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Discrimination of Food Amounts by the Domestic Dog (*Canis familiaris*)

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The current research examined the ability of dogs to discriminate between different amounts of food. Using a two-alternative-forced-choice procedure, dogs were required to discriminate between a constant amount of 4 pieces of food and another amount that varied across a range from 1 to 7 pieces. The dogs reliably selected the larger of the two alternatives. Discrimination was better when there were fewer than rather than more than 4 pieces of food available on the varying alternative. Specifically, 1 piece was discriminated from 4 pieces more easily than 4 pieces were discriminated from 7 pieces of food. These results confirmed the ability of dogs to discriminate food amount on a psychophysical choice procedure. This research addresses a question fundamental to theories of reinforcement of why reinforcer magnitude does not always control behavior in an intuitive way. We argue that the relative difficulty of discriminating smaller from larger amounts of food is an important factor in understanding the impact of reinforcer magnitude in the development of reinforcer control over behavior.

When reinforcers are being delivered with the intention of modifying behavior, it is important to use reinforcers that maximize rate of learning and subsequent performance. The use of a reinforcer of a preferred amount and/or quality results in more effective training sessions with humans (e.g., Piazza, Fisher, Hagopian, Bowman, & Toole, 1996). A review by Timberlake and Farmer-Dougan (1991) stressed the importance of understanding the conditions that determine the effectiveness of reinforcers, and others have noted the influence that different methodologies have on assessment of animals' preferences for different commodities (see Sumpter, Foster, & Temple, 2002). Vicars, Miguel, and Sobie (2014) showed that preference assessment successfully predicted reinforcer effectiveness with dogs. A fuller understanding of factors that may impact reinforcer effectiveness have obvious implications for situations where reinforcers are being used to train new, or maintain performance of, animals in applied settings, such as service/assistance dogs.

One important characteristic of a reinforcer is its magnitude. Much of the research into the effects of reinforcer magnitude on responding has shown that animals will work harder for more food, perhaps suggesting a preference for larger reinforcer magnitudes. For example, Reed and Wright (1988) found that increasing the magnitude of reinforcement increased rats' response rates on a variable ratio (VR) schedule of reinforcement. It has been suggested that reinforcement produces a general state of arousal (i.e., increases overall levels of activity), and that this state can serve to energize the level of instrumental performance (Killeen, 1994). Thus, it might be hypothesized that the greater the magnitude of reinforcement, the greater the state of arousal and hence the more behavior that is emitted. However, research has also shown that such an effect is not consistently reported as a positive linear relationship between reinforcer amount and rate of responding, as one might intuit (for reviews, see Bonem & Crossman, 1998; Pubols, 1960). For example, Bizo, Kettle, and Killeen (2001) found that rats did not always respond faster for more food on a VR schedule of reinforcement. Despite predictions that rats' response rates would increase with increases in reinforcer amount, one-pellet reinforcers paradoxically generated higher response rates than two-pellet and three-pellet reinforcers over a range of VR values. Clearly, it is not always the case that larger reinforcers support higher response rates than do smaller

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reinforcers. Bizo et al. (2001) showed that larger reinforcers that take longer to consume interfere with an animal's memory for the instrumental response emitted to earn the reinforcer, a finding that is consistent with predictions of Killeen's (1994) *Mathematical Principles of Reinforcement*. Killeen and Smith (1984) also showed that longer reinforcer durations interfered with pigeons' abilities to discriminate between preceding variable interval (VI) and variable time (VT) schedules.

On a choice task, however, when reinforcer magnitude is manipulated, reinforcer preference is sensitive to differences in reinforcer amount (e.g., Neuringer, 1967), and preference is sensitive to the delay to reinforcement (Ito, 1985). Killeen, Cate, and Tran (1993) assessed preference by giving pigeons a choice between two food alternatives of different magnitudes and recording what was chosen. There was a clear preference for larger grains, revealing that grain size strongly controls pigeons' preferences. Indeed, many studies have illustrated animals' preferences for a perceived larger quantity of food. Shettleworth (1985), for example, found that pigeons preferred fifteen 20-mg pellets to one 300-mg pellet. Capaldi, Miller, and Alptekin (1989) also found that rats preferred multiple pellets that had a total weight of 300-mg to a single 300-mg pellet. They suggested that a variety of dimensions may control preference for a different magnitude of food and that there might be a bias for animals to perceive an alternative with a large score on one dimension (such as number) to be further out on some other dimension of the food animals are indicating a preference for, such as such as weight per pellet, than is really the case. Another possibility is that estimates of volume were biased by the amount of feeder space occupied by the grains. For example, 15 small pellets projecting a larger retinal image than one 300-mg pellet may engender the perception that 15 small pellets is the larger food option, and that might be sufficient to engender a preference for those pellets (Capaldi et al., 1989).

One factor that might regulate an animal's preference for different amounts of food is its ability to discriminate between different amounts. Relative numerousness judgments are perhaps the simplest level of responding to number. These are judgments of inequality that take the form of a more-or-less comparison. Relative numerousness judgments are most successful when comparisons are between relatively small numbers of arrays containing disparate numbers of items, with these discriminations becoming harder as the absolute difference between magnitudes becomes smaller. Weber's law indicates that the ease with which numbers can be discriminated depends on the value of those numbers. Davis and Albert (1986) noted that with numerousness judgments, the greater the proportional difference between quantities, the easier the discrimination. In their experiment, they noted that two stimuli were more easily discriminated from three than three stimuli being discriminated from four stimuli. Beran (2006) has also noted that chimpanzees and rhesus macaques, like humans, will overestimate the number of items in a regularly arranged set of stimuli compared with randomly arranged items of the same number, confirming the sensitivity of discrimination to factors such as stimulus arrangement.

Numerosity discrimination has been investigated in a variety of species, including capuchin monkeys (Addessi, Crescimbene, & Vsalberghi, 2008), squirrel monkeys (e.g., Thomas & Chase, 1980; Thomas, Fowlkes & Vickery, 1980), bears (e.g., Vonk & Beran, 2012), horses (Uller & Lewis, 2009), rats (e.g., Fernandes & Church, 1982), chimpanzees and New Zealand robins (Garland, Beran, McIntyre, & Low, 2014; Garland & Low, 2014), and pigeons (e.g., Honig & Stewart, 1989). The ability of animals to discriminate between different numbers of items is sensitive to the number of items in the comparison. For example, Rugani, Cavazzana, Vallortigara, and Regolin (2013) showed with day-old chicks that there are disparities in discrimination performance when processing numbers of items smaller or greater than 4. Feigenson, Carey, and Hauser (2002) reported data from an experiment investigating human infant judgments of more or less and found that infants relied on object file representations of the amounts being compared rather than on an analogue magnitude system. The ability to discriminate more from less at its simplest is an ordinal discrimination and requires no representation of cardinal value. An analogue magnitude system account of numerosity judgment is ratio dependent and thus would predict that performance should be consistent with Weber's Law. Specifically, the difficulty of a discrimination will vary as an inverse function of the ratio of the numbers being discriminated. Dehaene, Dehaene-Lambertz, and Cohen (1998) noted that both the numerical distance effect and the number size effect occur in animals and humans. Specifically, as the difference between two numbers increases, performance improves - the number distance effect. The number size effect is when, for a constant difference, discrimination performance deteriorates as the size of the numbers increase.

It has been argued that dogs are a species for which an ability to discriminate number may be advantageous. Thus, dogs are likely to be successful in number discrimination tasks. The rationale is that for any socially complex species, the monitoring of the number of allies and enemies within a group may benefit from numerical competence. One such socially complex species is the gray wolf (*Canis lupus*), which has given rise to the domestic dog (Cooper et al., 2003; West & Young, 2002). Indeed, Bonanni, Natoli, Cafazzo, and Valsecchi (2011) argued that free-ranging domestic dogs assess the number of opponents during intergroup conflicts, clearly a situation in which numerical supremacy would have some obvious advantages. More generally, the systematic study of psychophysical abilities of different species informs our understanding of their comparative abilities and possible evolutionary influences (e.g., Akre & Johnsen, 2014).

Latterly, there has been a growth in interest in investigating whether or not dogs possess an ability to count or discriminate number (e.g., Macpherson & Roberts, 2013; Prato-Previde, Marshall-Pescini, & Valsecchi, 2008; Ward & Smuts, 2007). This interest in the numerical ability of canids has extended to wolves (Range, Jenikejew, Schröder, & Virányi, 2014; Utrata, Virányi, & Range, 2012) and coyotes (Baker, Shivik, & Jordan, 2011). Ward and Smuts (2007) found that dogs are naturally able to discriminate between differences in number with results indicating that the dogs consistently chose the larger of two food alternatives. Prato-Previde et al. (2008) demonstrated that dogs were more likely to select the larger of two food alternatives when provided with a choice between two amounts of food. Bentosela, Jakovcevic, Elgier, Mustaca, and Papini (2009) showed that dogs display an incentive contrast effect when preferred foods are replaced by less preferred foods. However, Macpherson and Roberts (2013), using a procedure in which the dogs could observe the food being placed in two bowls prior to the choice being made, reported that the dog's performance was not greater than chance except when the ratio was one to zero.

The aim of the current research was to assess the ability of dogs to discriminate between different numbers of pieces of food on a two-alternative forced choice procedure. It was expected that dogs would be capable of making appropriate discriminations between differing amounts of food. The comparative nature of the proposed experiment allowed for more or less comparisons and several studies have demonstrated that a number of animal species are able to discriminate under these conditions and often show a preference for larger reinforcer magnitudes (e.g., Catania, 1963; Neuringer, 1967). Hence, it was anticipated that dogs should also show some ability to discriminate the number of food items and choose the alternative that provided the larger number.

The present experiment used a simple choice procedure, based on that used by Killeen et al. (1993), in which two different amounts of food are presented concurrently, allowing the dog to choose which to eat. The method of constant stimuli was used because it was simple and easy to administer and because the dogs that were used in this experiment were only available for limited amounts of time. A constant amount of four pieces and a range of one to seven pieces for the varying amounts were chosen for practical rather than theoretical reasons, enabling quick and accurate resetting of the experimental apparatus, and to allow for the generation of a psychophysical function across a range of amounts of food. This method allowed the generation of reliable psychophysical function over a relatively small number of trials in comparison to an adjusting amount procedure.

Method

Subjects

Four dogs served as subjects, each weighing between 10 and 15 kg, and aged between 6 and 11 years: two border collies, one bearded-collie cross, and one parsons terrier. The dogs were recruited from local owners known to the experimenters. Only four dogs were able to attend test sessions. Two others scheduled for testing were not available. The dogs were not fed prior to testing and the dogs only attended the laboratory on the days they participated in an experimental session. Water was freely available during the experiment. One experimenter handled the dogs and another experimenter was responsible for putting food in the bowls and recording choices and did not interact with the dogs. This research had ethics approval at the University of Southampton, where the research was conducted.

Apparatus

Pieces of maintenance dry diet by Iams® were used as reinforcers, each individual pellet weighing 0.25 grams. The food was placed in two white plastic bowls. The second experimenter sat out of sight of the dog behind the apparatus and was able to place the food bowls in position from the rear of the apparatus. This procedure ensured the animals could not see the food items being placed in the food bowls prior to a choice being made and the side on which the different amounts were was placed was randomized across trials. The bowls were placed behind a clear Perspex screen (1-m long × 1-m high), which allowed the dogs to see the contents of the food bowls from a fixed starting point at the beginning of each trial (see Figure 1A). The amount of food eaten by the dogs in the experimental study ranged from 46.75 to 48.50 g and did not exceed the recommended daily meal size (150 g) for a dog weighing 15 kg. As with any experiment involving repeated access to food, satiation may confound the results (see Bizo, Bogdanov, & Killeen, 1998). Morgan (1974) suggested that satiation be defined "as a state in which the animal will no longer engage in a particular consummatory response (eating), even in the presence of the appropriate incentive (food)" (p. 449), and also noted that instrumental behavior that precedes the consummatory response would cease when an organism is satiated. The risk of satiation confounding these results was minimized because the dogs did not eat more than they would in a normal meal size for their weight over the course of the experiment.

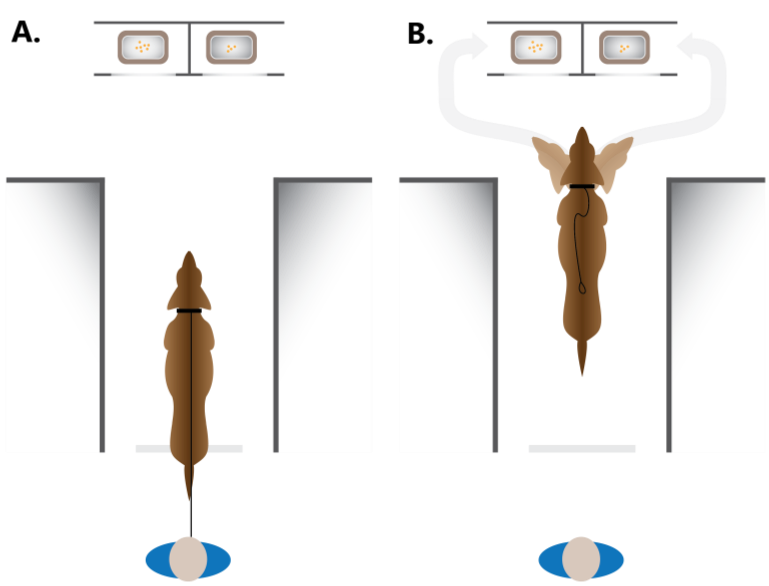

Figure 1. **An overhead view of the apparatus set-up. Panel A shows the starting position for each trial. Panel B shows the arrangement when the dog made a choice.**

Procedure

The dogs had 5 minutes of off-lead exposure to the experimental setting, equipment, and researchers prior to the first practice trial. This provided the dogs with an opportunity to habituate to the experimental setting.

The dogs discriminated between two different amounts of food on a two-alternative forced-choice procedure. One choice option was a constant number of four pieces of food. The varying alternative was either a smaller number of food pieces (one, two, or three pieces) or a larger number of food pieces (five, six, or seven pieces). To familiarize the dogs with the apparatus, the dogs ate four pieces of food from both sides of the apparatus followed by practice trials in which each food pair was presented in a random order.

After a short break, the 36 test trials commenced. Each of the food number pairs was presented six times. The order of presentation of the food pairs was randomized, and the side on which the constant food amount (four pieces) was presented was counterbalanced across both sides of the apparatus. At the start of each choice trial, the experimenter held the dog on a short lead on the opposite side of the screen from the two food sources within view of the food. The lead ensured the dog’s head was at the same starting point for each trial (see Figure 1A). The experimenter stood behind the dog and looked at the opposite wall to reduce any chance of interference by gaze cues. After approximately 5 s, the experimenter released the lead allowing the dog to choose one of the food options (see Figure 1B). All dogs responded promptly once the experimenter released the lead and all dogs made a choice on each trial. The experimenter led the dog back to the start position ready for the next trial after the dog had finished eating the food they had chosen. The food bowls were removed and pieces of food were replaced in preparation for the next trial. Each trial took approximately 2 minutes from start to finish including eating time.

Results

The dogs selected the alternative with the larger number of pieces of food more frequently than the alternative with the smaller number of food pieces.

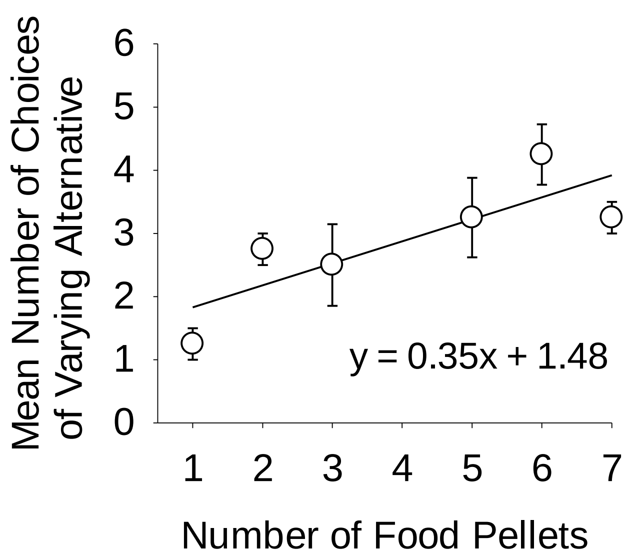

Figure 2. **The mean number of choices of the varying number of food pieces plotted as a function of the number of pieces of food available on the varying alternative. The solid line through the data points is drawn by a simple linear regression (slope = 0.35, intercept = 1.48, R^2 = 0.68). The error bars represent the standard error of the mean.**

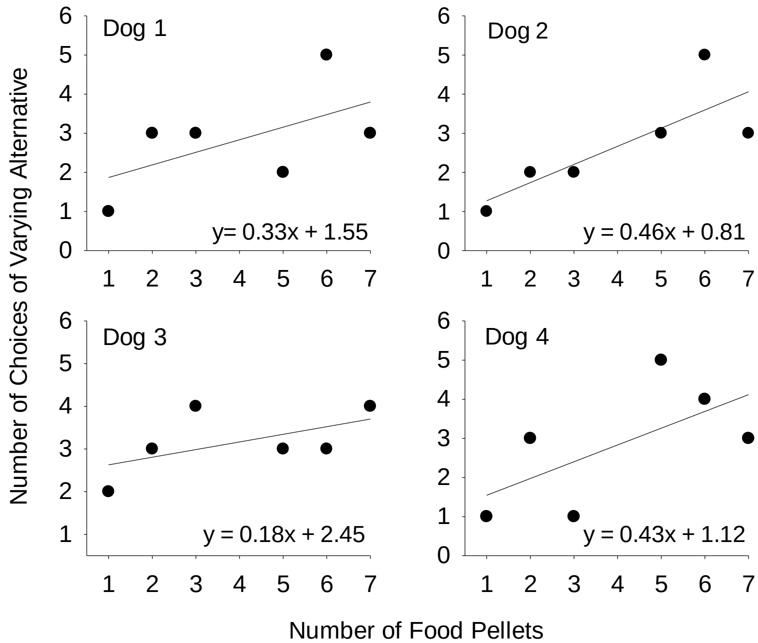

Figure 3. **The number of choices of the varying number of food pieces plotted as a function of the number of food pieces on the varying alternative for each dog. The solid line is drawn by a simple linear regression.**

Figure 2 shows the mean number of times that the varying amount was chosen plotted as a function of the number of food pellets available on the varying alternative. A simple linear regression analysis revealed a significant positive relation between number of food pellets and choice of the varying amount, $F(1, 5) = 8.68$, $p = .042$, with an R^2 of .68. The solid line through the data points represents the regression line.

Figure 3 shows the same analysis for individual dogs. All dogs demonstrated a tendency to pick the larger food amounts more often than the smaller food amounts, as shown by the positive slope of each regression line. The preference for larger amounts of food suggests some control by the number of food pellets over choice of option.

A repeated measures analysis of variance (ANOVA) confirmed a significant difference in the number of times different food amounts were chosen, $F(1, 3) = 43.1$, $p = .007$, $\eta_p^2 = .94$. The number of choices of smaller (one, two, or three) or larger amounts (five, six, or seven) were averaged for each animal and a paired samples *t*-test, $t(3) = 3.08$, $p = .026$, $r = .922$, confirmed that the dogs chose a larger food amount more often than a smaller food amount. The dogs chose the smaller amounts of food (one, two, or three pieces of food) less frequently than the constant alternative of four pieces of food, and chose the larger amounts of food (five, six, or seven pieces of food) more frequently than the constant alternative of four pieces of food.

Discussion

The dogs reliably chose the larger food amounts demonstrating that they were able to discriminate between different amounts of food. The psychometric functions shown in Figures 2 and 3 show a positive linear relation between the number of food pellets and the frequency of choosing the non-constant amount. Had the dogs not been able to discriminate the constant amount from the varying amount, the psychophysical function would have been horizontal with a slope of zero indicating an equal probability of selecting the constant versus the varying amount.

Many experiments that have investigated animals' abilities to discriminate number involve the simultaneous presentation of visual items (e.g., Davis, 1984; Hicks, 1956; Thomas et al., 1980). Because of the comparative nature of such experimental designs, which often require a more-or-less judgment, it is usually clear that subjects are using relative numerousness as a basis for the discrimination. In the present experiment, it appeared that the dogs were also making a simple more-or-less judgment.

Our choice of four items as our constant comparison might have been predicted to produce an asymmetrical psychophysical function for two reasons. One, if amounts less than four pieces of food were captured by an object file system and amounts larger than four by an analogue magnitude system, then this may have made this particular discrimination uniquely challenging as suggested by Rugani et al. (2013). Second, the ratio of the varying to constant amount was not held constant as we used an arithmetic rather geometric series. Weber's law asserts that the discriminations of one, two, or three pieces from four pieces should have been easier than five, six, or seven pieces from four pieces. However, it was not obvious from visual inspection of Figures 2 and 3 if there was an advantage to discriminating numbers less than four rather than numbers greater than four, although the easiest discrimination does appear to have been one from four pieces where performance was best. Future research might more systematically vary the ratio of small to large and the size of the constant comparison to confirm if indeed dogs were utilizing an object file system for numbers less than four and an analogue magnitude system for numbers greater than four.

It is likely that had we tested more dogs, exposed the dogs to a greater number of trials, or tested the dogs repeatedly over several sessions, the psychometric functions describing the dogs' abilities to discriminate would have become steeper and smoother, notwithstanding the effects of within-session satiation as previously mentioned. Moreover, performance did improve over the course of testing with the dogs' choices of the larger alternative increasing from an average of 51.4% for the first half of the trials to 65.3% for the second half of the trials.

In the present experiment, it is unclear to what extent the slope of the psychometric functions in Figure 2 reflects the dogs' abilities to discriminate number or the incentive properties of the food that we used to conduct the experiment. Future experiments could compare different types of food used to confirm preferences to assess the relative "quality" of the foods. In other contexts, food quality has been shown to dramatically increase rates of responding, such as when rats are given sucrose rather than normal rat pellets as reinforcers for bar pressing (e.g., Bizo et al., 2001). Additionally, one might expect that a discrimination of number of pieces of food would be better for more preferred foods and that such preference would be reflected as an increase in the slope of the psychometric function.

In conclusion, the assessment of dogs' reinforcer preference has applied implications for those using reinforcers, such as food treats, play, or access to toys, to train and work dogs, be that pet owners, police, or those working with service/assistance dogs. Trainers understand that dogs show individual preferences for different reinforcers, be those praise, play, type of game, or food/food type, and that this preference may vary at different times. Knowing an animal's preference should facilitate acquisition (training) and, once learnt, optimize motivation and performance of that behavior. The present study addresses a question fundamental to theories of reinforcement as to why reinforcer magnitude does not always control behavior in an intuitive way. We argue that the relative difficulty of discriminating smaller from larger amounts of food is an important factor in understanding the impact of reinforcer magnitude in the development of reinforcer control over behavior. This paper illustrates that preferences may be more subtle. The amount of food may also influence motivation in the course of acquisition and normal responding to a learnt cue.

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