most often a verbal command or hand gesture) that indicates which action the trainer would like the dog to perform (Pryor & Ramirez, 2014). Initially, the reward should be provided every time the bridging stimulus happens. However, because of operant conditioning, the bridging stimulus itself will soon become rewarding and the actual food reward can then be given more intermittently (Pryor & Ramirez, 2014). The reward should never be completely phased out but can be significantly reduced or changed to a different type of reward (verbal praise or a game of "tug" may be equally rewarding to a dog and may replace a food reward).

Many experiments require an animal to participate in a complex series of actions. For example, B.F. Skinner was able to teach a feral pigeon to bowl by breaking down the desired behavior into a series of steps (Peterson, 2004). Complex behaviors such as these can be most easily taught by using a technique known as successive approximation (also known as shaping) (Pryor, Haag, & O'Reilly, 1969). Historically, trainers altered the environment in increments to alter a behavior. Shaping usually starts with deciding on an end goal. This is the final target behavior that the trainer wants the animal to perform. The goal should be broken down into smaller steps, increments that are more easily achievable for the animal. In order to start working towards that goal, the trainer initially focuses on capturing an existing, already occurring, behavior. The behavior is marked at the moment that it occurs. Pryor and Ramirez (2014) explain that "since behavior is always variable, one can then being selectively marking variations in a desired direction towards the end goal". The end goal should be broken down into smaller steps that are more easily achievable for the animal. When the first movement towards the goal is operant, then the criteria can be shifted slightly, another step towards the final goal (Pryor & Ramirez, 2014). Each step is marked, rewarded and repeated until the animal is consistently performing that behavior. Then the criteria can be changed again and the trainer can start rewarding the next step towards the goal. The trainer will no longer need to reinforce the previous steps because animal will have understood that it was simply an indication towards the next step. There should be a high rate of reinforcement for each step, to ensure complete compliance with that step. By slowly shaping the behavior, the trainer will ensure that the goal is reached and the final shaped behavior is reinforcing in itself (Pryor & Ramirez, 2014). This can be ensured by providing a high rate of reinforcement throughout the shaping procedure.

Canid audition and vision

Hearing is quite variable and the ability of animals to hear high frequency sounds differs greatly from species to species and can potentially vary over three octaves (Heffner, 1983). According to Mikloski (2007), “The most critical feature of hearing is the frequency range that can be sensed by the auditory neurons” (p.143). Data comparing the auditory abilities of dogs and humans indicates that dog have significantly superior hearing abilities with higher frequency sounds, while dogs and humans hear similarly well at the lower range of frequencies (Lipman & Grassi, 1942). In addition, Lipman and Grassi (1942) found that “the frequency locus of maximal sensitivity is somewhat higher in the dog” than in a man. Heffner (1998) also found that “the comparison of dog and human audiograms show similarity at the lower range but dogs hear well above the frequency range of humans (dogs 67 Hz to 45,000 Hz; humans 64 Hz to 23,000 Hz”), although other researchers found that humans may have superior hearing at a lower frequency with a range of 20 Hz to 20,000 Hz (Rossing, 2007).

Since all animals use multiple sensory modalities (such as hearing and seeing) simultaneously, it is imperative that they combine sensory information from various sources in order to make appropriate behavioral decisions (Rowe, 2005). Since some of their perceptual abilities are superior to those of humans (such as hearing or smelling in canids), it is possible that non-human animals are more adept at discriminating and categorizing information when presented with information from multiple modalities. It is unknown exactly how vision and hearing are linked, but the more information that is presented to an animal the better it may be able to make an educated decision (Rowe, 2005). Therefore, it may be possible to improve the learning process when multiple modalities are combined. Miller & Murphy (1995) explain that "the canine visual system has adapted to exploit a particular ecological niche by enhancing visual performance under low light conditions but still retaining good function under a wide array of lighting conditions, including daylight" (p.1623). Therefore, canid vision is highly adapted for both nocturnal and diurnal conditions and dogs are much more adept than humans at detecting lower levels of illumination (a wide range of photic conditions), which could greatly benefit them when hunting (Heffner, 1998; Pretterer, Bubna-Littitz, Windischbauer, Gabler & Griebel, 2004).

In both humans and dogs, the rods are the receptor cells in the eye that allow for monochromatic vision in the dark. In a dog's eye, the rods represent approximately 97% of the receptor cells, which allow for an acute ability to see in a very dim light (Pretterer, et al., 2004), while humans have 95% receptor cells that are rods. The tapetum lucidum is a reflective layer behind the retina in the eye which increases the amount of light needed for night vision. Improved canid night vision could be due to a superiorly located reflective tapetum lucidum, which would enhance the contrast between dark objects (Miller & Murphy, 1995). The superiorly located tapetum lucidum is what makes canid night vision more sensitive than that of humans, despite canids and humans having the same rod pigment with the dog's maximum peak sensitivity of the rods at about 506-520n (Miklosi, 2007). In 2004, Pretterer et al., tested the brightness discrimination abilities of dogs by presenting them with a simultaneous choice situation with two grey targets of varying brightness" (p.243). They found that dogs could discriminate more easily between differences in the dark range of the grey scale than in the lighter range.

Therefore, dog's eyes function very well at low light levels since the minimum threshold of light for dogs is much lower than that in humans. There is still very little known about brightness discrimination is dogs and how it relates to their lifestyle. The flicker rate in dogs is approximately 70 Hz, which is higher than the 50-60 Hz in humans (Miller & Murphy, 1995). It is only recently, with the advent of 1080p, HD and plasma TVs that the use of a TV or computer screen when testing a dog became possible. In the past, using computer screens was not optimal since a heightened sensitivity to flicker meant that an on-screen image cohesive to a human may have appeared as a rapid flicker to a dog.

Discrimination Learning

Fantino and Logan (1979) explain that "if a response that has been conditioned in the presence of certain stimuli is emitted also when new stimuli are presented, we say that stimulus generalization has occurred (the response has generalized to the new stimuli). If the response is not emitted, discrimination has occurred (the new stimuli have been discriminated from the old ones)" (p.119). When a number of dimensions are involved, the subject may attend to one dimension more than another. Experiments that involve compound stimuli may have one dimension of the compound complex that emerges as more salient and, therefore, acquires more control than the other dimension.

In an experiment conducted by Haney and Crowder (1977), the attention and discriminative abilities of dogs were tested. Using water as a reinforcer, they used multimodal stimuli (a tone and light) to determine which component was more salient. They found that the visual component, in a test involving multimodal compound stimuli, acquired more discriminative control than the auditory stimuli, although the auditory stimuli did exert a minimal amount of control. It is possible that when a test is run where multiple stimuli affect the same sensory modality, one may appear to overshadow the other. Pavlov (1927) described overshadowing as a situation in which "the weaker element when presented alone failed to elicit a conditioned response (CR) after a series of trials that would have been sufficient to establish a CR had the weaker element been presented alone during training" (p.161).

Therefore, Haney & Crowder (1977) had the stimulus tones located in two different locations, to aid the dog in differentiating between them. Despite this alteration, they still determined that visual stimuli exerted the majority of the control in the experiment, although the auditory stimuli did exert some control over responding. This was apparent when the dogs selected the auditory stimuli for the discriminative response, rather than the visual stimuli. Haney and Crowder (1977) stated that "if the data indicate equal control by each stimulus component, as denoting *shared* attention, and to the extremes of the continuum (exclusive control by either stimulus component) as more appropriately labeled as *selective* attention."

Categorization

Range, Aust, Steurer and Huber (2008) examined the visual categorization abilities of dogs using a touchscreen testing procedure. The subjects were trained to discriminate between pictures of dogs and pictures of landscapes. The subjects then were tested on their ability to transfer the information to novel pictures. The dogs were then presented with images that combined both the dog pictures with the landscapes, in order to determine which item would be more salient to the subjects. When the contradictory information was provided to the dogs, the dogs utilized a perceptual response rule (based on their immediate sensory experience) in order to classify the nature photographs (Range et al., 2008). This would indicate that the dogs were abstracting the provided information to categorize the features of what would determine a "dog", rather than use a prototype of a background to fixate on that item alone. Range et al. (2008) were not surprised by the abstraction ability of dogs because it has already been established that animals have been known to use varied and often unexpected cues to help them make their decisions.

Since there are still limited studies on dog categorization, Range et al. (2008) discussed the categorization abilities of other species. They suggest that the difference between human and pigeon categorization may not be a difference in ability level but that the pigeons' responses may be based on definitions that humans rarely used but that were biologically appropriate for the pigeons (Range et al., 2008). This would suggest that the problem is with the definition of the word "abstraction" and that some experimenters should not be limiting other species to their own species-specific defined categories. If one species abstracts information in a specific way, it does not indicate the lack of ability to abstract information at all. Different species may utilize different strategies to interpret information, and it is a huge leap to determine the lack of abstraction when using human-only defined categories. Range et al. (2008) found that although dogs did classify the stimuli in accordance with the experimenter's expectations, they believed that it was also possible that the dogs utilized another, parallel, rule that was unknown to the experimenter. Ashby and Maddox (2005) state that "when interpreting a category-learning result, it is critical to consider carefully the specific task that was used" (p.172) because different tasks would require different categorization strategies; strategies that may vary from species to species. Finally, the literature shows that that humans use multiple memory systems in category learning (Ashby & Maddox, 2005), which leaves open the possibility that non-human animals may use multiple memory systems but ones that differ from those of humans. This may mean that humans have developed a different way of categorizing information that may not be inferior to that of pigeons or dogs, but that may just be significantly different. Dogs are particularly social animals and depend on humans for many social cues to direct them throughout the day (Schmidjell, Range, Huber, & Viranyi, 2012). It is important to study the categorization abilities of dogs in the absence of human cues so that we may understand their actual mental processes, outside of human influence.

Autier-Derian, Deputte, Chalvet-Monfrey, Coulon, and Mounier (2013) studied the categorization abilities of dogs in regards to whether they were able to discriminate between images of dogs vs. other species. The experiment involved exposure to 3,000 images of cross-bred and purebred dogs, which illustrated the variability in dog appearance, including head shape, hair length and pinnae shape. The photographic stimuli included dog images with their heads in different positions, directly in front, profile and ¾ views. The images of dogs greatly varied, since images of several different breeds were used. In addition, 3,000 images of non-dog animal species, including humans, were used as a contrast to the dogs. The subjects were trained to a S+ generalization task for dog images and then a reversal reward contingency task for non-dog species. Using a "simultaneous discrimination paradigm", the dogs were then tested on their ability to differentiate between the images of dogs and images of other species (Autier-Derian et al., 2013, p.639). The results of this study were quite conclusive that dogs were very skilled at discriminating between images of dogs, regardless of breed or head position against images of other species. The experimenters suggest that "there may be some variation in dog morphotypes that allow the nine subjects to group pictures of very different dogs into a single category despite the great diversity in canid species" (Autier-Derian et al, 2013, p.647). It is likely that these dogs based their categorization of dog faces on perceptual cues with the help of certain factors which would create "interest in certain categories of stimuli which carry more informative value" (Autier-Derian et al, 2013). The experimenters concluded that the dogs had most likely created a rule to help them categorize dog faces, while other species faces were identified without being categorized (Autier-Derian et al, 2013). This definition of one rule for dog images and the exclusion of other images without forming a definite rule could possibly be an example of open class categorization. Finally, Autier-Derian et al (2013) believe that this open-class categorization may actually demonstrate higher level processing, and may indicate abstract or conceptual categorization.

Range, Aust, and Steurer (2008) investigated how dogs categorize visual stimuli by training dogs to categorize photographs as containing, or not containing dogs. They also presented dogs with novel images in order to determine if they could transfer the learned information and identify novel dogs (or the absence of dogs) in novel images. First they presented the dogs with a forced two choice procedure followed by a generalization test. They wanted to see if the dogs would classify the stimuli based on strict rote learning or if they were able to classify the pictures in a more abstract way. They then presented the dogs with a reversed contingencies test in order to determine if the dogs were categorizing information based on the features of the target or if the dogs were simply memorizing the properties of each item encompassed in each stimulus presented. (Range et al., 2008). Finally, they studied the classification errors made during the experiment to gain insight into the categorization performance of the dogs in their study. In the experiment, the dogs were clicker trained to use a touch screen computer to make their responses to images presented on the computer screen. The dogs were trained to discriminate between 40 dog pictures and 40 landscape pictures as training stimuli. The dogs were presented with a picture of a dog without a landscape, a landscape without a dog, or a dog superimposed onto a landscape. Novel testing stimuli were interspersed among the training stimuli. Range et al. (2008) found that the dogs were adept at identifying dogs in the presented pictures, even when the pictures were previously unknown to them. They determined that the subjects were categorizing their definition of "dog" in a way that was easily transferred to novel stimuli.

Range et al. (2008) pointed out that when studying the categorization abilities of an animal, there are two strategies that the subject may employ to make their decision. The first strategy, an item-specific strategy, "requires a subject to learn about the individual properties of each stimulus and their associations with (non-) reinforcement, i.e., class membership", while a category-specific strategy "requires a subject to extract and combine features common to most (or maybe even all) instances of a class and then to react in the same way to all stimuli possessing those features. They found that dogs, like pigeons, would make their decisions on category inclusion based on category-relevant features. They determined that the dogs were easily able to classify photographic stimuli according to a perceptual response rule. However, they believe that it is possible that the rules as determined by the dogs may differ from the rules set by the experimenter. Interestingly, Range et al (2008) believe that this difference does not show an inferior or superior method of categorizing information, but rather that each species develops rules based on what is the most effective way to process the information.

Humans utilize more than one system of learning at a time; these systems often compete with one another when an individual is learning new information (Vermaercke, Cop, Willems, D'Hooge & de Beeck, 2014). There is both an explicit system and implicit system of category learning that may be used, depending on necessity. Humans tend to rely first, and more heavily, on an explicit learning system since it is involves a conscious decision-making process, is based on self-determined rules, and is often verbalized by the learner. When using an explicit system of learning, the human must understand and memorize the content in order to apply it to problem at hand. The individual must break down the information into dimensions in order to garner more information about each of the parts in order to make a decision about the whole. It is during explicit learning that working memory and attention are more heavily used. Humans rely more heavily on an explicit learning system than non-human animals, since they are conscious of many of their learning processes and tend to verbalize the rules they apply to learning new rules and representations (Smith, Berg, Cook, Murphy, Crossley, Boomer, Spiering, Beran, Church, Ashby, Grace, 2012).

In an implicit system, the information is not dissected into dimensions but is processed holistically and incidentally, without a conscious decision making process. This means that information is abstracted representations rather than memorized representations. It tends to be restricted to other tasks or representations that are similar to the original item or task. Implicit learning is not conscious or verbalized and is, therefore, not accessible for conscious recall by the individual (Smith et al., 2012). Non-human animals use implicit learning systems, while humans switch between learning systems, as needed (Vermaercke, Cop, Willems, D'Hooge & de Beeck, 2014). It is unknown whether non-human animals' use of implicit learning is purely instinctual or if they are conscious at all of their decisions.

Interestingly, current research has been interpreted to suggest that non-human animals, such as rats and pigeons, tend to use both learning systems equally (Vermaercke, Cop, Willems, D'Hooge & de Beeck, 2014). It appears that non-human animals switch from an explicit system to an implicit system when more dimensions of an element must be learned - the information is possibly integrated into a whole before it is learning. Primates and humans tend to do worse on implicit learning tests than rats and pigeons, although they do eventually use some abstraction techniques when learning (Vermaercke, Cop, Willems, D'Hooge & de Beeck, 2014). There is some current debate whether animals are actually abstracting the information given or if they are simply making instinctual and more biologically base decisions (Smith et al., 2012). One of the purposes of this study was to examine whether dogs are more likely to utilize implicit or explicit learning strategies when presented with a multimodal task.

The methods by which we study how dogs process, discriminate between and categorize information, are still limited and require further investigation. The majority of the current research considers a dog's ability to categorize one type of stimuli at a time. However, in their environment, dogs are presented with multiple types of stimuli simultaneously. The current study, therefore, sought to investigate more completely the way that dogs perceive and categorize multimodal stimuli. Using a touchscreen computer, we were able to present multiple levels of an auditory stimulus combined with multiple levels of a visual stimulus and recorded the behavioral responses of the subject. Using this method, we were easily able to measure the discrimination and categorization abilities of the dog when presented with multimodal stimuli created by various combinations of light and sound levels. This allowed us interesting insight into the possible ways that dogs perceive, understand and internalize the information they receive from their environment. When designing this study, my goal was to answer the following questions:

- How do dogs process multimodal stimuli?
- Do dogs consider only one or multiple dimensions of stimuli?

Hypothesis and Predictions

Hypothesis 1: A dog, trained to make one choice in the presence of a soft sound paired with a dim light and the alternative choice in the presence of a loud sound paired with a bright light will, when presented with new combinations of light and sound intensity, base his choices on intensities levels on both dimensions.

Method

Subject

Boston, a 4-year-old neutered male American Staffordshire Terrier/German Shepherd mix, a companion animal of the researcher, served as the subject. At the date of testing, Boston was 25" tall and weighed approximately 84 lbs. He lives indoors with his family but has several hours of supervised exercise time outside each day. He shares his home with another large dog and four cats. Boston was adopted when he was 6 months old from Animal Care and Control. His history previous to his adoption is unknown. As a puppy, he was trained by the experimenter to perform various tasks in response to verbal commands such as "sit", "stay" or "touch" for a treat. He has a history of resource guarding and severe separation anxiety, both of which were fully resolved by consistent training by his trainer. He was trained only using clicker training and only positive reinforcement in response to verbal commands, and hand signals. Relevant to this study he also had experience using a paint program to produce images of himself on a cell phone and to produce paint patterns on a touch screen tablet.

Apparatus

A Toshiba Satellite laptop was used to run the training and testing software. All software was designed via the MIT App Inventor 2 program and run using the Bluestacks App software for laptops. The Bluestacks program is designed for use on Android computers but can be run on regular PC computers as well. The Toshiba laptop was connected via HDMI, USB and Audio cables to an Acer T272 (27 inch LCD) touch-screen monitor. As illustrated by the photograph and diagram in Figure 1 the monitor was placed on a platform and held in place by Velcro strips at the closed end of a large cardboard box, hereafter referred to as the "voting booth" (Figure 1).

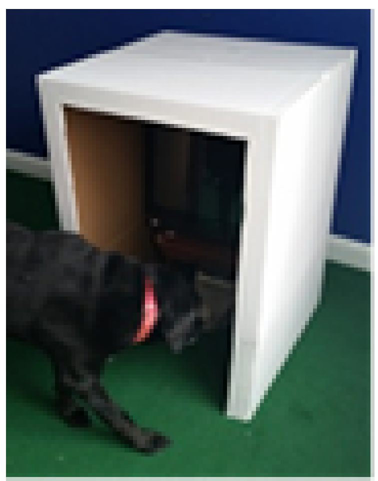

Figure 1. The "voting booth" containing the feeder and computer touch screen monitor.

The "Manners Minder" remote reward system, developed by Sophia Yin, was placed under the platform. This remote reward system was filled with the dog's regular daily kibble – Merrick Buffalo and Sweet Potato dry food. The food consists of flat discs, approximately ½ inch in diameter. The Manners Minder system delivers a variable number of treats when the remote is pressed - this can vary from two to five pieces of dried food each time.

Stimuli

The range of intensities of both the auditory and visual stimuli was limited by the available range possible using the present apparatus. The minimum levels were adjusted to be just barely discriminable for a human observer. Since this experiment was a pilot study, the levels were determined based on human discrimination levels in order for the experimenter to easily differentiate between the various levels without a mechanical aid. The four levels of grey were produced using used MS Excel which produces different luminance level by roughly logarithmic reductions from 100 percent of red, green and blue outputs to the monitor. One level of white noise was entered into the Audacity program. The four levels of white noise were then determined by manipulating the decibels of the original white noise. The four levels of white noise that were used in the experiment were logarithmically spaced via the Audacity program. The stimuli on both dimensions were roughly equally spaced on a logarithmic scale (see Table 1). The light and sound levels were determined using a Photo Research spectral radiometer and a Radio Shack sound pressure level meter.

Table 1.

Luminance and Sound Levels Used in Training and Generalization Testing.

Luminance Levels log (cd/m^2)	Sound Levels (dB) re. 0002 dyne/cm^2
Luminance 1 (L1) 1.15	Sound 1 (S1) 59
Luminance 2 (L2) 1.67	Sound 2 (S2) 68
Luminance 3 (L3) 1.99	Sound 3 (S3) 78
Luminance 4 (L4) 2.25	Sound 4 (S4) 89

As summarized in Table 2 discrimination training consisted of presentations of luminance L2 paired with sound S2 (the lower intensity pair) and on other trials luminance L3 paired with S3 (the higher intensity pair). For the generalization tests there were 14 other combinations composed of the remaining possible with four levels of light and four levels of sound intensity (see Table 2).

Table 2.
Light Sound Compounds Used in Training and in Generalization Testing.

	Luminance 1 (L1)	Luminance 2 (L2)	Luminance 3 (L3)	Luminance 4 (L4)
Sound 1 (S1)	S1/L1	S1/L2	S1/L3	S1/L4
Sound 2 (S2)	S2/L1	S2/L2	S2/L3	S2/L4
Sound 3 (S3)	S3/L1	S3/L2	S3/L3	S3/L4
Sound 4 (S4)	S4/L1	S4/L2	S4/L4	S4/L4

Note: The two compounds used in training are highlighted.

Training conditions

The training and testing was always done in the same room. The room was an empty bedroom in the experimenter's house. The room was kept dark and the curtains were closed during each session. Sessions also took place after dark to further control for outside light. The room was in an isolated part of the house, in the countryside, so that there were virtually no extraneous sounds. Except for training to eat from the Manners Minder, all training was done with the dog inside the voting booth (see Figure 2).

Boston typically received two meals a day, each consisting of one 8 oz. cup of Kibble. His sessions took place before his evening meal, to ensure that he was hungry enough to work. (The rewards given were not sufficient enough to replace his evening meal, so he was fed his regular meal after his session was complete.) Kibble, equivalent to that normally received during that meal served, as a reinforcer for correct choices. Water was freely available in the training room. He participated of his own volition, was never forced to participate. On most occasions he appeared to anticipate participating.

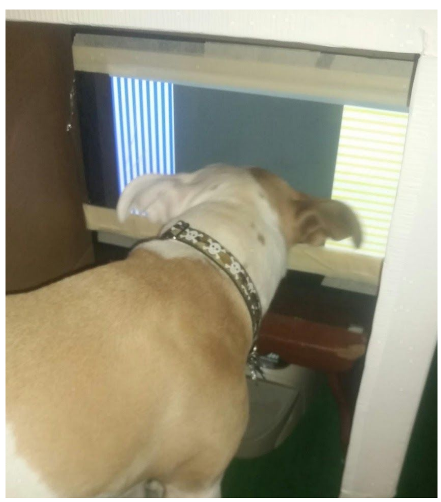

Figure 2. Boston using the apparatus

Preliminary training

Using previously learned commands such as “sit”, Boston readily learned to retrieve food the Manners Minder at the sound of the beep that signaled food delivery. Prior to this study

Boston had learned to touch a tablet computer with his nose when given the command "touch." This earlier training easily transferred to touching the monitor used in this experiment.

At the start of training to touch the monitor the experimenter put a drop of peanut butter at various locations on the unilluminated monitor while the dog was watching. When the dog licked the peanut butter off the monitor, the experimenter pressed the remote, the tone sounded and the reward delivered.

This same procedure was used to train the dog to touch whichever side panel was illuminated. Figure 3 shows the side panels illuminated with their specific colored display. When the panel was touched, it disappeared, the beep was sounded and the food delivered. Touches anywhere else on the monitor screen had no consequences. The monitor remained blank while the dog ate the food, a period of approximately 5 seconds. After a few trials the peanut butter was no longer required and was no longer used.

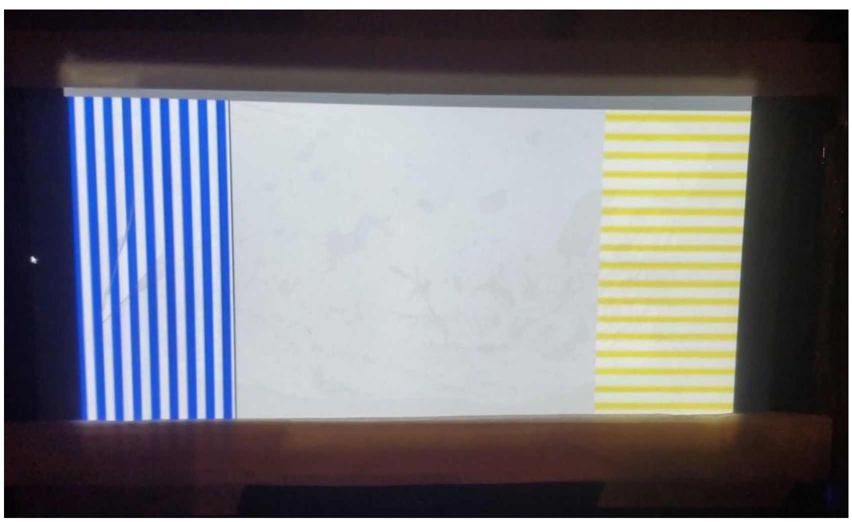

Figure 3. The monitor, with side panels and center stimuli illuminated.

Training was first done with the right panel, then the left panel and then with the panels illuminated in an unordered manner. Preliminary sessions were approximately 15 minutes in length. As Boston became adept at using the apparatus, he received approximately 20 rewards per session. A reward consisted on one to three pellets of Kibble delivered into the feeder.

Following this, the left or the right panel was illuminated in a random order. They were never presented together. The dog was rewarded only when he pressed the illuminated panel. If the dog pressed anywhere else on the screen nothing happened until he pressed the illuminated panel. Early in this phase of training the dog tended to show a preference for one side of the monitor. This was usually whichever panel had been illuminated first. However, after several sessions he responded to whichever panel was illuminated as determined by the semi-random order in which the sequence was programmed.

In preparation for discrimination training in which each trial would begin with a touch of the center panel, the dog was then trained to touch this panel. For this phase of training the center panel was illuminated with blue and yellow diagonal stripes. After this panel was touched, one of the side panels was highlighted in a semi-random order. When the dog touched the side panel both the center and side panel disappeared, the beep was sounded and the dog received the treat. The sequence, touch of the center panel, followed by illumination of a side panel, a touch of this panel and food delivery, was repeated until Boston completed readily completed this cycle. There were 10 presentations of each side panel in each session.

Discrimination training

Training to discriminate between Pair 2 (S2/L2) and Pair 3 (S3/L3) began with a procedure designed to produce errorless performance. The start of each trial was signaled by the random appearance of one of the two light-sound pairs. A single touch of the center panel produced the corresponding correct side panel for that pair. The left panel was defined as correct for Pair 2 (S2/L2), the more intense stimulus pair and the right panel was correct for (S3/L3) the less intense stimulus pair. A touch of the correct panel removed the sound-light stimulus from the center panel, darkened the side panel, a beep was sounded. Food was delivered and consumed. During this 5 sec. interval, the *intertrial interval* (ITI), the screen remained dark and touches anywhere on the screen had no effect. This was true for this and all subsequent ITIs.

Discrimination training between the two light-sound pairs began when the dog was consistently pressing the side panel every time it was illuminated. Now, both panels were illuminated 2 s after a touch of the central panel in the presence of the programmed sound-light pair. If the correct side panel was touched, this was followed by the beep, the 5 s ITI. The start of the next programmed stimulus pair was signaled by illumination of the center panel and the onset of the sound. Following an error, after the 5 s ITI, the stimulus pair in the presence of which the error occurred was presented again. Now, 2 s after a touch of the center panel only the correct choice panel was illuminated. The dog touched this panel and received the reward. Responses of these correction trials were not used in the data analysis.

Except for the first seven sessions of discrimination training during which the stimuli were presented in a random order, the two stimulus pairs were presented equally often during each session. Session length was gradually increased from 10 to 20 trial sessions over 5 days. Discrimination training ended when the dog was correct 90% or more in eight-sequential training sessions. Boston completed discrimination training in 57 sessions.

Generalization testing

Generalization tests ranged in length from 40 to 45 trials. Each test began with at least one training stimulus. From 14 to 19 presentations of the two stimulus pairs used in training appeared in a random order within each session. Correct choices in the presence of these stimuli were reinforced; errors were not. The correction procedure that was used during training was discontinued. Testing consisted of single presentations of each of the 14 test stimuli. These test stimuli were randomly interspersed among the training stimuli. In the presence of a test stimulus whichever choice was made was followed by the beep and delivery of the treat.

Results

Discrimination training data

There were 57 trials in the discrimination-testing phase. The subject was trained to discriminate between the two stimulus compounds and then tested on the learned behavior until he achieved an average of 95% correct on three sequential trials. Figure 3 illustrates the rate at which Boston learned to discriminate between the two stimulus compounds.

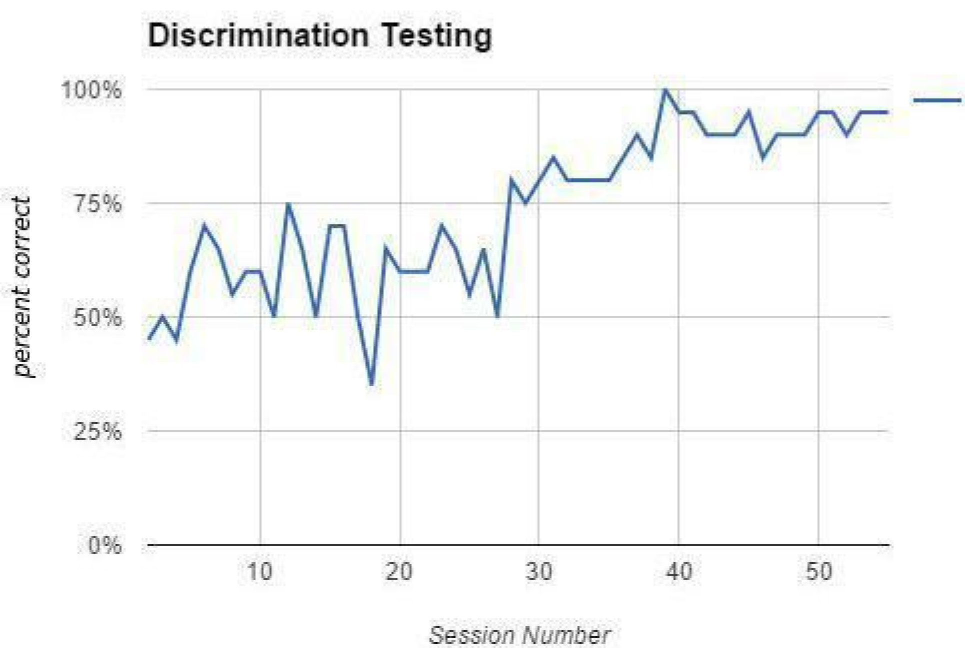

Figure 4. Percent correct of each session during discrimination testing.

The accuracy of the each trial may have been influenced by other factors including the time of day that the trial was run; later in the day (closer to dinner time) appeared to produce better results. The subject was possibly less accurate when there was a distracting noise outside, or if there was wildlife (deer) outside. Finally, the subject was possibly influenced by the mood of the experimenter, and poorer results were obtained when the experimenter was tired or upset. Although the subject could not see the experimenter during the testing, he did observe the experimenter before the testing began, and this may have influenced his own behavior.

Generalization test data

A human subject, Paul, was provided two sessions to learn which panel corresponded to each stimulus compound. Paul then had one session of discrimination testing before the generalization test was run. Paul is an artist by profession. We had anticipated that Paul would show a preference for visual stimuli over auditory stimuli. However, it seems that Paul more frequently (although not exclusively) used auditory information to make his decisions about which panel was the correct choice (Figure 5).

Paul					
L1	Left	Left	Right	Left	**Brightest**
L2	missing	Left	Right	Right	
L3	Left	Right	Right	Right	
L4	Left	Left	Left	Right	**Dimmest**
	S1	S2	S3	S4	
	Loudest			**Softest**	

Figure 5. The results of Paul's Generalization Test

The experimenter, Kathy, also ran herself on the generalization test. Although Kathy knew the purpose of the experiment, she exclusively used visual stimuli to make decisions about which panel she believed was the correct choice (Figure 6).

Kathy					
L1	Left	Left	Left	Left	**Brightest**
L2	missing	Left	Left	Left	
L3	Right	Right	Right	Right	
L4	Right	Right	Right	Right	**Dimmest**
	S1	S2	S3	S4	
	Loudest			**Softest**	

Figure 6. The results of Kathy's Generalization Test

The subject, Boston had 20 sessions of generalization testing. The proportion of R2 (left) panel selection over the total number of presented stimuli was calculated (Figure 7). Proportions were .50 or below for the brighter/louder stimuli and .5 or higher for the dimmer/softer stimuli.

Boston					
L1	0.05	0	0.05	0.25	**Brightest**
L2	0	0.2	0.35	0.55	

L3	0.45	0.85	0.93	0.95	
L4	0.35	0.65	0.95	1	**Dimmest**
	S1	S2	S3	S4	
	Loudest			**Softest**	

Figure 7. The proportion of R2 (left panel selection by Boston

Figure 8 and Figure 9 illustrate Boston's distinct preference for R2 when the stimuli were more salient (bright/loud) and R1 when the stimuli were more subdued (dim/soft). In comparison, Figure 10 suggests that Paul's selection of R2 was primarily dependent on sound intensity.

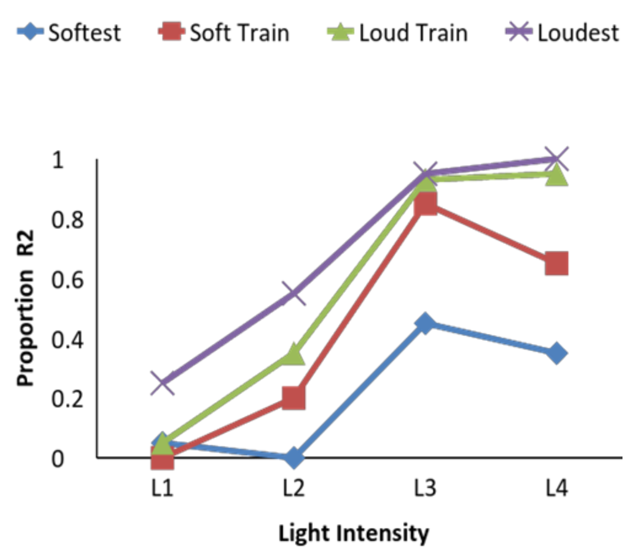

Figure 8. Proportion of Boston's R2 selection based on light intensity

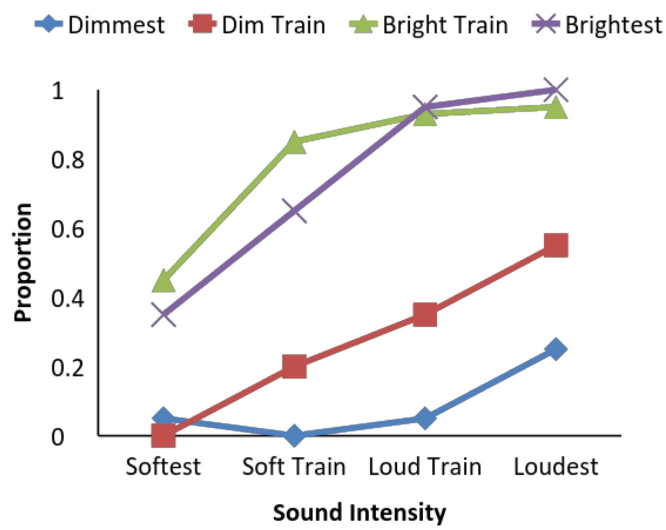

Figure 9. Proportion of Boston's R2 selection based on sound intensity

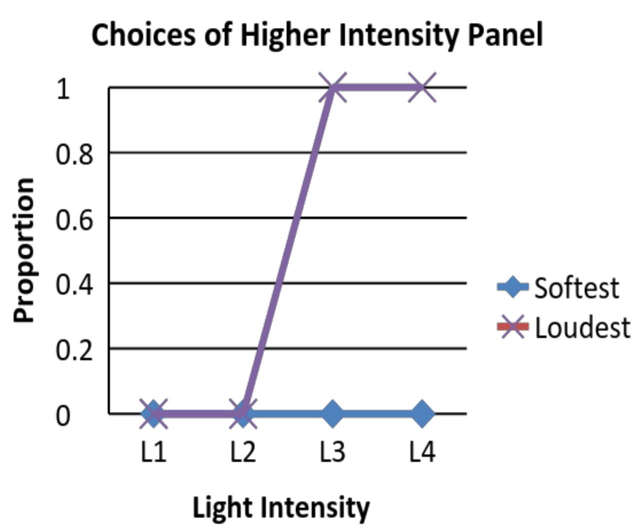

Figure 10. Proportion of Paul's R2 selection based on Light intensity

The higher proportion of R2 selection of brighter light/louder sound stimuli, and lower proportion of R2 selection of dimmer light/softer sound stimuli by Boston suggests that he may have been using both dimensions (light and sound) to determine which was a correct choice.

Paul appears to have considered both dimensions to make his choice, with a definite preference for auditory stimuli as a deciding factor. Kathy appears to have ignored the sound stimuli completely, and made her choices using visual stimuli alone.

Discussion

This study was designed to analyze the discrimination and categorization abilities of dogs under controlled conditions. Two human subjects were also tested on the same experiment in order to compare the results of human perception and learning with that of the canine subject. Results indicate that the dog paid attention to both types of stimuli – sound and light. The dog based his choices on both the light and the sound intensities of the pairs of the training stimuli as revealed by his choices in the presence of the test stimuli. In contrast, the human subjects both divided their attention between the stimuli and selectively paid attention more to one stimulus dimension than the other. It appears as if some humans may have a preference for auditory stimuli while others have a preference for visual stimuli. One of the human subjects is a visual artist; the other is a psychotherapist. Surprisingly, the artist appeared to prefer the visual stimuli and tended to chose that modality to the exclusion of the visual stimuli. The psychotherapist appeared to prefer the visual stimuli, despite relying heavily on auditory communication in her field of work.

Animals tend to follow set routines that rarely change; this is to guarantee their success in their environment (Rowe, 1999). A behavior that is established as successful will be repeated because success will be guaranteed. Therefore the same set of stimuli tends to result in the same set of responses because the result will always be adaptive and beneficial. Therefore, animals rarely vary from an established routine because there is no need to vary from an already successful pattern of behavior. They already know what to do in a given circumstance and there is no need to learn a new skill in order to achieve the same result. However, relying on an established routine is not always possible since the environment rarely remains static and animals must learn to adapt to frequent changes. Motivation is key when an animal changes its behavior. A change in motivational state is not always indicative of learning, but can be an instinctually driven adaptive behavior.

The utilization of an implicit learning system is more of the instinctual, biologically driven decision making process that we expect from non-human animals. In the wild, non-human animals may not have the time to break information down into individual dimensions in order to learn new items or behaviors. Therefore, the use of an implicit system is more biologically appropriate. Non-human animals, such as dogs, must rely on an implicit learning system in order to optimize the selection of appropriate choices. (Humans utilize both learning systems, implicit and explicit, as the situation dictates.) If it is important that non-human animals attend to multiple stimuli, they must be able to do that; they must be able to utilize an implicit learning system when necessary. For example, they must know if a frog with certain colors or a certain sound is going to be poisonous before they eat it. A frog may have one of these dimensions alone and the non-human animal must decide if it is enough to avoid the frog. However, they do not always have time to attend to each of these individual dimensions. A animal may have only enough time to make a quick, instinctual decision in order to remain alive in a dangerous world.

Humans tend to use language to help them internalize and understand environmental stimuli. Language is an important part of the learning process in humans. Through verbalization, humans are able to express ideas clearly in their head and define more abstract concepts. Abstraction is the process of adding or removing certain traits of an item in order to reduce it to its essential characteristics. This is key in categorization because it simplifies the information and increases the efficiency of the subject to make definitive choices. The resulting internalized object is a representation that can be used to compare with new objects. An inability to express ideas clearly may cause the information to be interpreted as vague and difficult to understand. This is often seen with non-verbal autistic children with language processing difficulties. They tend to have more concrete thinking and are sometimes incapable of complex concepts such as object permanence. An abstraction, therefore, will include all the relevant aspects of the item and not of the extraneous aspects. There is some controversy surrounding the theory of non-human animal abstraction of information. Smith et al. (2011), suggest that the utilization of an implicit learning system suggests a more primal and less developed learning system, since it is primarily instinctual. However, the actual processes involved in implicit learning have yet to be determined and it remains unknown whether abstraction is involved or not.

Humans use language as their primary method of discriminating and categorizing new information. The internal dialogue in humans helps them create an internal representation of new stimuli. This is an algorithm that may or may not be unique in humans. There is still a lot to learn about the language of other species and how it may affect learning. The process of implicit learning is very vague and poorly defined and it is unknown exactly how it influences learning. It is unfair to say that implicit learning is more basic and base, since language is not involved, since non-human animals tend to utilize a strategy that optimizes the selection of a correct choice. If an animal, such as a great ape, is unable to understand syntax, does that also mean that it is not processing information in an optimal way? If a running internal dialogue is the optimal way for humans to learn, is it actually optimal for other species? If non-human animals are lacking in this internal dialogue, and are only using external stimuli to process information then, perhaps, it is because this method is the most effective method for the survival of their species.

It is difficult to determine if explicit or implicit learning is a more optimal technique. It is impossible to determine whether animals are abstracting information when utilizing implicit learning techniques or if it's simply instinctual. It is also unknown whether abstraction is really the most effective learning technique for that species in their natural environment. A single optimal solution does not mean that it is the only useful or meaningful solution. The final decision is based on which of the various possible aspects of the stimuli are more relevant to the individual in that moment and the correct answer may be to choose between mutually incompatible stimuli when this may be the result of the unnatural environment as set up by the experiment. It's possible that when presented with bimodal stimuli in a situation that the animal, or human, finds more urgent, the results may be different.

Although abstraction may be useful in human learning, a single solution is not always optimal in all situations (Lavie, Hirst, Fockert, & Viding, 2004). We may not yet understand non-human animal information processes because they are able to abstract multiple pieces of information at the same time, form multiple categories and then switch between each depending on which is more useful in a given situation. Morgan's canon states that we should not interpret animal behavior in human terms. Therefore, we cannot say that animals are incapable of abstraction. Rather, we should consider that they may abstract or interpret information in a way that is more biologically appropriate for the survival of their species. They may have an internal dialogue that we are not aware of and it is possible that they are capable of more complex abstraction that humans. There is much to learn about animal categorization and broad sweeping assumptions about animal abstraction, such as those by Smith et al. (2011), are unfounded and may be incorrect. Different perspectives on the same stimuli do not and should not imply a lesser or more evolved form of learning.

Children with autism and learning disabilities, especially those with difficulty processing language, often find it difficult to focus and pay attention to meaningful information while filtering out meaningless information (Lovaas, Schreibman, Koegel, & Rehm, 1971). They may also be more easily distracted because the information that is salient to them in one moment may soon be discarded as irrelevant. They may also require more time to process information because they are unable to internalize the information and unable to use language to discriminate and categorize new information. Non-verbal autistic children are useful to compare when discussing non-human animal behavior because they may process information in a similar way (if we assume that animals do not have an internal dialogue. It is suggested that non-verbal autistic children may similarly have a lack of or limited internal dialogue (Lovaas, Schreibman, Koegel, & Rehm, 1971). This may be why selective attention is such a typical characteristic in autistic children. Selective attention is defined as when a subject filters out all other stimuli in order to focus on one specific stimulus. Studies have been conducted that show that adult humans often have selective attention when speaking on a cellular phone – their awareness of their environment becomes significantly reduced and the potential to make mistakes increases greatly. Selective attention is an adaptive skill – there is simply too much information presented in the world to process at once. The mind must decide which information is more relevant to that specific moment. We have a limited capacity for processing information and for a limited duration of time. This is similar to computer processing – there is a limited amount of memory (RAM) available to use at any given time.

Treisman (1964) postulated that attention is controlled by an attenuator that makes stimuli more or less salient based on whatever other stimuli are present. That is to say that the other stimuli are never ignored, but they may be considered less or more important than other stimuli depending on the situation. This means that no information is fully ignored. It is just compared and deemed more or less relevant depending on what outcome is desired. According to Treisman (1964), this means that all the stimuli are processed at the same time, but on different levels. Multiple forms of analysis happen simultaneously. Sternberg (2009) postulated that perceptual load was the most important aspect of attention. The amount of information presented at one time affected how stimuli were attended to. Humans tend to make more correct choices on selective attention experiments when experiencing a low cognitive load than when there is multimodal information that is presented simultaneously. The relevance of the information presented and the goal of the task affected which information was considered more salient. Subjects will always base their choice on the potential for making more correct choices. Again, this may differ among species. Although humans may find the need to use abstraction as a tool to categorize new information and determine which information will help them make a correct choice, non-human animals may find this same behavior instinctual. They may not need to abstract information to make a correct choice or their choices may be based more on instinctual drives. Again, this does not determine that animals are incapable of abstraction. Rather that it may be a skill that they do not use in a manner similar to humans.

In this study we obtained evidence that our humans participants primarily attended to one dimension over another dimension when making their choices. It appears that they utilized an explicit, rule-based strategy and broke the compound stimuli down into individual dimensions. They each then decided which dimension was more salient and more useful when attempting to make a correct choice. Paul primarily chose sound as the relevant dimension, while Kathy chose image brightness as the relevant dimension. They appeared to compare each stimulus in the testing phase with the exemplar they had created. However, Boston used a more implicit learning strategy. He appeared to look at the information holistically and integrated the information from both dimensions when making his decisions. Boston chose both brightness and sound level as relevant characteristics. It is difficult to determine whether Boston was actually abstracting the information presented or whether his decision making process was instinctual. In either case, he utilized the system which provided him with the higher probability of making a correct choice.

Some researchers assume that the dependence on an implicit system suggests a more primitive type of learning about the environment (Smith et al., 2011). Although humans do use both systems in categorization they most frequently depend on explicit learning (Smith et al., 2012). In order to compare rats and humans on implicit and explicit learning processes, Vermaercke et al. (2014) trained rats and humans on stimuli that varied on two dimensions, line tilt and width, followed by a test for generalization. When tested for generalization the rats based their choices on both dimensions, suggestive of implicit processing); the humans based their choice on only one of the dimensions, suggestive of explicit processing). The finding that the rats made fewer errors when tested for generalization than the humans lead the authors to conclude that “more complex brains are not always better” (p. 1080)”.In the present study when presented with new compounds of light and sound intensities Boston used information of both dimensions. Information on only one of the dimensions, light or sound intensity, was used by the human participants.

This leaves us the question as to whether utilization of an implicit system suggests a higher order of learning than previously thought. Ability to attend to multiple dimensions at once may depend on the processes that require implicit learning, learning of associations between stimuli and responses. The results of the present study and that of Vermaercke et al. (2014) suggest that a dependence on an explicit, rule-based learning system, may in some cases prevent humans from making the choice that is most likely to be correct. Under some circumstances language in humans may actually impede making the optimal decision.

Limitations and further research directions

One limitation in this study was the sample size of one for the canine subject. Although the study started out with three canine subjects, one passed away without completing the experiment and another had to stop for medical reasons. The single canine subject in this experiment gives us an idea of how dogs may discriminate and process information; however, it is possible that these results reflect only the personal experiences of this individual dog. Another study with a much larger sample size should be conducted in order to confirm the results of the current study.

Another limitation is the use of only two human subjects to compare with the canine subject. It is unknown why one subject preferred the visual stimuli over the auditory stimuli and vice versa. It would be interesting to survey the subjects after the experiment in order to see why they found one modality more salient than the other. One of the human subjects, the experimenter, knew the purpose of the study beforehand. It is possible that this may have impacted her results. It would be more beneficial if all the subjects of the experiment did not know the purpose in order to achieve more valid results. In addition, the training phase for the human subjects could be extended and multiple testing phases could be included to see if the preference for one modality would remain the same or if the subject would change their preference as they became more accustomed to the experiment.

Future directions for this study could include an analysis of the amount of time subjects, human or canid, take to make their decisions. This would help to determine if each of the three subjects really weighed their decision carefully or if the choices made were more instinctual. It would help determine if the subject made his decisions more quickly as he became more skilled at using the apparatus and more comfortable with the experiment. This would help determine the rate at which animals learn and whether they internalize the new information quickly and how they access their working memory.

Finally, it would be interesting to see if more subtle changes in the stimuli levels would be as easily detected by the subjects. Since dogs have been shown to find moving stimuli more interesting, it may also be beneficial to use moving images, rather than stationary images, on the screen when presenting the visual stimuli.

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