Ideal Free Distribution in Canines: Free-Operant Evaluation of Group Foraging

By
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Abstract

The ideal free distribution describes behavior of organisms in groups and is an extension of the matching law that suggests the allocation of the number of organisms across two or more resource sites will be distributed equally across those resource sites (Fretwell & Lucas, 1970; Herrnstein, 1970). This initial project sought to develop a new method of foraging research for canines by validating a novel dispenser in basic behavioral research. The purpose of this study was twofold: to evaluate if the Treat & Train® dispenser could function as a viable method to deliver treats on a variable-time schedule and to determine if the Ideal Free Distribution equation could describe the behavior of the domesticated canine in a daycare setting with and without an imposed bias. Researchers recorded canine behavior in a free operant arrangement on various variable-time schedules of reinforcement. Results indicate the Treat & Train® dispenser offers a novel and effective method to study basic behavioral processes in canines without compromising data quality. Undermatching or matching occurred in the canine sample, which is consistent with other group foraging research. Citronella did not function as a bias in the current study. Implications and future directions involve expanding the Treat & Train® dispenser's use to study other behavioral processes and extending foraging research in the domesticated canine.

Keywords: ideal free distribution, canine, group foraging, ecology, citronella

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Scientific research exists on a continuum of pure basic to pure applied interests. In between these anchors is the notion of "translation" – whether basic work translated into application or applied interests translated backward into basic concepts. These two ends of the continuum were disconnected and treated as two separate fields of study in behavior analysis in the late 1970s and 1980s (Mace, 1994). However, translational research offers utility to both basic and applied researchers. Translational research explicitly considers the applicability of a phenomenon while maintaining a high degree of experimental control, a complement to both areas of research (Mace & Critchfield, 2010; Vollmer, 2011). Translational research is unique because it focuses on "innovation through synthesis" of principles, ideas, and technology (Mace & Critchfield, 2010, p. 296). More recently, in behavior analysis, "use-inspired basic research" has been emphasized as a way for basic scientists to favor basic questions of societal relevance, which falls into translational research (Critchfield, 2011a; Critchfield, 2011b; Stokes, 1997). These studies demonstrating how basic mechanisms underlie application are referred to as "bridge-studies" (Hake, 1982). Resources, such as funding, are often dominated by studies with practical importance or social significance. Therefore, basic researchers may consider translational work as a realistic alternative to "pure basic" research (Critchfield, 2011b; Mace & Critchfield, 2010).

To best leverage bridge-study options, translational researchers can assess the degree to which principles derived under laboratory conditions apply to the real world (Critchfield, 2011a; Lerman, 2003). Furthermore, extensions from the laboratory may *only* be generalizable when conducted with the population or setting of interest and, therefore, is a useful avenue to pursue (Vollmer, 2011). Toward the end-goal of use-inspired translational work, the current study sought to incorporate a well-established experimental and quantitative paradigm—concurrent operant schedules within matching theory—to ideal foraging and reinforcer sensitivity/bias with canines (Critchfield & Reed, 2009).

Matching Theory

The matching law is a quantitative model of choice that states an organism's relative proportion of responding will match the relative proportion of reinforcement on that alternative (Herrnstein, 1961). Herrnstein showed the pecking of pigeons corresponded with the relative frequency of reinforcement. Said simply, the pigeons "matched" their relative allocation of behavior to the relative rates of reinforcement delivered by the experimental preparation. As demonstrated by Herrnstein and others (Herrnstein 1961, 1970; Baum, 1974), matching is typically studied using concurrent arrangements in which two independent variable-interval (VI) schedules of reinforcement are available. The rationale for a concurrent arrangement is that opportunities to choose are often continuous - an organism may stop engaging in one behavior at any time and begin to engage in another (McDowell, 1989). Nonhuman matching law studies often use two levers or pecking keys with two independent schedules of reinforcement in an operant chamber. In contrast, applied research has studied other potential reinforcers such as attention in the natural environment, demonstrating broad areas of study (Reed & Tiger, 2015). For example, Borrero and Vollmer (2002) retroactively assessed direct observational data with children with intellectual and developmental disabilities and determined the rate of problem behavior matched reinforcement in the natural environment.

Herrnstein's matching relation can be described as follows:

$$\left(\frac{R_1}{R_1 + R_2}\right) = \left(\frac{r_1}{r_1 + r_2}\right)$$

Equation 1

with R_1 being the response rate on one alternative and the R_2 representing the rate on another alternative, and r_1 and r_2 representing the rate of reinforcement obtained on the respective alternatives. By algebraically rearranging and simplifying the above equation, researchers can express the matching relationship in terms of ratios rather than proportions (Baum, 1974; McDowell, 1989):

$$\frac{B_1}{B_2} = \frac{R_1}{R_2}$$

Equation 2

in which $\frac{B_1}{B_2}$ describes the ratio of behavior allocation on a concurrent schedule and $\frac{R_1}{R_2}$ represents the obtained ratio of reinforcement on that schedule.

Baum (1974) demonstrated that strict matching is rare; rather, organisms tend to deviate from strict matching, warranting a generalized form of the matching equation. The generalized matching equation transforms Herrnstein's equation by taking the logarithm of both sides of the equation to more efficiently study deviations from the matching law. Baum (1974) logarithmically transformed the above equation and added two components:

$$\log\left(\frac{B_1}{B_2}\right) = s\log\left(\frac{R_1}{R_2}\right) + \log(b)$$

Equation 3

with the slope, *s*, representing the sensitivity parameter and log *b*, the y-intercept, representing the bias parameter. The definition of perfect matching is a slope of 1.0 (a straight line) with a y-intercept of 0 (Figure 2).

Systematic deviations from the matching law include undermatching, overmatching, and bias. Undermatching often occurs when an organism has poor discrimination of the contingencies and is shown through any value *less* extreme than what is predicted by the matching law (Baum, 1974). Mathematically, undermatching is represented by a slope or *s* value less than 1.0, suggesting that a one-unit increase in the relative reinforcement ratio is met with a less than one-unit increase in the relative behavior ratio. By contrast, overmatching describes cases in which responses are *more* extreme than what would be predicted by the matching law, with a slope greater than 1.0; mathematically, a one-unit change in the relative reinforcement ratio is met with a greater than one-unit increase in the relative behavior ratio. Bias (*b*) describes differences in responding not accounted for by the reinforcement schedule. Simply put, bias represents unprogrammed preference or preference that the experimenter is unable to control (Baum, 1974). When *b* is equal to 1 (and therefore log *b* is equal to 0), there is no bias. Examples of bias include 1) response bias, such as when one lever is slightly more difficult to press than another, 2) qualitatively different reinforcers, such as comparing food with water, or 3) qualitatively different schedules of reinforcement such as fixed-interval (FI) versus variable-interval (VI) schedules (Baum, 1974; Nevin, 1971; Trevett et al., 1972).

Several studies have assessed these systematic variations to study matching (e.g., Baum, 1974; Nevin, 1971). Nevin (1971) compared FI and VI schedules and found systematic undermatching. The overall responding of the pigeons departed from matching law to the individual FI schedules; however, relative rates of reinforcement suggested systematic changes in responding, which resembled undermatching. Baum (1974) discussed data obtained from pigeons when bias occurred, such as a side/response bias. Using the generalized matching equation, researchers would be able to account for bias and describe the qualitative differences in reinforcers. Of the studies assessing systematic variations of matching, most have resulted in undermatching despite the species of study, the type of analysis employed, and reinforcers used (Wearden & Burgess, 1982). The degree to which undermatching occurs appears to change little with different procedural variations. Researchers have also found undermatching occurs with farm animals such as cattle (Foster et al., 1996) and chickens (McAdie et al., 1993; McAdie et al., 1996), furthering the suggestion that undermatching is a cross-species phenomenon.

Researchers have not limited studies assessing systematic variations with matching theory to nonhuman animals. In one application of matching with humans, Mace and colleagues (1990) found that children with intellectual and developmental disorders matched their responding on academic tasks to the richer reinforcement schedule. Follow-up studies found similar results with children with emotional disturbances (Neef et al., 1994) and adolescents (Mace et al., 1994). Notably, Mace et al. (1994) found significant undermatching until adjunct procedures (i.e., change over delays and limited holds) were introduced. Murray and Kollins (2000) studied the effects of a stimulant on children's matching behavior for children with attention deficit hyperactivity disorder. Results indicated the variance accounted for by the matching equation was higher in the medication condition than the placebo.

McDowell (1989) discussed asymmetrical choice as an extension of the literature on matching law. Given differences in responding between qualitative and quantitative differences would constitute a bias, researchers can determine which direction the bias occurs with the generalized matching equation. From these mathematical descriptions of behavioral phenomena, McDowell (1988; 1989) suggested the matching law's applied relevance. Researchers can determine which reinforcers are more valued than others because bias results from differences in reinforcer and response values. Furthermore, manipulations may suggest that biasing *away* from stimuli represent an aversive stimulus. Despite Baum's (1974) study of undermatching and bias in pigeons, little applied work has been done to manipulate variables to induce a bias in responding. One exception is a human study showing bias when math problem difficulty was manipulated (Reed & Martens, 2008). Reed and Martens (2008) demonstrated a bias toward easier math problems when researchers manipulated response effort (difficulty) in concurrent schedules using the generalized matching equation. The manipulation pushed responding toward the easier math problems and, therefore, increased the bias parameter in the direction of the easier station. However, the preference for easier problems may be partially due to stimulus control rather than schedule control alone. Ultimately, results showed response effort contributes to deviations from matching in application.

As an exception to studying bias with nonhuman animals, McAdie and colleagues (1993) assessed the aversiveness of noise through the introduction of noise to a concurrent VI schedule. The authors assessed different sounds and assessed the sound's aversiveness through the bias away from the stimulus. Researchers tested different sounds such as music, a train noise, a hose, and the sound from a poultry shed at varying decibels. Sounds from a poultry shed tended to induce the greatest bias even when the sound intensity was low. The authors suggest that researchers may quantify the aversiveness of stimuli using a matching law paradigm and measuring bias with comparators.

Ideal Free Distribution

Extending from the matching law, the ideal free distribution (IFD) is a theory that predicts how groups of organisms will distribute themselves across food sources or resource sites (Fretwell & Lucas, 1970; Gray, 1994). Unlike the matching law, distribution is at the group level rather than individual responses from an organism. According to IFD, organisms will optimize energy intake by heading to food sites with the most preferred or suitable resources or, said simply, organisms will attempt to maximize their obtained reinforcers in the context of the group (Fretwell & Lucas, 1970). As a result of the average foraging rate being directly dependent upon other foragers in an area, switching to more or less dense resource sites should result in similar capture rates among individuals in the resource sites. For example, if an area holds twice as many resources, IFD would predict twice as many organisms will be in that area as another area with half the resources. The central thesis on IFD from Fretwell and Lucas (1970) is that the distribution does not account for the foragers' individual behaviors, rather the behavior of the group.

Similar to the matching law, IFD describes that the distribution of groups of animals should match the obtained resources in an environment (Fagen, 1987; Houston et al., 1995; Kennedy & Gray, 1993). The simplest form of the IFD equation is:

$$\frac{N_1}{N_2} = \frac{A_1}{A_2} \qquad \text{Equation 4}$$

Where *N* represents the number of organisms in a particular site, and *A* represents the available resources at each site. This ratio parallels Equation 2 in that the number of foraging organisms will "match" the number of resources in an area. Perfect matching has been termed "habitat matching" in IFD literature (Pulliam & Caraco, 1984). Pulliam and Caraco (1984) recognized the IFD equation is similar to the ratio version of Herrnstein's matching law equation (1970). However, the equations differ in that the matching law observes one organism's responses, while habitat matching refers to the location or allocation of groups of organisms.

The generalized ideal free distribution equation states:

$$\log\left(\frac{N_1}{N_2}\right) = s\log\left(\frac{A_1}{A_2}\right) + \log(b) \qquad \text{Equation 5}$$

in which N_1 is the number of organisms in one resource site, N_2 is the number of organisms in the second resource site, and A_1 and A_2 are the available resources at the corresponding resource sites (Fagen, 1987; Kennedy & Gray, 1993). The sensitivity parameter, *s*, and the y-intercept, log *b*, the bias parameter, remain the same as the generalized matching equation (Equation 3).

The IFD makes several assumptions (Kennedy & Gray, 1993). Specifically, the IFD assumes the foraging organisms (1) have "perfect knowledge" of the contingencies in place, or behaviorally, can discriminate between the schedules, (2) allocate behavior to maximize efficiency, (3) are at equivalent levels of fitness or competitive ability, and (4) will obtain fewer resources with the introduction of additional competitors. Multiple studies have shown systematic deviations from habitat matching. Like the matching law, these deviations often present themselves as undermatching (e.g., Baum & Kraft, 1998; Gray, 1994; Madden et al., 2002; Sokolowski & Tonneau, 2004). At least one of these assumptions is often violated in an experiment, but these systematic deviations can be accounted for with the sensitivity parameter (Baum & Kraft, 1998; Kennedy & Gray, 1993).

Despite focus on IFD's relation to behavior analysis, the origin of IFD was in ecology. In an early study on IFD, Harper (1982) observed a group of mallard ducks in a pond while throwing predetermined amounts of bread into the water. He found that initially, the ducks distributed between patches conforming to IFD. However, some ducks were more competitive than others and therefore led to unequal payoffs. Thus, ducks initially conformed to IFD and the frequency of delivery of reinforcers but eventually used other cues, such as avoiding more competitive animals when dispersing themselves.

Some of the concerns surrounding IFD, such as competition, are discussed in a review by Kennedy and Gray (1993), which explained systematic deviations from habitat matching within 52 studies and offered new models for studies in which competition, interference, and unequal competitive abilities may be analyzed. Authors concluded that IFD, as it stands, lends itself to systematic undermatching in most studies due to these additional variables, similar to matching theory (see Wearden & Burgess, 1982). Given organisms rarely have perfect discrimination of the contingencies, this result is not surprising; with perfect knowledge, near habitat matching occurs (Madden et al. 2002). Competitive interference or unequal competitive abilities may also play a role in systematic undermatching but the adjustments to the IFD equation proposed by Kennedy and Gray (1993; Milinski, 1984; Sutherland, 1983); have not been as well documented as the generalized IFD equation.

Baum and Kraft (1998) experimentally addressed the concerns of Kennedy and Gray (1993; Gray & Kennedy, 1994) by conducting an experiment with approximately 30 pigeons to demonstrate how competition, travel, and barriers impact IFD. Baum and Kraft assessed patch type with a broad area (low competition), a trough (moderate competition), and bowls (high competition). The researchers also evaluated the distance to each patch site ranging from adjacent, or near-site, to requiring travel from site to site. Lastly, Baum and Kraft assessed whether visual ability impacted habitat matching. Results indicated a greater sensitivity with the lower competitive areas as compared to the higher competitive bowls. Undermatching was more prominent in the more competitive conditions and closer to habitat matching in the low competitive area. The authors concluded competition dampens group distribution shown through undermatching. Additionally, there was greater sensitivity in travel distance as compared to adjacent sites. Organisms were less likely to switch sites when the response effort was higher rather than spurious switching, which resulted in a slight increase in undermatching. Even with the observation of undermatching, the model described all variables adequately with the generalized equivalent of IFD (Equation 5).

Despite systematic undermatching in experimental research, IFD may have utility for wildlife ecology (e.g., Bautista et al., 1995; Beckmann & Berger, 2003; Křivan, 1997). Beckmann and Berger (2003) assessed IFD with a black bear population. They accounted for animal sex, urban and rural resources, and competition, and the researchers found that the ideal-despotic model, a modification of IFD, described the organisms' movements. Cranes also conformed to IFD, but only when the closest patches to the nesting areas exceeded carrying capacity (Bautista et al., 1995). Similar distributions have been obtained through descriptive analyses with bees (Dreisig, 1995) and songbirds (Haché et al., 2013). Note, none of these studies experimentally manipulated resource sites and instead comprised descriptive analyses of the natural environment, such as recording the number of flowering plants or deforestation. That said, some studies, such as an ecological study of Coho salmon (Grand, 1997), experimentally manipulated patch size to study unequal competitive ability with IFD.

In addition to nonhuman animals, the IFD has been used to describe humans' movements as well. In an example from anthropology, researchers used the behavioral ecology model of IFD to describe the migration patterns of humans (Kennett et al., 2006). These archival analyses were conducted based on archaeological data of colonization and obtained food in Oceania. Other cultural studies have used IFD to describe contemporary events. Disma et al. (2011) observed children selling water in Istanbul, Turkey in a field study examining IFD. Experimenters counted the number of cars in a given lane and the number of children attempting to sell water bottles at traffic lights. The ratios of children matched the ratios of vehicles stopped at each "resource site," which was defined as the car lane. Experimenters observed slight undermatching, which is unsurprising given the lack of perfect knowledge, or behaviorally, a lack of perfect discrimination, of the contingencies. These studies emphasize the utility of IFD for descriptive analysis with humans in naturally occurring foraging contexts.

These naturalistic descriptive studies provide a means to describe humans' movements but cannot demonstrate experimental control. However, it is possible to use laboratory settings to experimentally manipulate relevant variables, thereby providing more insight into human group behavior. To experimentally extend behavioral ecology studies of IFD with humans, Kraft and Baum (2001) conducted an experiment using IFD in social settings. Researchers asked undergraduate students to raise cards that corresponded to points in a discrete trial set-up and that the two people with the most issues would obtain cash rewards. The researchers instructed participants to earn as many points as possible throughout the study and that a certain number of points were available by choosing either red or blue cards. Researchers also gave participants sheets to record their earned points on every trial. Participants were able to switch their choices based on observations on their peers' choices in the study. A high degree of matching occurred, explained by the ability to discriminate the options obtained by viewing others' choices. Choices were more variable prior to switching than after switching. Because of the uneven number of students, habitat matching was not possible. However, Kraft and Baum (2001) found that in instances where this uneven phenomenon occurred, participants were more likely to undermatch than overmatch, thus maximizing each individual's points.

As a systematic replication of Kraft and Baum (2001), Madden and colleagues (2002) conducted a series of studies with discrete-choice and free-choice operant procedures on IFD. The first two experiments examined human habitat matching in discrete trial situations. Participants sat in chairs in a circle and held cards with blue on one side and red on the other. Each color represented a "resource site," which corresponded to available extra credit. Researchers conducted six conditions with the available reinforcement in each resource site varying by condition. In the first experiment, participants were able to observe the choices of their peers and, in the second, were required to make their choices independently and without watching others. The authors observed high degrees of matching in both experiments, with slight undermatching in the second experiment. Researchers conducted Experiment 3 in a free-operant arrangement with participants free to move around a classroom with two resource sites on either side of the room. Researchers told participants their job was to earn points by moving to the zones. The group was sensitive to the contingencies and matched to the point deliveries. However, of the three studies, the free operant arrangement produced the highest degree of undermatching.

Experiment 3 of Madden et al. (2002) provided the closest model of IFD to the ecology literature while maintaining experimental control through structured resource allocation. The free operant experiment provided a model for the current research; we aimed to control reinforcers in a group foraging context without interfering with the organisms' interactions. As such, one of the purposes of this thesis (Experiment 2) was to systematically replicate Madden et al. (2002) with domesticated canines. We chose to study dogs in the current experiment for a number of reasons: 1) understanding canine behavior has been of interest recently with a focus on behavioral principles (Burch & Bailey, 1999; Pryor, 1999), 2) dog daycare offers a semi-naturalistic environment that resembles literature in ecology while still providing avenues for experimental control, and 3) a socially significant bias would be able to be introduced and studied with this population, epitomizing the translational nature of this study through the synthesis of basic principles and application to the natural environment (Edwards & Poling, 2011; Zimmermann et al., 2015). Therefore, the current study's general purpose was to develop a way to assess IFD with the domesticated canine and then attempt to introduce a bias in responding with an added—and socially relevant—stimulus. To accomplish this purpose, I first validated a typical apparatus for dog training on variable-time (VT) schedules (Experiment 1). I then assessed IFD with canines in a free operant arrangement in a daycare setting by systematically changing the VT schedules from the validated apparatus (Experiment 2). Finally, after determining matching occurred in a daycare setting, I introduced a stimulus to promote a bias away from the resource site in which it was placed (Experiment 3).

Experiment 1: Validation of the Treat & Train®

The purpose of Experiment 1 was to identify the suitability of an affordable treat delivery system from the retail market (Premier® Treat & Train® dispenser; see https://drsophiayin.com/category/treat-n-train/)[1] to be used for scientific purposes related to IFD with nonhumans. The Treat & Train® dispenser is a treat delivery system available on the retail market for approximately $120 USD. The dispenser is marketed to dog owners to help train dogs using positive reinforcement, namely through small rewards contingent upon appropriate behavior (Chewy, n.d.; Yin, 2014). The product includes the device, a target stick, and a remote control to deliver treats manually. Despite marketing to a lay audience, the product description explains positive reinforcement to train dogs to complete several obedience behaviors.

Since the product's release, training with the Treat & Train® has expanded into a tool to aid in reactivity and guest arrival rather than merely general obedience (Chewy, n.d.; Yin, 2004). The automation of treat delivery devices allows researchers to expand from applied animal training to understanding basic behavioral processes in canines using a mechanical tool that allows for a high degree of experimental control.

Method

Materials

The Treat & Train® dispenser has dimensions of 40.64 x 26.67 x 25.91 cm and weighs 2.79 kg. According to the product manual, the equipment complies with the limits for a Class B

[1] Note: I received no product support or financial compensation from Premier® or Dr. Sophia Yin to use, evaluate, or report on the Treat & Train®. I thereby have no conflicts of interest with respect to this product.

digital device, pursuant to Part 15 of the Federal Communications Commission Rules (Yin, 2004). The dispenser operates via four D batteries. The dispenser comes with two disks with different-sized holes for kibble or treats to fall. The product includes a target training wand with a detachable base to allow for trick training, heel, or jumping. The handheld remote is made by Radio Systems® Corporation and runs on a 23A-12V battery. The remote allows for distance training from a distance up to 30.48 m and runs on four separate channels, allowing multiple dispensers to be used at once independent of each other. Advertisers describe the product as "one of the first training systems to be tested [using the scientific method]" (Yin, 2004, p. 2).

The machine includes two general settings for treat delivery: remote control to manually deliver a treat, or a "down/stay" option which provides treats on predetermined schedules automatically (See Appendix A for images of the dispenser). The automatic option includes a fixed-time (FT) schedule and a VT schedule with treat rates from 3 s to 300 s. The treat dispenser also can deliver one treat at a time or multiple treats at once.

Procedure

Researchers tested select schedules advertised on the Treat & Train® dispensers to determine how the rate of delivery corresponds with the advertised values. The VT schedules used for analysis were: 15 s, 30 s, and 45 s. I placed two cups of kibble-like training treats into the dispenser. Researchers turned the dispenser to the "on" position in each of the experimental VT schedules. I set the Treat & Train® dispenser to the "down/stay" function with the multi-treat option selected. The "down/stay" function presented treats on the set schedules automatically, rather than with a button pressed by a researcher. Once on, the dispensers dropped treats without interference or additional control from the researchers. Researchers tested the dispensers in 30-min increments. Researchers recorded the time of each delivery, the number of treats delivered, and the number of times the machine malfunctioned (e.g., a jam of treats). I recorded each schedule for a minimum of nine hours, with the 15, 30, and 45 s schedules recorded for 9, 10, and 9.5 hr, respectively.

Data Analysis

A Shapiro-Wilk test of normality determined which statistic was most appropriate to use with the samples. This normality test compares the values of the sample to a normal distribution with the same mean and standard deviation to determine if the sample is normal (Ghasemi & Zahediasl, 2012). To then compare the resulting values from the recorded deliveries with those advertised on the Treat & Train®, I conducted a one-sample Wilcoxon Signed-Rank Test against the advertised values on the Treat & Train®. A one-sample Wilcoxin Signed-Rank Test determines whether there is a significant difference between the advertised values and the resulting values from testing; the *t*-test assesses means and assumes a normal distribution, whereas the Wilcoxon Signed-Rank Test assesses median ranks and is suitable for data that are non-normally distributed. The Wilcoxin Signed-Rank Test compares the median of the tested values from the dispenser against a hypothetical median (Motulsky, n.d.a); in this case, the hypothetical median was the advertised values of 15 s, 30 s, or 45 s.

To assess schedule fidelity and validate the apparatus's accuracy, the dependent variables were the latency between each treat delivery to determine the VT schedule, the number of treats delivered on a given trial, and the number of times the dispenser malfunctioned in a given session. I collected interobserver agreement (IOA) for each duration measure and the number of treats delivered. Two independent observers observed the dispensers and recorded the time of delivery and the number of treats delivered during 30-min sessions. Mean-duration-per-occurrence IOA determines the IOA for each timing and then divides by the total number of timings (Reed & Azulay, 2011). This IOA choice results in a more conservative measure than total-duration IOA. Trial-by-trial IOA results in as stringent of a measure as exact agreement IOA by measuring the number of trials with agreement by the total number of trials. I calculated mean-duration-per occurrence for the VT schedules and trial-by-trial IOA for the number of treats delivered per trial. I did not calculate IOA for the number of malfunctions due to the low prevalence of dispenser error. Instead, I reported the total number of malfunctions per all testing contexts.

Results

Results indicated the VT schedules tested on the Treat & Train® dispensers adequately matched the dispenser's advertised values. The 15-s VT schedule delivered treats on average every 14.00 s (see Table 1). The 30-s VT schedule delivered treats on average every 29.10 s (see Table 2), and the 45-s schedule delivered treats on average every 43.81 s (see Table 3) in 10.5 and 9.5 hr of testing, respectively. The average number of treats delivered in the 27.5 hr of testing was 3.11 treats. Figure 1 shows a cumulative record for a representative 30-min session on each VT schedule.

Schedule Fidelity

Using visual analysis to observe and the Shapiro-Wilk test to confirm, VT 15-s, VT 30-s, and VT 45-s values did not have a normal distribution. Therefore, the nonparametric Wilcoxon Signed-Rank Test assessed the difference between the sample values and the values on the Treat & Train®. The nonparametric Wilcoxon Signed-Rank Test indicated significant discrepancies in duration for the assessed values than the hypothetical median of 15 s, and the actual median = 13.54, $p < 0.001$. The Wilcoxin Signed-Rank Test also indicated significant discrepancies in duration for the 30 s hypothetical median with the actual median = 28.79, $p = 0.04$. The Wilcoxin test did not show disparities for 45 s test with a hypothetical median of 45 s and the actual median = 43.95, p = 0.13.

Inter-Observer Agreement

I calculated inter-observer agreement (IOA) for a minimum of 20% of each duration of the VT schedule and the number of treats delivered on each trial (Friman, 2009; Kelly, 1977). I calculated mean-duration-per-occurrence for the VT schedules with an overall IOA of 96.61% across the three schedules (93.62% for VT-15, 98.43% for VT-30, and 97.77% for VT-45). I calculated trial-by-trial IOA for treat delivery with a total IOA of 96.63% (97.21% for VT-15, 96.93% for VT-30, and 95.75% for VT-45). Inter-observer agreement was collected for both duration and treat delivery for VT-15, VT-30, and VT-45 at 24.91%, 31.34%, and 25.20% of sessions, respectively.

Researchers also analyzed the Treat & Train® dispenser's mechanical reliability by recording the number of malfunctions or jams the device encountered during testing. On the VT-15 s trials, the device jammed seven times over 2066 trials or 0.34% of trials. The VT-30 and VT-45 s trials were similar with six jams over 1180 trials and four jams over 836 trials, or 0.51% and 0.47% of the trials, respectively.

Discussion

Before use in any behavioral studies understanding the apparatuses involved is paramount in research design. The lack of significant difference in the larger of the tested duration value suggests that the Treat & Train® may be a viable behavioral research apparatus. However, the significant difference between the VT-15 s and VT-30 s sample with the advertised value suggests researchers should be cautious in how the Treat & Train® is used.

The differences between the VI-15 s and VT-30 s samples and the hypothetical values may result from several factors. For example, the algorithm programmed for delivery may not average to 15 s or 30 s within the 30-min sessions. Given many research designs involve 30-min or shorter sessions, this would suggest researchers need to be cognizant of the types of studies using shorter durations and collect data on the individual treat deliveries to ensure high integrity within a study. Additionally, human reaction time is limited; therefore, with these short durations, it is plausible human error was not captured by IOA due to average reaction times for both observers. For example, if a treat was delivered 2 s after a prior delivery, a human may not respond to the timer efficiently enough to capture the accurate time. This hypothesis seems unlikely, given the average time on the VT-15 s and VT-30 s sample was a *shorter* duration than predicted. Lastly, the percentage of difference in seconds for the VT-15 s and VT-30 s time are larger proportions than VT-45 s. A 1-s difference from 15 s is 6.66% of the total, whereas a 1-s difference between 45 s is 2.22%. This absolute difference alone may have resulted in statistically significant results from the Wilcoxin despite an average of a one-second shorter duration for all three samples.

Despite the possible limitations of the shorter durations with the Treat & Train®, results suggest the dispenser may have utility as an apparatus with behavioral research. The average treat delivery across all three samples remained consistent at approximately three treats per delivery. In addition, the percentage of times the dispenser jammed or malfunctioned was meager: less than half of one percent for each testing cycle. An advantage of using an apparatus to create VT schedules for behavioral research is reducing or eliminating human error through timing or delivery of the reinforcer. Fleshler & Hoffman (1962) offered an equation to calculate VT schedules; however, those schedules would need to be manually implemented by a trained researcher. Using a machine to deliver treats on a VT schedule eliminates human error involved in this aspect of behavioral research.

Overall, results suggest the Treat & Train® dispenser offers a novel and effective method to study basic behavioral processes in canines without compromising data quality. The Treat & Train® dispenser offers behavioral scientists additional means of conducting research. In this study, researchers assessed the VT timers of specific durations and how many treats were delivered and how many times the device malfunctioned in a testing period. In addition to the VT timers, the Treat & Train® offers FT schedules, a target to teach analog responses, an ability to deliver treats manually, and additional durations ranging from 3 to 300 s. Although not explicitly explored in this study, the device offers a number of means to accomplish behavioral research.

Experiment 2: Evaluation of a Novel Procedure to Describe Group Foraging in Canines

The purpose of this experiment was to use the validated Treat & Train® to set up a free-operant arrangement in a dog daycare setting. By experimentally manipulating the VT schedules, we aimed to determine if domesticated canines in a daycare setting conform to IFD.

Method

Materials and Setting

I composed the setting to an 8.53 x 8.83 m space in which dogs could move freely. Researchers placed colored duct tape on the floor to make a 4.57 x 3.05 m "resource site" on either corner of the room. I chose the size of the resource sites to a) have enough space between the sites to have the staff member with one dog on either side walk in the neutral zone, and b) make the area large enough to hypothetically hold all dogs in the experiment at one time. I placed treat dispensers in the corner of each resource site 1.82 m from the floor to allow the treats to fall freely into the resource site (see Appendix C for a visualization). I placed two cups of kibble-like treats into each dispenser and turned the dispensers to the same channel to ensure identical timing using a single remote.

Participants

I recruited six privately-owned domesticated canines for this experiment. Each dog was a current member of Wagmore Canine Enrichment® as a daycare attendee and was familiar with the other dogs in the study. All dogs were adults (1-6 yrs), comprised of both mixed-breeds and purebred dogs. As a requirement to attend daycare, all dogs passed temperament tests administered by the Wagmore staff (see Appendix B for a sample of the temperament test). None of the dogs had experience with experimental or the Treat & Train® system. The Institutional Animal Care and Use Committee approved all components of this research with Animal Use Statement 251-01 (see Appendix C for an image of the consent form).

Magazine training involved eight dogs. However, one animal displayed fear responses toward the beep of the Treat & Train® and was subsequently removed from the study. A second dog withdrew from the study prior to the first condition when the owner took the animal home from daycare, leaving a final sample of $n = 6$ dogs.

Pre-Session Training

Prior to running sessions, I introduced all canines to the Treat & Train® through magazine training in the group setting. I turned on one dispenser for 90 s where the machine would emit a beep and deliver treats, followed by 90 s on the opposite treat dispenser, both at a VT 10-s schedule. The final two min of magazine training involved both dispensers running on 10-s VT schedules concurrently to approximate the experimental sessions. A staff member turned off the lights in the session room after magazine training. One staff member remained in the session area during all conditions.

General Procedures

I evaluated treat dispensers for malfunctions and added treats prior to each condition. A researcher turned the lights off in the experimental area between each condition while others prepared the dispensers. One 15-min condition involved two concurrent operant VT schedules with the Treat & Train® (Table 4). Dogs moved freely between resource sites. The procedure was based on that described by Madden et al. (2002, Experiment 3). The treat dispensers automatically delivered treats at the specified schedule while a researcher recorded the time. I recorded data via video camera and coded off-site. Research assistants and I coded videos and collected IOA from the videos.

Researchers set up Treat & Train® dispensers on opposite corners of the experimental area, from 1.83 m off the floor such that treats could fall into the resource site (see Appendix D for a full schematic of the room). After magazine training, I implemented the four IFD conditions (see Table 4 for schedules). Each session lasted 1 hr in duration. To start a session, I turned the lights off, set up each treat dispenser to the required VT schedule, and started the dispensers while simultaneously turning the lights on in the experimental space. Due to the free operant set-up, dogs were free to move in and out of the resource sites throughout the sessions and during the set-up times between sessions. Dogs remained in the experimental space for the duration of the session. Upon completing the study, dogs were either returned to their owners or remained in the daycare setting until the end of the day.

Data Analysis

Researchers coded each condition for treat deliveries, number of dogs in each site, malfunctions of the dispenser, and the time each of these events occurred. I defined treat delivery as each instance the dispenser released treats. I coded the sites as the "Blue" resource site, the "Red" resource site, or "Neutral," which represented the open space between the two resource sites. I coded the dogs as being in a resource site if at least one paw was in a resource site at the time of delivery, as defined by an audio "beep" from the Treat & Train® dispenser. Researchers also coded any time a malfunction occurred with a treat dispenser preventing treat delivery for that trial. I coded the time, in seconds, for each event relative to the start of the condition and the latencies between each treat delivery.

Researchers recorded the frequency of treat deliveries for each resource site and the total number of dogs in each resource site. The number of total dogs in the Red resource site was divided by the number of total dogs in the Blue site for each condition, $\frac{N1}{N2}$. The number of treat deliveries for the Red site was divided by the number of treat deliveries in the Blue resource site, $\frac{R1}{R2}$. I log-transformed the resulting values for both dogs and treat deliveries as dictated by the IFD equation. I analyzed the data using Graph Pad Prism® version 8.3.1. I used an Extra Sum of Squares F-Test to examine whether the 95% confidence interval (CI) of the fitted (a) bias parameter contained 0.0 and (b) slope parameter contained 1.0. The null hypothesis for the Extra Sum of Square F-Test is that the simpler, or in this case, hypothetical, model is correct (Motulsky, n.d.b). The purpose of an Extra Sum of Squares F-Test is to balance the improvement of fit from the sum of squares with more parameters. If one fails to reject the null hypothesis, there is no compelling evidence to reject the simpler model. The Root Mean Square Error (RMSE) is the standard deviation of the residuals and measures how concentrated the data points are around a line of best fit. Typically, a smaller RMSE value demonstrates the residuals hover more closely to the line of best fit. A value of 0 would indicate a perfect fit to the best-fit line.

I collected minute-by-minute locations of the dogs by recording the total number of animals in a site at each treat delivery every minute and dividing by the total number of instances of treat delivery per minute. I calculated the expected number of dogs in the Blue condition by taking the total number of active dogs each minute and dividing by the specified ratio per condition.

Results

Researchers collected IOA by having two individuals code the recordings of sessions independently. Independent researchers coded for the number of dogs at both the Blue and the Red resource sites at the time of treat delivery. I collected trial-by-trial IOA for 50% of the videos, and IOA was 91.61% (range: 87.34%-95.88%).

Figure 3 shows the results of the first session modeled by the IFD equation. The IFD rendered a best-fit slope of 0.59 and a best-fit y-intercept (bias) of -.07; the model sufficiently account for the data with an $r^2 = 0.82$. The RMSE for the line was 0.14. The 95% CI for the slope fell between -0.25 to 1.43, meaning there is a 95% chance the slope falls within those values, which contains 1.0. The slope of the line fit to the data are not significantly different than habitat matching or a slope of 1. Regarding the y-intercept, the 95% CI fell between -0.44 and 0.30, containing 0.0. The y-intercept did not significantly differ using a comparison of fits from 0 with $p = 0.50$. Visually, undermatching appears to occur in the sample, which is representative of much IFD work (Kraft & Baum, 2001). The gray line depicts participants' predicted distribution based on the IFD equation, or habitat matching (Equation 5).

Figure 4 depicts the aggregate number of dogs in each resource site in 1-min "bins." The total number of dogs in the Blue resource site at the time of treat delivery for each min is depicted with closed circles, with error bars representing standard deviation (SD). The dotted line shows the "expected" number of dogs in the resource site by taking the total number of dogs in either resource site during each bin, dividing by the number of treat deliveries in each bin, and finally dividing the total by the ratio value for each condition. Overall, the dogs appear to distribute themselves as predicted by IFD as the session progressed. Final "bins" tended to align with predicted matching values more closely than the initial bins, as demonstrated by closer adherence to the dotted line depicting habitat matching.

Discussion

IFD adequately describes canine foraging behavior in controlled environments. Results indicated matching occurred in the canine sample with a slight visual appearance toward undermatching within Experiment 2, consistent with extant literature on group foraging. The lack of a bias further supports the evidence that canines conformed to IFD when no additional stimuli were included. However, with only 4 data points, the number of conclusions drawn from statistical analysis must be tempered. Despite only 4 data points, the aggregate data (Figure 4) demonstrate how with experience in each session, the canines conformed to IFD. While each session lasted only 15-min, the dogs could distribute themselves to best maximize the delivered resources. The proportion of variance accounted for by IFD was similar to those in other ecological studies (Kraft & Baum, 2001; Madden et al., 2002). I achieved within-session replication, and therefore, a demonstration of experimental control through the replication of conditions.

As an initial study evaluating whether canines in a naturalistic environment conform to IFD, the current study offers researchers across multiple disciplines a better understanding of environmental variables that may influence nonhuman organisms' behavior with substantial experimental control. Basic researchers typically study phenomena outside of the naturalistic environment to demonstrate control. Applied researchers then extend these laboratory findings to socially significant events. On the other hand, translational work bridges basic and applied research by considering the everyday relevance of the research question while adhering to basic principles of behavioral science and demonstrating experimental control (Critchfield, 2011b; Mace, 1994).

The current study is unique in that it offers a translational approach to IFD with canines. I conducted the work in a naturalistic environment; this is the same environment in which the dogs spend daycare. An equivalent approach would be conducting research in a classroom when studying the behaviors of preschoolers. However, an advantage of the current arrangement with canines is that experimental control is more easily acquired through the removal of many extraneous variables such as toys, cleaning equipment, or additional humans. In this way, the current study examined basic behavioral mechanisms through schedules of reinforcement without the limitations typically observed in applied settings.

The current study demonstrates IFD in a novel population with a demonstration of experimental control through replication. Many IFD studies with nonhuman animals have either taken place in highly controlled settings, such as operant chambers, specialized feeding areas, or across acres or miles of terrain in the natural environment. This experiment offers a bridge between these two dichotomous research domains by combining a highly controlled environment with a naturalistic one without sacrificing vital aspects of either environment.

Despite the strengths of Experiment 2, there are limitations to consider. First, there may have been satiation effects as fewer dogs participated in the last few minutes of the last condition. It may be more likely that the canines adhered to the temporal patterns of being picked up at the end of the day rather than satiation, as a limited number of treats were delivered to 6 different dogs in the course of the hour-long session. Further validation may allow researchers to understand better the degree to which satiation plays a role in IFD with canines in a similar experimental arrangement. Future research must also account for the time of day, as there was a noticeable decline in participation in the last few minutes of the study when owners typically pick up their pets.

Experiment 2 offers a bridge between highly controlled assays and naturalistic foraging studies conducted in ecological fields. Using the Experimental Analysis of Behavior framework, behavior analysts have the opportunity to inform other disciplines, such as ecology, of ways to study foraging behavior with a high degree of experimental control. This experiment also provided a strong methodological foundation for Experiment 3. With an understanding of how canines distribute themselves in a daycare setting by manipulating the schedule of reinforcement, we could then assess whether additional variables would introduce a bias. Assessing a bias is impossible without first establishing a baseline and ensuring various components such as the Treat & Train® are appropriate apparatuses in a naturalistic environment.

Experiment 3: Introduction of a Bias through a Deterrent

Behavior problems are common complaints of dog owners, including but not limited to barking (Beaver, 1994; Campbell, 1986). To reduce the frequency and intensity of barking, many owners turn to aversive contingencies such as shock collars or spray collars (Juarbe-Diaz & Houpt, 1996). Owners typically prefer the use of spray collars to shock-collars and deem them more humane (Moffat et al., 2003). Furthermore, the Certification Council for Professional Dog Trainers will not condone the use of shock collars, but allow the use of spray collars under specific conditions (CCPDT.org, n.d.; Juarbe-Diaz & Houpt, 1996; Moffat et al., 2003). Spray collars are designed to deliver a spray contingent upon barking, often with either a remote for manual delivery or a sensor that sprays automatically when the animal barks. The spray collar typically comes in two forms: citronella scented or unscented. Spray collars effectively reduce the frequency of barking, particularly when used continuously as compared to intermittently (Wells, 2001).

Moffat and colleagues (2003) assessed the difference between citronella scented spray and an unscented spray to reduce problematic barking in canines at a veterinary hospital. The study aimed to directly compare a citronella spray collar's efficacy compared to the unscented version. Researchers tested 30 dogs with the citronella collar, 29 with the scentless only, and 21 were involved directly compared with both the citronella and scentless, counterbalanced across dogs. Both collars showed a statistically significant improvement in barking as compared to controls. The improvement in the citronella collar as directly compared to the scentless was not significant. Still, it trended toward significance with seven instances in which the citronella collar showed improvements in barking, whereas the scentless did not. The authors suggested that olfactory sense may play a role in the efficacy of spray collars.

With the improvement from both spray collars, researchers may find difficulty parsing apart the role of citronella becoming a conditioned punisher, as it was always paired with the spray. Current advertisements claim the scent of citronella alone may act as a deterrent for behaviors other than barking, such as digging, aggression, and other behavioral problems (ASPCA, n.d.). According to a number of pet-friendly websites, citronella is a "natural deterrent" because canines do not prefer the citrusy smell from the lemongrass plant (e.g., Millburn, n.d.; dogsndogs, 2020.) Although this explanation may be plausible, behavioral scientists may also describe this phenomenon as avoidance responses of dogs to a conditioned punisher from citronella collars' spray-action. Most citronella collars spray a small amount of citronella-scented liquid under the mouth area of dogs when engaging in inappropriate behavior, and this spray could be paired with the smell of citronella alone.

The purpose of Experiment 3 was two-fold: (1) replicate Experiment 2 to determine whether IFD could describe the behavior of the domesticated canine in a daycare setting and (2) empirically test citronella as a deterrent for common behavior problems with dogs by evaluating if a bias away from the stimulus occurred as described by IFD.

Method

Baseline

The Institutional Animal Care and Use Committee approved all components of Experiment 3 with Animal Use Statement 251-01. I conducted a direct replication for Experiment 2 in a 9.14 m x 10.36 m space with 3.66 m x 4.27 m resource sites. I recruited 12 novel animals for this study, with none withdrawing early. All dogs were adults (1-6 yrs) and were both naïve to the Treat & Train® and citronella spray collars through owner and daycare staff verification. I recruited both purebred and mixed-breed dogs. All experimental manipulations remained constant to Experiment 2: the Treat & Train® dispenser remained approximately 1.83 m from the ground, and the same four VT conditions were tested.

Deterrent Condition

I recruited a subset of $n = 8$ dogs from the baseline replication session for the citronella condition. I used the same room and dimensions from the replication session. Magazine training and general experimental conditions were also held constant.

I sprayed PetSafe® Spray Control Citronella Refill[2] spray into a rag and placed it into an 18.93-liter pail with half-inch holes spaced 2.54 cm apart around the entirety of the pail (Appendix D). I chose the PetSafe® brand for the study as it is a commonly used product for dog owners. Researchers sprayed enough citronella spray onto the rag to approximate filling a standard spray collar (approximately holding the canister for 30 s). I placed the citronella spray pail in the center of the Blue resource site. I set a pail with a water-soaked rag into the Red resource site to control for the additional stimulus in the resource site. Therefore, both resource sites contained an additional stimulus with only the citronella scent differing between the sites. After the first session with citronella in the Blue resource site, I replicated the session with the same animals and the citronella in the Red site with a water-soaked rag in the Blue site. I conducted the two citronella sessions on the same day with an approximately 20-min break in between sessions.

Results

Inter-observer agreement occurred for 50% of the videos obtained from the citronella sessions. Trained observers watched and coded videos with the same criteria as Experiment 2. In the first citronella session, trial-by-trial IOA was 98.22% (range: 95.35%-100%). The IOA for the second citronella conditions was 92.53% (range: 89.80%-96.55%).

[2] Note: I received no product support or financial compensation from PetSafe® to use, evaluate, or report on the PetSafe® Spray Control Citronella Refill. I thereby have no conflicts of interest with respect to this product.

The replication with new dogs indicated similar results to Experiment 2 with the IFD equation rending a best-fit slope of 0.94 and a best-fit y-intercept (bias) of -0.08; the model sufficiently account for the data with an $r^2 = 0.81$ and an RMSE of 0.07. Using an Extra Sum of Squares F-test as the comparison of fits test, neither the slope nor the y-intercept were significantly different than the hypothetical values representing habitat matching, 1 for the slope and 0 for the y-intercept $p = 0.88$ and $p = 0.58$ respectively (see Figure 5). The 95% CI for the slope fell between 0.58 and 1.53, meaning there is a 95% chance the slope falls within those values. The 95% CI for the y-intercept was -0.13 and 0.25, containing 0.0.

A second session introduced the citronella on the Blue resource site (Figure 6). The rendered best-fit slope was 1.05, and the best-fit y-intercept was 0.06. The $r^2 = 0.98$, and the RMSE was 0.07. A comparison of fits test indicated no significant differences for either the slope or the y-intercept with $p = 0.67$ and $p = 0.32$, respectively. The 95% CI for the slope was 0.58 to 1.53, and the 95% CI for the y-intercept was -0.13 to 0.25. I moved the citronella to the Red resource site for the last session with a rendered best-fit slope of 0.68 and a y-intercept of 0.07; the $r^2 = 0.87$, and the RMSE was 0.19 (see Figure 7). The comparison of fits test indicated no significant difference for either the slope ($p = 0.24$) or the y-intercept ($p = 0.54$) from 0 or 1 respectively. The 95% CI for the slope was -0.13 to 1.50 and was -0.32 to 0.46 for the y-intercept.

The aggregate number of dogs in each resource site for the replication of Experiment 2 can be found in Figure 8. Figures 9 and 10 display the aggregate number of dogs in each citronella condition. These figures display the total number of dogs in the Blue resource site at the time of treat delivery for each min depicted with closed circles, with error bars included. The dotted line represents the "expected" number of dogs in the resource site by taking the total number of active dogs and dividing the values by ratio for Blue in each condition. Therefore, the data visually depicts how closely the group conforms to habitat matching by how close the number of dogs in the site are to the line showing habitat matching. There is visually more variability in the dogs' locations in the first sessions compared to the later sessions shown through a further distance from the dotted habitat matching line. Within each session, the dogs tend to conform to habitat matching more closely toward the end of the condition than the initial trials of the condition. I observed the same phenomena at the session level as well; the dogs engaged in more variable responding at the beginning of the session than at the end.

Discussion

Experiment 3 extends Experiment 2 by demonstrating IFD within a canine population and manipulating additional variables to attempt to establish a bias. The current study only used an aversive stimulus, citronella oil, as a potential bias as it is one of the most common deterrents on the market for dog owners. The initial study in Experiment 3 also functioned as a direct replication of Experiment 2, furthering the reliability of this type of methodology in the current environment.

Results of Experiment 3 suggest citronella does not function as a deterrent for canines. One potential explanation is that, perhaps, the scent of citronella requires conditioning as a punisher. For example, Hake and Azrin (1965) paired a clicking tone and a color change in an operant box with a shock. The stimulus (tone and color change) was presented immediately before a shock for pigeons working on a VI schedule for food. The researchers then presented testing contexts in which the stimulus was presented alone. If pigeons suppressed their behavior for the stimulus alone, researchers achieved a suppression effect, and the stimulus functioned as a conditioned punisher. The citronella scent could be functioning as a conditioned punisher in much the same way. When citronella is used in the context of a spray collar, the smell of citronella may become paired with the spray action to the underside of the chin of the animal (Moffat et al., 2003).

Additionally, prior punishment studies with humans suggest water misting may act as a punisher for self-stimulatory behavior (Friman et al., 1984) and self-injurious behavior (Bailey et al., 1983; Dorsey et al., 1980). Furthermore, Dorsey and colleagues (1980) successfully paired the word "no" with water mist to develop a secondary punisher. Therefore, it is possible that the citronella scent takes on the properties of the spray itself and becomes a conditioned punisher. The conditioned punisher theory may explain why Moffat and colleagues (2003) observed some differences between scentless and scented spray bark collars. For owners who use a citronella-scented spray collar, the conditioned punisher of the smell of citronella may act as a deterrent for other locations, such as digging areas or the kitchen table. Therefore, these owners may see an anecdotal difference in their respective animals' behaviors.

All dogs recruited for the current study were naïve to citronella's scent – as used in a spray collar or otherwise. The data from Experiment 3 show the smell alone did not act as a deterrent for the animals. The lack of bias from both citronella conditions suggests the citronella scent alone functioned as a neutral stimulus within the IFD paradigm. The data suggest matching improved from the baseline condition to the first citronella condition, which is expected as organisms repeatedly experience the contingencies (Baum & Kraft, 1998). The subset of dogs from the first session was recruited for the citronella conditions, meaning the animals gained experience through repeated exposure to the IFD paradigm, explaining better matching in the first citronella session.

To our knowledge, this is the first experiment to assess citronella scented spray apart from the spray action collar with the domesticated canine. Numerous reports to the general public about the benefits of citronella as a deterrent may be based on a partial truth, or, more specifically, a misunderstanding of conditioned punishers. By introducing citronella smell alone, researchers can better understand the role of popular deterrent stimuli used with the privately-owned domesticated canine without introducing a punisher.

The most apparent limitation to Experiment 3 may be the lack of bias due to the citronella. While this appears to be a limitation, the results may provide important insight into the use of citronella, especially when taken with the results of other studies. For example, Moffat and colleagues (2003) saw no significant difference between scentless and citronella-scented spray on barking. Both collars reduced the frequency and intensity of barking, which, by definition, would suggest the spray functioned as a punisher. We were able to assess the effects of citronella without introducing a potential punisher directly to each dog. These two studies taken together suggest citronella has little if any aversive properties on its own, but when paired with an active spray, citronella may develop aversive properties. Future research should evaluate the current experimental arrangement with dogs who have a history of a citronella spray collar to test this hypothesis.

A limitation to the conditioned punisher theory from Experiment 3 is that the lack of effect does not indicate a null effect. It is possible other confounding variables resulted in no bias away from the citronella. Some variables could be an inability for the animals to smell the citronella due to low concentrations, failure for the containers to release the scent into the resource sites, or difficulty containing the smell to the resource sites alone. Given canines' generally superb olfactory organs (Fox, 1964), it is unlikely the first confound played a role in the current study. Additionally, anecdotal video evidence shows dogs approaching the containers to sniff at the citronella containers, which likely eliminates the second confound. Despite turning off the air heating and cooling system of the building and keeping all doors closed during sessions, there is a possibility the citronella scent permeated through the entire session area. Future research could evaluate how the smell of citronella moves beyond the resource sites or expand resource sites such that there is a reduced probability of overlapping scents. Additional studies could also assess bias before and after citronella collar training. If citronella functions as a conditioned aversive, the citronella may bias responding away from the resource sites after conditioning in the form of being sprayed.

Another limitation specific to Experiment 3 is the reduction in fit from the Blue citronella condition to the Red citronella condition. Typically, as organisms are exposed to the contingencies, they improve on IFD assessments (Baum & Kraft, 1998). However, the citronella sessions were the only two sessions that researchers conducted on the same day. Satiation or attrition may have played a role in the final condition, as the dogs had been exposed to nearly 2 hr of sessions by the end of the day. Researchers terminated the last session after 10 min because of an attrition effect from the dogs. Half of the animals laid down or stopped responding during the last portion of testing. Although required to maintain the community sample, future research should attempt to separate all sessions on different days to reduce this effect. General distractions such as doors opening may have also introduced unaccounted variability, which occurred more frequently toward the end of the second condition, as the daycare continued its daily operations.

General Discussion

The study as a whole offers several additional strengths to the literature. Many ecological studies of IFD are descriptive assessments rather than experimental studies. The current study provides an ecologically valid experimental arrangement by experimenting in the participants' natural environment. The manipulation of independent variables through the schedules of treat deliveries provides experimental control, which is nearly impossible when studying broad migration patterns or other areas of ecology. A translational study such as this may continue to provide evidence of IFD in these broad naturalistic environments.

The current study is also one of a limited number of studies to experimentally assess bias in IFD and the first to do so in a translational setting. Researchers can use bias to determine differences in stimuli that have not been experimentally tested due to the potentially aversive properties of the stimuli. This paper uniquely addressed the gap in the literature by looking at possible deterrents used in the daily lives of pet owners. Citronella is advertised as a deterrent, but it is difficult to parse apart the aversiveness of the smell alone from the spray action of the spray collar. Attempting to show these differences in a novel way provides a more ethical means of assessing aversive stimuli. Future research could replicate a bias with other potentially aversive smells such as the odor of a skunk or bear urine.

The use of privately-owned dogs offers a unique set of strengths and challenges that provide different lines of behavioral research. Having access to the population of interest is ideal even when conducting basic research such as in Experiment 2. Authors were able to utilize the data obtained from the initial study with privately-owned dogs to applicable follow-up studies, namely the use of citronella as a deterrent.

As opposed to other basic research with nonhuman animals, privately-owned canines are exposed to many different histories that may impact responding. For example, I asked owners to limit the amount of food provided the morning of the study but had no way of validating the instruction. Additionally, the treats used were small, kibble-like training treats that may not have been highly preferred based on the respective residences' treats. For example, jerky treats, raw treats, and other soft treats are available outside of the experimental space. They are often fragrant, meaty, or in different ways more valuable than treats that resemble typical dog kibble. A formal preference assessment was outside of the scope of the study and, moreover, the Treat & Train® dispenser required a specific type of treat to prevent malfunctions.

The current study offers several avenues to conduct future research – whether translational, basic, or applied. Given the popularity of the domesticated dog and the surge in positive reinforcement training, understanding how stimuli may function is socially relevant work. The recent boom in applied animal work resulting from changing training practices will likely result in several behavioral studies using the domesticated canine (Burch & Bailey, 1999; Pryor, 1999). In fact, functional analysis research has evaluated dog problem behavior (Dorey et al., 2009; Feuerbacher & Wynne, 2016; Winslow et al., 2018). Behavior analysts are also applying principles of behavior to shelter dogs (e.g., Protopopova et al., 2012; Protopopova & Wynne, 2014). Providing adequate training for volunteers (Howard & DiGennaro Reed, 2014) and owners (Echterling-Savage et al., 2015) are other ways behavior analysts have used their skills to aid in animal welfare. Sophia Yin and colleagues evaluated the Treat & Train® for problem behavior of dogs at the front door as well (2008). These applied studies have direct social relevance, but I challenge behavior analysts to also consider basic and translational research when considering canines for behavioral research.

Regarding the Treat & Train® dispenser, researchers may create cost-effective ways to conduct basic research with novel populations. Expenses include one-time events such as purchasing the site or building, operant chambers and other equipment, and cleansing units (Walker & Stevenson, 1967). Then, recurring costs accrue, such as bedding, food, and the animals themselves. The recurring fees are embedded into a per diem ranging from $0.53 for frogs to $21.64 for calves, using one public institution with care rates publicly available as an exemplar for costs (University of Michigan, 2020). Daily care costs for rodents range from $0.84 to $2.13. These costs quickly add up when considering the number of organisms and the length of experiments.

Given the difficulty in maintaining these costs, creating novel methods to demonstrate the basic principles of behavior would behoove behavior analysts. Additionally, ABAI has 33 accredited universities with four additional universities applying for accreditation (ABAI, 2020). Accredited programs require experimental analysis of behavior courses. With the difficulty of maintaining live organisms for demonstrations, some programs may resort to online demonstrations such as the RatLab toolkit (Schönfeld & Wiskott, 2013) or Sniffy, the virtual rat (Graham et al., 1994). Utilization of the Treat & Train® dispenser would likely provide demonstrations with live animals, especially because students prefer live rodents to virtual ones in learning courses (Elcoro & Trundle, 2013).

In addition to demonstrations, researchers can study basic behavioral paradigms with these novel laboratories. The current study assessed IFD, but a matching study could be another avenue of exploration with the Treat & Train®, especially with the attached target stick as an easily obtained analog response. Rather than merely measuring the organism's location, the target stick could be a functional equivalent to a nose poke or a lever-press. Future studies could also assess bias with additional potentially aversive or even appetitive stimuli. Competitive behavior or foraging strategies at the individual level in group settings may also be of interest when studying canines. However, researchers need not limit themselves to demonstrations of the matching law or its derivates with the Treat & Train®. They could use the domesticated canine for both basic and applied studies. Other applied studies using the Treat & Train® to teach socially appropriate behaviors would extend the literature into the more strictly "applied" sector of behavior analysis. Researchers will only be limited by their creativity when exploring this new apparatus.

Grouping research into basic or applied ends of the continuum does not limit exploring areas of interest. Experiment 2 was a demonstration of IFD and therefore, a basic study demonstrating behavioral mechanisms. Experiment 3, on the other hand, is built from those principles to study a socially valid product. These two studies are arguably more robust than independent pieces and, therefore, bridge the gap from basic to applied with a true translational study. Furthermore, by understanding ecological literature, behavior analysts may use these studies to "bridge the gap" to different fields. Behavioral perspectives can be a tool for many areas of study outside of our domain of expertise. Bridge-studies such as the current experiments will hopefully provide a link between basic and applied research and extend the field into new and exciting disciplines.

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Figure 1

Cumulative Record of Representative Sessions during Treat & Train® Testing

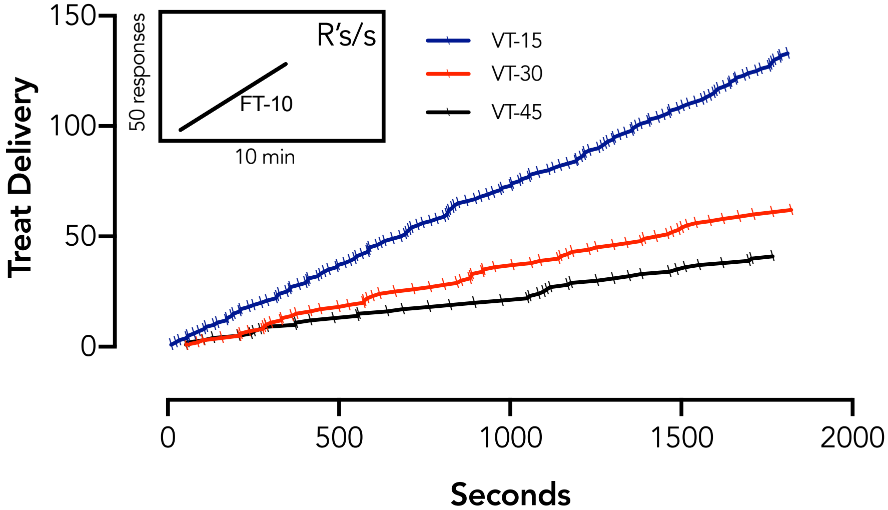


Figure 2

Example of Habitat Matching

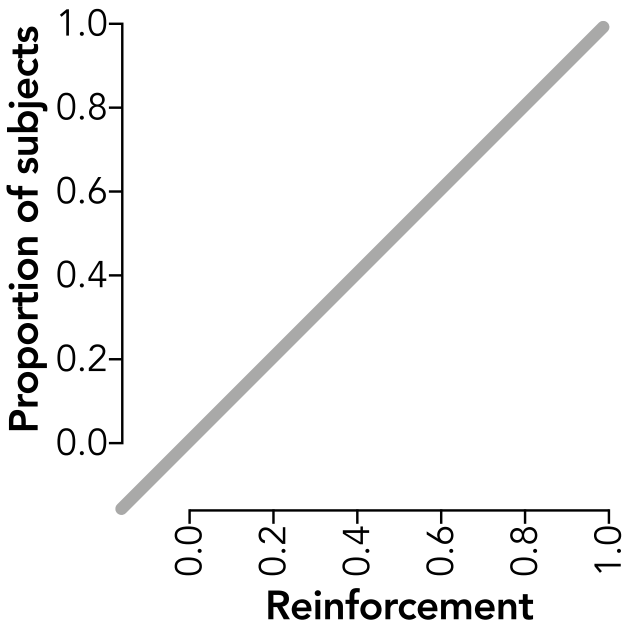


Figure 3

Choice Relations in Logarithmic Coordinates for Experiment 2

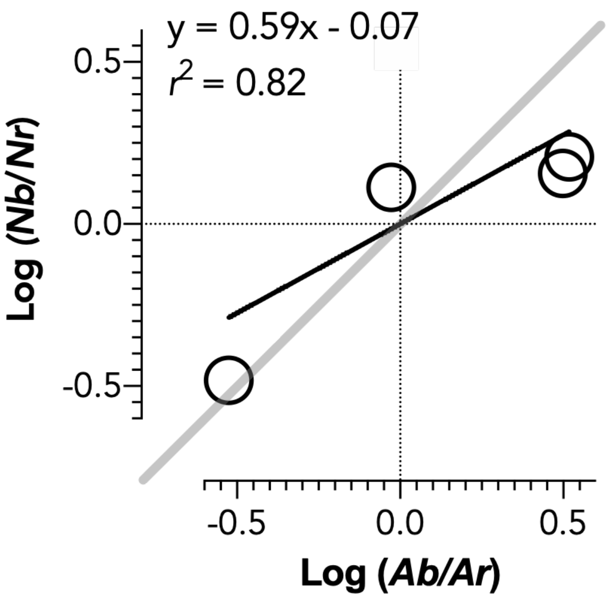


Figure 4

Aggregate Number of Dogs in Minute by Minute "Bins" for Experiment 2

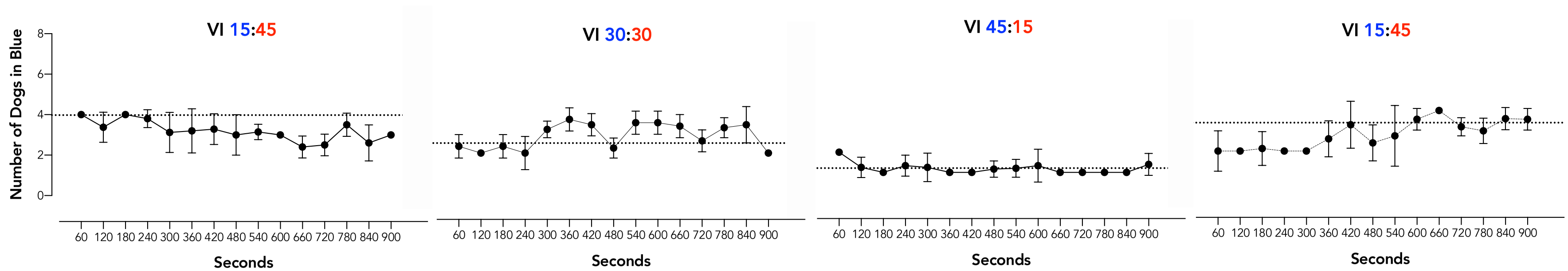


Figure 5

Choice Relations in Logarithmic Coordinates for Experiment 3

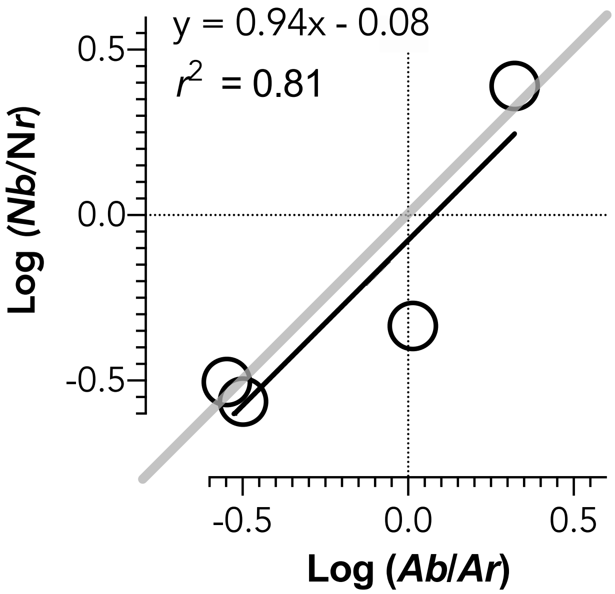


Figure 6

Choice Relations in Logarithmic Coordinates for Experiment 3 with Citronella in the Blue Resource Site

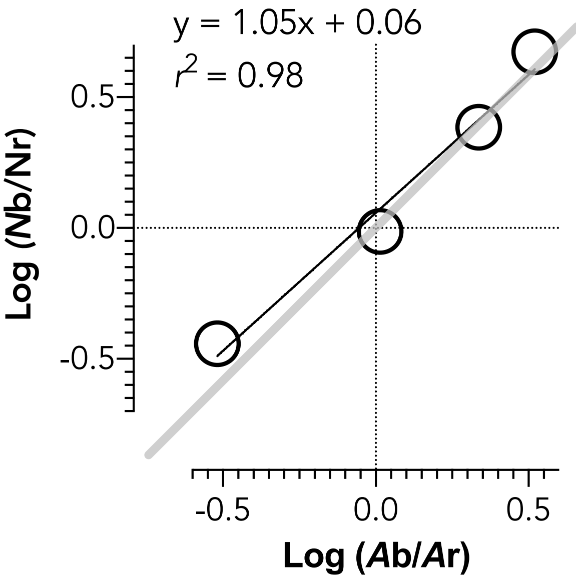


Figure 7

Choice Relations in Logarithmic Coordinates for Experiment 3 with Citronella in the Red Resource Site

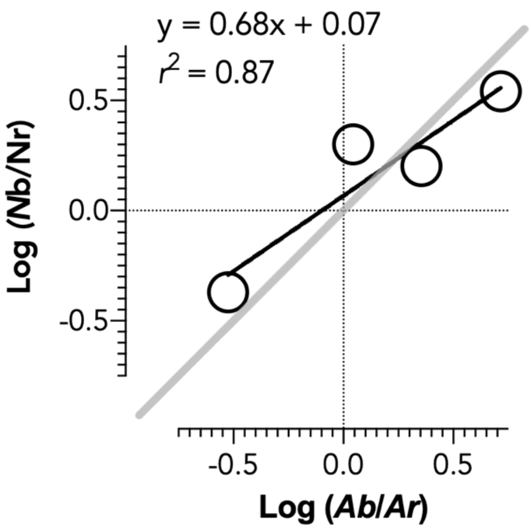


Figure 8

Aggregate Number of Dogs in Minute by Minute "Bins" for Experiment 3

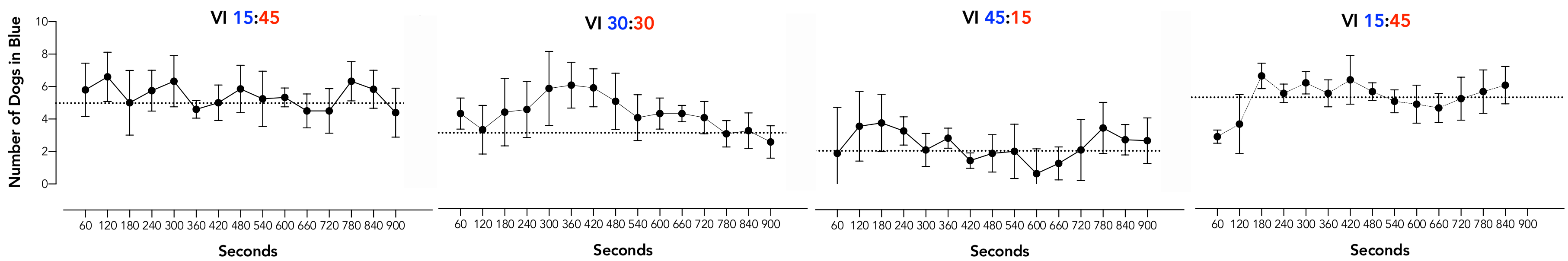


Figure 9

Aggregate Number of Dogs in Minute by Minute "Bins" for Experiment 3 with Citronella in the Blue Resource Site

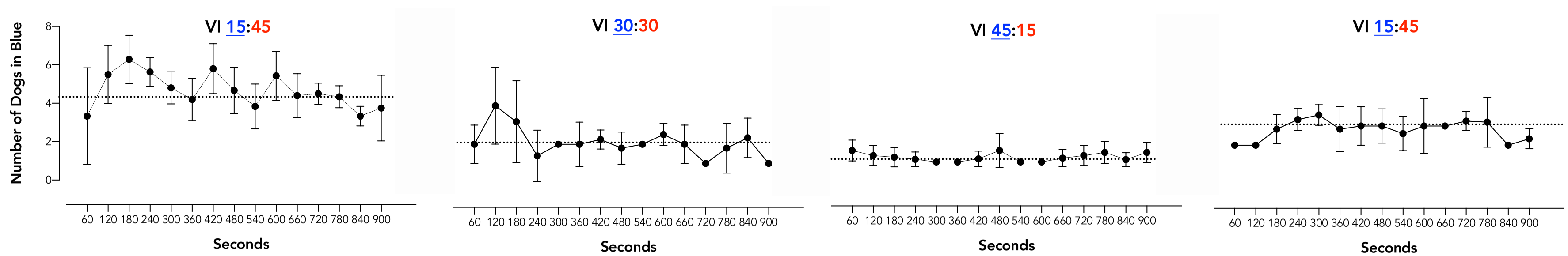


Figure 10

Aggregate Number of Dogs in Minute by Minute "Bins" for Experiment 3 with Citronella in the Red Resource Site

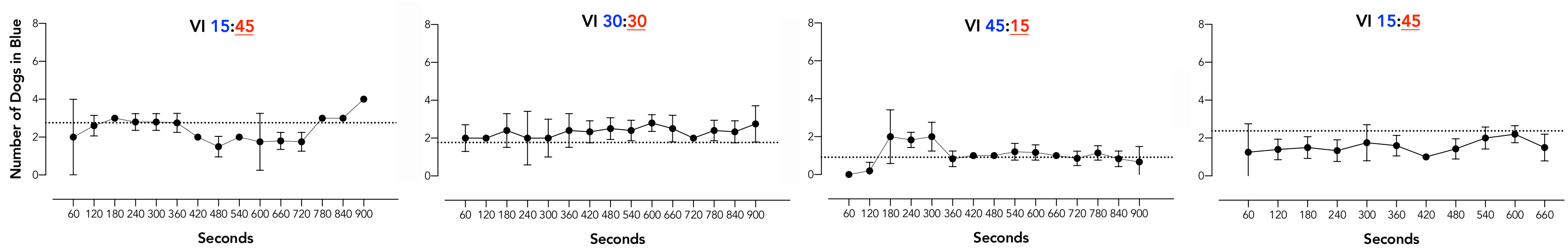


Table 1

Average Treat Delivery on VT-15 Second Sessions

Session	Average Time (s.ms)	Treats Delivered
1	13.84	2.89
2	13.80	2.98
3	13.51	2.94
4	13.81	3.00
5	15.93	2.88
6	14.58	3.03
7	13.49	3.09
8	14.65	3.27
9	13.49	2.96
10	14.69	2.93
11	13.84	2.93
12	13.61	3.04
13	13.56	3.13
14	13.64	3.07
15	13.71	3.13
16	13.81	3.13
Total	14.00	3.03

Table 2

Average Treat Delivery on VT-30 Second Sessions

Session	Average Time (s.ms)	Treats Delivered
1	32.84	3.30
2	29.14	3.10
4	30.09	3.12
5	28.46	3.09
6	29.33	3.08
7	28.51	3.13
8	28.35	3.09
9	29.12	3.29
10	28.69	3.14
11	28.25	3.08
12	29.04	2.97
13	29.90	3.10
14	28.70	3.15
15	27.71	3.11
16	29.37	3.23
17	29.71	3.18
18	28.25	3.31
19	30.40	3.08
20	28.16	3.08
21	28.15	3.16
Total	29.11	3.14

Table 3

Average Treat Delivery on VT-45 Second Sessions

Session	Average Time (s.ms)	Treats Delivered
1	41.83	3.23
2	44.32	3.22
3	42.39	3.16
4	45.47	3.08
5	44.16	3.21
6	42.57	3.09
7	42.58	3.16
8	43.83	3.04
9	44.37	3.12
10	42.14	3.20
11	43.64	3.02
12	44.05	3.05
13	45.97	3.13
14	45.14	3.24
15	43.72	3.00
16	43.09	3.12
17	44.50	3.14
18	44.19	3.37
19	44.42	3.10
Total	43.81	3.14

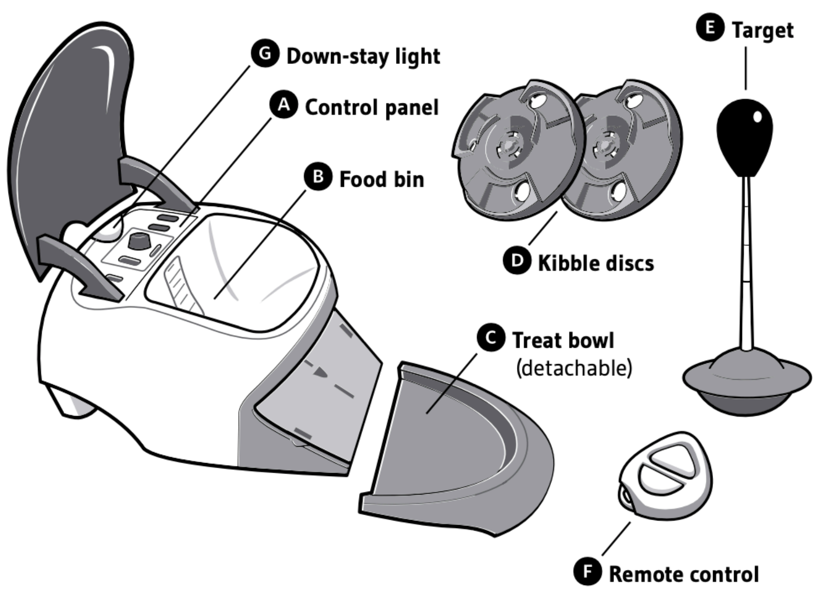
Table 4

VT Schedules per Condition

Condition	Blue	Red	Ratio
A	45	15	3:1
B	30	30	1:1
C	15	45	1:3
A	45	15	3:1

Appendix A

1 Know Your Treat&Train®



Appendix B

Trial Daycare Assessment

Dog's Name: __

Owner's Name: __

Bite inhibition

Poor				Excellent
1	2	3	4	5

Ability to appropriately correct other dogs if offended or overwhelmed during interaction

Poor				Excellent
1	2	[illegible]	4	5

Ability to share space ([illegible] et, water bowl area, etc. with other dogs)

Poor				Excellent
1	2	3	4	5

Ability to receive corrections from other dogs without striking back inappropriately

Poor				Excellent
1	2	[illegible]	[illegible]	5

Ability to allow leashing up for walks outside (dog does not run from person with leash)

Poor				Excellent
1	2	3	4	5

Ability to be called by day care monitors from play or overexcited play

Poor				Excellent
1	2	3	4	5

Dog's ability to respond to its name

Poor				Excellent
1	2	3	4	5

Appendix C

Study Consent and Authorization Form
Study Title

Ideal Free Distribution in Companion Animals

INTRODUCTION

The Department of Applied Behavioral Science at the University of Kansas, in collaboration with Wagmore, is providing the following information for you to decide whether you wish to allow your canine to participate in a behavioral research study. You may decline to sign this form and your canine will not participate in this study. You should be aware that even if you agree to allow your canine to participate, you are free to withdraw his/her participation at any time. If you do decide for your canine to participate or withdraw from this study, it will not affect your relationship with Wagmore, the services it may provide to your canine, or your relationship with the University of Kansas.

PURPOSE OF THE STUDY

The primary purpose of the research is to use a group foraging and an individual foraging paradigm to further understand the behavior of companion pack animals, namely the domesticated dog.
Our aims are to:
- fit a model to the behavior of small groups of dogs within the concurrent operant arrangement
-fit a model to individual dog behavior within the context of the group setting
- compare competitive groups, non-competitive groups, and mixed groups of dogs

The secondary purpose of the research is to compare results of individual dog behavior to intake assessments used at the animal day-care.
Our aims are to:
-validate dog behavior assessments currently in use in the day-care
-evaluate manipulations of the environment as reflected in foraging behavior of dogs

PROCEDURES

During potentially multiple 1 ½-2-hour monitored sessions, we will expose a small group of dogs to a concurrent variable-interval schedule of reinforcement (i.e. treats delivered after variable amounts of time) within their typical environment in the Wagmore facility outside of the typical daycare hours. Upon completion of the group session, dogs will be involved in the same procedure, but by themselves. Dogs will be selected for a grouping based on Wagmore's intake assessment. All dogs will have had previous day care experience at Wagmore. Researchers will observe and record the behavior during the sessions. Each 1 ½-2-hour session will involve up to 12, ten to twenty-minute trial blocks with variable treat delivery with time for researchers to reset the treat delivery system and video cameras. Animals will be involved in up to two sessions. The sessions may take place in the same day.

Within the day care play area there will be two treat dispensers on either end of the room. At variable times, each dispenser will release a set number of treats. Video cameras will monitor the location of the animals at every point of the session. One to two sessions of different variable schedules will be used for each of three groups of dogs. The treats used in this study will be the ones distributed in typical daycare hours: dry, kibble-like, chicken and beef flavored round treats of approximately 5 calories each. The estimated number of treats delivered in a session is between 150-180 treats or 25 to 30 treats per dog. These procedures are identical for all sessions.

Some conditions may introduce an additionally stimulus such as a scent into the environment to test if particular scents impact foraging behavior on dogs. These scents will be diluted as to not cause stress for the animal and will be scents likely encountered within the context of the dogs' natural lives.

Researchers will have limited interaction with the animals in this study. The only interactions will be when activating the treat dispenser. Dogs will be handled by the trained staff employed by Wagmore only. Wagmore staff will observe all sessions to ensure its usual standard of care is met and will intervene at any time participating canines exhibit problem behavior. Wagmore staff, at their discretion, may withdraw a participant canine from a session or from the study, if necessary to assure the safety and welfare of any or all of its animal clients.

RISKS

There are no anticipated risks beyond those assumed in day-to-day interactions at the daycare to the canines who participate in this study. The study incorporates common enrichment activities utilized in day-to-day daycare practices and all sessions are monitored by Wagmore staff, who will intervene, if necessary, to maintain its standard of care in the daycare setting. It is not anticipated that the study procedures will cause any need for veterinary care. Veterinary care of the animals is the responsibility of the owner and not the responsibility of KU.

BENEFITS

The environment is meant to offer additional enrichment to the animals in the context of day care. It is anticipated that researchers will learn how these specific animals interact with each other in a systematic way as well as make direct comparisons between appetitive scents and deterrents. Their observations will be used to validate behavioral assessments currently used by Wagmore. Research data and analysis from this study will be shared with Wagmore. Information gathered from this study may help us better understand environmental variables that influence canine behavior and how canines interact with each other in unstructured settings.

PAYMENT TO PARTICIPANTS

Canines and their owners will not receive any form of payment for participating in this study.

PARTICIPANT CONFIDENTIALITY

Your and your dog's names will not be associated in any way with the information collected or with the research findings from this study. The researcher(s) will use a study number or a pseudonym instead of your dog's name. The researchers will not share personal information about you or your dog unless required by law or unless you give written permission.

DECLINING TO SIGN CONSENT AND AUTHORIZATION

You are not required to sign this Consent and Authorization form, and you may decline to do so without affecting any services your canine is receiving or may receive from Wagmore, the Department of Applied

Behavioral Sciences, or the University of Kansas. If you decline to sign, your canine cannot participate in this study.

CANCELLING THIS CONSENT AND AUTHORIZATION

You may withdraw your consent for your canine to participate in this study at any time. You also have the right to cancel your permission to use and disclose further information collected about your canine in writing, at any time, by sending your written request to: asalzer@ku.edu.

If you cancel permission to use the information of your canine the researchers will stop collecting additional information about him/her. However, the research team may use and disclose information that was gathered before they received your cancellation, as described above.

QUESTIONS ABOUT PARTICIPATION

Questions should be directed to the researcher(s) listed at the end of this consent form.

CANINE OWNER CERTIFICATION:

I have read this Consent and Authorization form. I have had the opportunity to ask, and I have received answers to, any questions I had regarding the study.

I agree to allow my canine to take part in this study as a research subject. By my signature, I affirm that I am at least 18 years old, I am the owner of the dog(s) named below, and that I have received and understood this Consent and Authorization form.

____
Animal Name

_____________________________ ____________________
Type/Print Owner Name Date

____
Owner Signature

Researcher Contact Information

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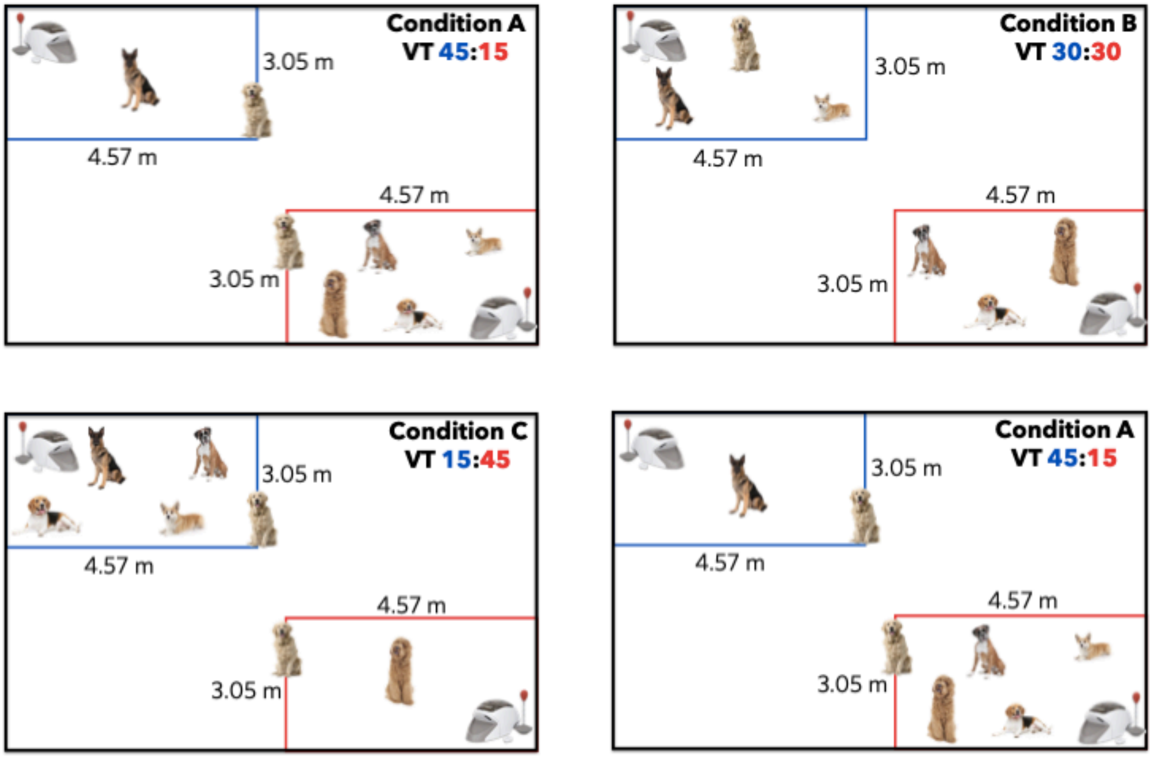
Appendix D



Condition A
VT 45:15
3.05 m
4.57 m
4.57 m
3.05 m
Condition B
VT 30:30
3.05 m
4.57 m
4.57 m
3.05 m
Condition C
VT 15:45
3.05 m
4.57 m
4.57 m
3.05 m
Condition A
VT 45:15
3.05 m
4.57 m
4.57 m
3.05 m

Appendix E


PetSafe
protect. teach. love.
Spray Control™
Citronella | Citronnelle
CAUTION:
CONTENTS UNDER PRESSURE.
Keep out of reach of children.
Read Cautions on back panel.
ATTENTION :
88.7 mL | 3 oz