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SHORT COMMUNICATION

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Do domestic dogs show any evidence of being able to count?

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Abstract Numerical competence has been demonstrated in a wide range of animal species. The level of numerical abilities shown ranges from simple relative numerousness judgements to true counting. In this study we used the preferential looking technique to test whether 11 pet dogs could count. The dogs were presented with three simple calculations: "1+1=2"; "1+1=1"; and "1+1=3". These calculations were performed by presenting the dogs with treats that were placed behind a screen that allowed manipulation of the outcome of the calculation. When the dogs expected the outcome they spent the same amount of time looking at the result of the calculation as they did on the initial presentation. However, when the result was unexpected dogs spent significantly longer looking at the outcome of the calculation. The results suggest that the dogs were anticipating the outcome of the calculations they observed, thus suggesting that dogs may have a rudimentary ability to count.

Keywords Counting · Domestic dogs · Numerical competence · Preferential looking time

Introduction

A wide variety of animal species including birds (Pepperberg 1991), rodents (Capaldi and Miller 1988), dogs (Kobayashi and Tanaka 1999) and primates (Boysen and Berntson 1989) have been said to show some degree of numerical competence. However, numerical competence does not imply that a species possesses the ability to count. Numerical competence may be expressed as: relative numerousness judgements (i.e., X is greater than Y); subitizing (i.e., assigning a numerical tag to a small quantity of items); estimation (i.e., the process of subitizing when the array contains six or more items) and counting (see Davis and Perusse 1988).

Gelman and Gallistel (1978) have outlined five principles behind a robust definition of counting.

1. One to one correspondence, each component of a counted set must correspond to one single numeron.
2. Stable order, the numerons must be ordered and correspond to each of the items that are being counted in a sequence that is reproducible every time.
3. Cardinality, the last numeron in a sequence also represents the total numerosity of the set.
4. Abstraction, counting applies to homogenous and heterogeneous groups of individual objects of both physical and mental construction.
5. Order irrelevance, the number in which the numerons correspond to each item in a set is not important in the counting process.

Many of the numeracy studies conducted on non-human animals have involved lengthy training periods (e.g., Pepperberg 1991). The problem with using long training periods is that it increases the probability that animals use discriminative stimuli and not cognitive processes to solve the problem. For example, Povinelli and co-workers (1996a, b) found that, in an experiment, chimpanzees solved a problem of who to beg food from, not from understanding the attentional significance of gaze (i.e., a cognitive understanding) but from learning that eyes could be used as a discriminative stimulus (i.e., associative learning).

Wynn (1992) used a technique for assessing numeracy in pre-verbal human infants (5 months old) without the need for any training called preferential look time (PLT). This technique taps into the spontaneous cognitive processing that occurs during numerical reasoning, it works on the principle that subjects (originally human infants)

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should look longer at an event that is unexpected (i.e., contradicts their knowledge). In the original experiments, infants (5 months old) were presented with sequences of correct and incorrect additions and subtractions of small numbers of objects (dolls). The amount of time spent looking at the outcome of individual calculations was recorded (e.g., “1+1=2” or “1+1=1”). Results showed that infants looked significantly longer when the outcome of the calculation was unexpected. This suggests that the infants were able to compute the calculation and were surprised to see an incorrect outcome (i.e., they could perform simple mathematical calculations). The results of this study therefore imply that pre-verbal human infants have a limited ability to count.

The preferential looking technique has been applied to two species of non-human primate, the rhesus macaque (*Macca mulatta*) and the cotton-top tamarin (*Saguinus oedipus*) (see Hauser et al 1996; Hauser 1997). Results of these studies are comparable with those of human infants; both primate species were able to complete simple mathematical computations without prior training, implying that elementary numerical competence characterises these species.

It would not be surprising that primates have developed a high degree of numerical competence (i.e., the ability to count) as this would be advantageous to any species that has evolved within a socially complex society (Byrne 1995). For example, it would allow the monitoring of the number of allies and enemies with the group. Another species that evolved in socially complex groups is the wolf (*Canis lupus*), which has given rise to the domestic dog. A previous study on numerical competence in dogs (Kobayashi and Tanaka 1999), involving an extensive training period, established that they displayed relative numerousness judgements (i.e., X is greater than Y). In this operant conditioning study dogs were presented with two panels covered in dots; dogs rewarded for choosing the panel covered with the most dots. The aim of the present study was to establish, using the preferential looking technique, whether dogs have evolved a level of numerical competence that includes counting. However, it is important to note that a positive result does not mean that dogs compute calculations in the same manner as humans.

Methods

Subjects and test arena

The subjects used in this study were 11 domestic pet dogs (seven male and four female); eight different breeds were used and the dogs ranged in age from 1 to 8 years old.

The test stimuli consisted of seven white polystyrene bowls (diameter: base=0.085 m, rim=0.15 m and height=0.04 m) placed upside down behind a 1.96 m×0.38 m×0.004 m (length × height × thickness) hardboard screen (see Figs. 1, 2). The screen was hinged in the middle to allow it to stand freely. The bowls were numbered 1–7 from left to right and spaced 0.1 m apart. Three of the bowls had slits cut into the base to allow the food treats to stand unaided. The food treats used were Pedigree Chum Trek (these are brown in colour, and approximately 0.145 m long and 0.08 m high). A marker was placed central to and in front of the board, and at a distance of 1.5 m (this was used to position the dogs). The binocular vision of dogs is approximately 70° giving in this experimental set-up a visual field of 3.6 m.

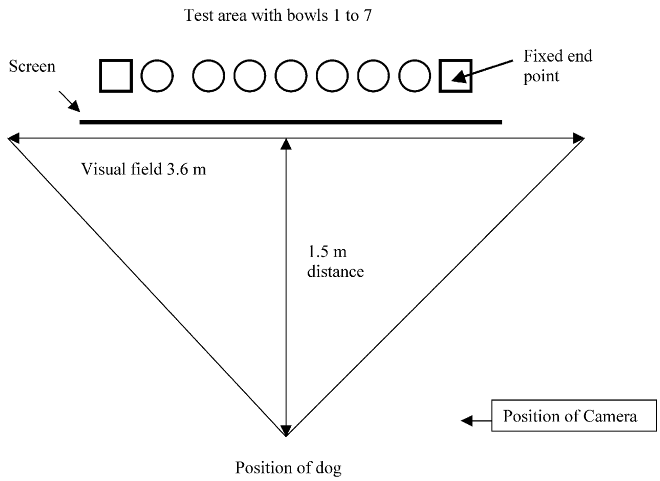

Fig. 1 Set-up of experimental arena and test area (not to scale)

Experimental protocol

The first test, test 1, was “1+1=2” (expected). A single treat was placed behind the screen in position 4 and then the dog brought into the test arena and placed on the central marker and held in place on a lead. Once the dog was settled, video recording began (the camera was placed side on to the experimental set-up; see Figs. 1 and 2). The screen was lowered by hand to allow the dog to see the test stimuli. The screen was raised once the dog looked away for more than 2 s. Next a second treat was introduced, by the experimenter, in view of the dog and placed behind the screen in position 6. The screen was lowered again to allow the dog to see the test area. The test was terminated once the dog looked away for more than 2 s. The dog was then removed from the test arena and given a food reward.

Test 2 was “1+1=1” (unexpected). A single treat was placed behind the screen in position 4 and then the dog brought into the test arena and placed on the central marker. Once the dog was settled, video recording began. The screen was lowered to allow the dog to see the test area. The screen was raised once the dog looked away for more than 2 s. Next, a second treat was introduced in view of the dog but not placed in the test stimuli area, instead it was surreptitiously hidden out-of-sight of the dog. The experimenter carefully hid it on their person. The screen was lowered revealing the test area and one treat. The screen was raised when the dog had looked away for more than 2 s. The dog was then removed from the test arena and given a food reward.

Test 3 was “1+1=3” (unexpected check). In this test only five dogs were used. A single treat was placed behind the screen in position 4 and then the dog brought into the test arena and placed on the central marker. Once the dog was settled, video recording began. The screen was lowered to allow the dog to see the test stimuli area. The screen was raised once the dog looked away for more than 2 s. Next a single treat was introduced into the test stimuli area in view of the dog and placed at position 6, and surreptitiously at this time a hidden treat was placed at position 2. The experimenter carefully removed a treat from their person. The screen was lowered revealing three treats and the test terminated when the dog had looked away for more than 2 s. The dog was then removed from the test arena and given a food reward.

The amount of time dogs spent looking at the test area was recorded using a stopwatch from the video footage: each taken timing was repeated 4 times and the average used in the analyses.

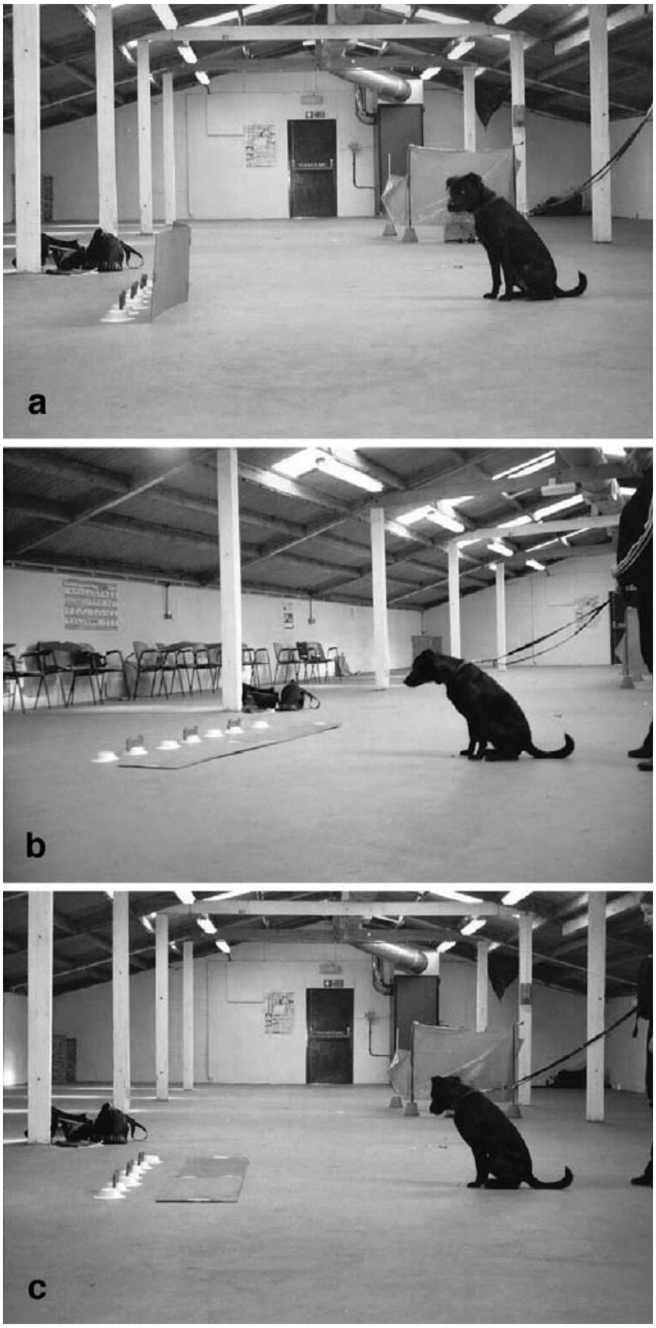

Fig. 2a–c Photographs of a typical test 3 ("1+1=3"). **a** Dog is shown the calculation. **b** Dog looks at the result of the calculation. **c** Dog looks away for more than 2 s and the test is terminated

A single observer, the experimenter, did all observations. An interval of at least a day occurred between tests.

Data were analysed using a paired *t*-test; the independent variable was the number of treats behind the screen at the end of the "1+1" part of the test. The dependent variable was the amount of time the dogs spent looking at the outcome. We tested whether dogs differed in time spent looking at the test stimuli area between the initial presentation (one treat) and the outcome of the calculation for all three tests. Each dog was only exposed to one trial.

Results

The first test ("1+1=2") produced a non-significant result (t=1.12; n=11; P=0.29), thus dogs spent the same amount of time looking at the initial presentation of one treat and looking at the outcome of the manipulation (see Table 1). The second test ("1+1=1") produced a significant difference (t=3.35; n=11; P=0.0055) with dogs spending a longer time looking at the outcome of the manipulation than of the initial presentation of one treat (see Table 1). The third test ("1+1=3") also produced a significant difference (t= 3.91; n=5; P=0.017) with dogs spending a longer time looking at the outcome of the manipulation than of the initial presentation of one treat (see Table 1).

Discussion

Research by Kobayashi and Tanaka (1999) established that domestic dogs had the ability to subitize. The results of this study suggest that domestic dogs have a limited ability to count (see Gelman and Gallistel 1978; Davis and Perusse 1988). We draw this conclusion based on the facts that to perform simple additions dogs need to be able to order numerosities (i.e., one to one correspondence, stable order and order irrelevance) and judge total numerosity (i.e., cardinality). We feel it is important to point out that the aforementioned definition of counting is a human definition. We are not suggesting that dogs perform these mathematical functions in the same manner as humans or primates, just that they perform behaviour that matches this definition. The actual mechanism that the dogs used in this experiment needs further experimentation to clarify.

The non-significant result of test 1 ("1+1=2") suggests that dogs did not alter their looking time when the result of the presented calculation was expected. However, this does not prove numerical ability, it may simply be that dogs do not know what to expect and therefore show no reaction. The significant difference detected in test 2 ("1+1=1"), that dogs spent more time looking when the result of the calculation was unexpected, implies a degree of numerical competence. It appears that the dog is "surprised" to see only one object and spends longer looking in a search for the missing object. However, this result could be explained by dogs' reasoning that one object plus another object equals more than one object rather than specifically two. In this situation dogs would be equally surprised to see one object behind the screen and would therefore adjust their looking time accordingly. The significant difference in test 3 ("1+1=3") dismisses this possibility, and suggests dogs are as equally surprised to see three objects after a "1+1" calculation as they are to see one.

In one study using the preferential looking technique the size of the field of view was not controlled (Wynn 1992) and it could be argued that the subjects were making some measurement of area (i.e., relative numerous-

Table 1 Preferential looking times (s) for the three tests. *N/T* Not tested

Presented dog ID	Test 1a 1	Test 1b 1+1=2	Test 2a 1	Test 2b 1+1=1	Test 3a 1	Test 3b 1+1=3
1	5.69	5.28	6.72	8.19	5.12	6.72
2	5.53	6.69	6.84	8.15	5.29	6.88
3	4.62	5.03	3.38	4.50	N/T	N/T
4	4.97	3.76	4.14	4.56	N/T	N/T
5	6.60	7.96	6.62	9.41	N/T	N/T
6	6.24	6.68	5.12	5.94	N/T	N/T
7	5.03	4.48	5.34	5.61	N/T	N/T
8	4.73	5.26	5.41	6.75	N/T	N/T
9	11.03	11.63	9.38	15.59	9.57	13.07
10	5.25	4.52	4.38	5.59	4.25	4.79
11	9.71	11.75	9.57	11.94	8.81	11.4
Mean	6.31	6.64	6.08	7.84	6.61	8.57

ness judgements). We controlled for this by having a constant field of view, and by ensuring wide spatial separation between objects (see Methods and Figs. 1, 2).

Research into numerical competence seems to imply that it is common within the animal kingdom, which is not surprising given the evolutionary advantages it would provide to animals. For example, knowing the number of allies and enemies you have in a social group. However, this could be done by a low level of numerical ability such as relative numerousness judgements (i.e., X is greater than Y; see Davis and Perusse 1988). We would predict that higher levels of numerical competence (e.g., counting) would have evolved in species that have evolved in socially complex societies, such as primates (Byrne 1995). Where perhaps knowing the precise number of allies versus enemies you have may be vital in determining the success of behavioural strategies (e.g., challenging for a higher position in the social hierarchy). However, experimenters have only tested (socially complex) primate species using the preferential looking technique, it may be that high levels of numerical competency are widespread in the animal kingdom. The present study appears to demonstrate that domestic dogs have also evolved levels of numerical ability that includes a limited ability to count. To answer evolutionary questions about species' ability to count requires that a large number of species be investigated; so that comparative analyses can be undertaken (see Harvey and Pagel 1991). It appears that the preferential looking technique as used by Wynn (1992) is easily adapted to be used with other species, especially as it requires no specific training of animals.

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