Quantity discrimination in felines: A preliminary investigation of the domestic cat (Felis silvestris catus)

Article *in* Journal of Ethology · May 2009

DOI: 10.1007/s10164-008-0121-0

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J Ethol (2009) 27:289–293
DOI 10.1007/s10164-008-0121-0

SHORT COMMUNICATION

Quantity discrimination in felines: a preliminary investigation of the domestic cat (*Felis silvestris catus*)

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Received: 21 July 2008 / Accepted: 8 September 2008 / Published online: 2 October 2008

Abstract A large body of studies has investigated the capacity of non-human primates, dogs, birds and lower vertebrates to estimate different quantities of objects or events. Little attention, however, has been devoted to felines, and no study has specifically concentrated on cats' numerical cognition. The present study aims to investigate the capacity of domestic cats to distinguish between two and three dots in order to obtain food; results showed that cats can be trained to discriminate between the two quantities. Furthermore our research suggests that cats do not spontaneously use numerical information, but rather seem to make use of visual cues that co-vary with numerosity in order to solve the task.

Keywords Cat · Numerical competence · Quantity discrimination · Counting · Animal cognition

Introduction

Numerical skills appear to be fairly widespread among species: a large number of experiments conducted in the laboratory and in the field have provided compelling evidence that numerical abilities are not uniquely human (Hauser et al. 2000). Lyon (2003), for instance, reported a spontaneous use of numerical information in a natural context as a strategy to reduce the costs of conspecific brood parasitism in American coots. Previously, Wilson et al. (2001) demonstrated how, in wild chimpanzees, the decision to enter an intergroup contest depends on favourable numerical asymmetries between the groups rather than range location or other factors known to affect response in other territorial species.

The ability to count seems to involve complex cognitive skills, as outlined by Gelman and Gallistel (1978). According to the authors, a robust definition of counting should include five different principles: 'one-to-one correspondence' (each component of a counted set must correspond to one single numeron), 'stable order' (numerons must be ordered in a sequence that is reproducible every time), 'cardinality' (the last numeron in a sequence also represents the total numerosity of the set), 'abstraction' (counting applies to homogeneous and heterogeneous groups of objects of both physical and mental construction) and lastly 'order irrelevance' (the number in which the numerons correspond to each item is not important in the counting process).

If, however, counting can be considered the highest level of mathematical process, the simplest form of numerical knowledge may be represented by a discrimination between two quantities, usually called 'judgement of relative numerosity' (Anderson et al. 2005) or 'quantity discrimination' (Agrillo et al. 2007; Stevens et al. 2007). The ability to distinguish among different quantities may have evolved to enhance survival of organisms in different ecological contexts, such as foraging, group conflicts, parental care and predator avoidance (Lyon 2003; McComb et al. 1994; Wilson et al. 2001). It is possible that quantity information may be more relevant in nature: for example, in foraging situations animals often attempt to maximise the amount of food acquired per unit time spent foraging (Stephens and Krebs 1986). According to this,

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even though number often predicts total amount, sometimes this is not the case, in particular when the size of food items differs greatly (e.g. four very small grapes can be less advantageous than three larger ones for a monkey). Animals may therefore use non-numerical quantitative variables such as surface area as the basis for discrimination, especially when the goal is to maximise amount (and not number), and it has been well demonstrated that the overall area of the stimulus is one of the main non-numerical cues used in quantity discrimination tasks when visual stimuli are presented (Agrillo et al. 2008; Davis and Perusse 1988; Feigenson et al. 2002).

To date, little attention has been focused on quantity discrimination in felines. McComb et al. (1994) reported a rare example of the use of quantity information in nature. In playback experiments, recordings of single female lions roaring and groups of three females roaring together were played back, in order to simulate the presence of unfamiliar intruders in the Serengeti National Park. Results showed that defending adult females were less likely to approach playbacks of three intruders than a single intruder; furthermore, when the subjects approached three intruders, they did so more cautiously. However, the exact nature of such a skill is still unclear: since several features of the stimuli tend to co-vary with numerosity, control experiments are necessary to confirm whether felines can count or, conversely, use other visual or auditory information to compare two quantities. It is worth noting that, surprisingly, we must record a lack of further studies in felines, with the exception of a subsequent study on African lions (Heinsohn 1997) in which, using a playback technique that followed that of McComb et al. (1994), it was confirmed that lionesses can distinguish among different quantities of conspecifics roaring.

The present study aims to fill this gap. Four domestic cats were initially trained to discriminate between groups composed of two and three dots. Then, subjects were observed in a control test, where the overall areas of the stimuli were exactly matched within each pair of stimuli presented, in order to see whether cats have previously learned the task by counting the elements or, in contrast, by comparing the amount of area (or other non-numerical cues that co-vary with area and numerosity) between the two groups.

Materials and methods

Subjects and stimuli

Four domestic pet cats (*Felis silvestris catus*) were used for this experiment. Subjects were mature females (Nerina, Wieso, Wilde and Suesse) between the ages of 4 and 5 years (mean age: 4.25). They were fed with meat and dry cat food before and after the experiment. During the training and test phases, however, no food was provided outside the experimental session. The whole experiment was set up inside a comfortable room in the private house of the first author and videorecorded by a camera placed behind the subjects and opposite the experimental setting.

Two green plastic bowls (11 cm diameter) were placed 40 cm apart, adjacent to a white wall. In the middle, an opaque barrier (50 × 50 cm) divided the two bowls in order to force the cats to choose between the two alternatives soon after being released by the experimenter, thereby reducing the potential influence of olfactory cues on the cats' choices. The cats were released 145 cm from the wall where the two bowls were presented (Fig. 1). A sheet of A4 paper (21 × 29.7 cm) on which the stimuli were presented was placed 10 cm above each bowl. The stimuli consisted of a group of three black dots or a group of two black dots; during the training phase all dots were the same size (diameter: 3.07 cm). A total of 30 different pairs of stimuli were used during the training; the position of the elements was changed to avoid the cats learning how to distinguish on the basis of the overall configuration of the stimuli rather than on the quantity/numerosity of the sets.

In the test phase, the stimuli were figures that differed in numerosity (three elements and two) but that were matched for the overall area, i.e. elements in the two-dot groups were enlarged and/or the elements in the three-dot groups were reduced. Thirty different pairs (with different object

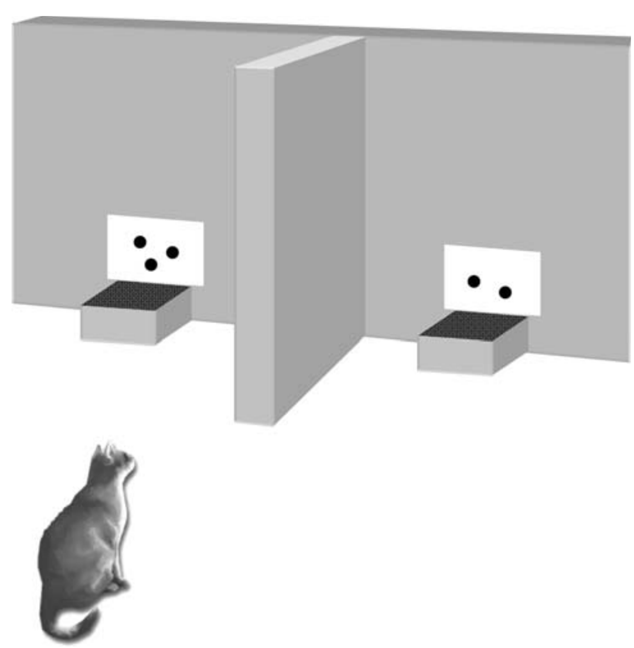

Fig. 1 Experimental setting used. Two bowls were placed the same distance from the cat, and the bowl chosen by the subject was recorded after each trial

sizes and positions) were used in the test phase. Also during the test phase, the position of the elements was varied.

Procedure

During the training phase, cats were individually observed in a binary choice between two bowls: only the one associated with the reinforced numerosity presented food (commercial wet cat-food as normally eaten by the subjects before the experiment). The empty bowl was scented at the beginning and in the middle of each session with food to prevent olfactory cues being used to find the reward. Furthermore, a small amount of food was provided them during each trial in order to reduce any olfactory cue and to motivate cats to reach the bowls for the whole session. Two cats (Suesse and Wieso) were reinforced toward the smaller quantity (2), whereas the two other subjects (Nerina and Wilde) were reinforced toward the larger quantity (3).

Two 10-trial sessions were performed daily, one in the morning and the second one in the afternoon, for 5 days, and for a total of 100 trials. The location of food (and hence the position of the two numerosities) was swapped in half of the tests during each session: half of the trials presented the reinforced numerosity on the left and the second half presented it on the right. The position of the reinforced quantity was randomly distributed within each session. When cats found the reinforced bowl, they were allowed to feed for a maximum of 10 s; a total of 10 s was also allowed for the time between when they selected the empty bowl and started the new trial. Only one experimenter was inside the testing room during each trial. The experimenter released the cat and stayed 80 cm behind the starting point of the test. After the cat selected one bowl, the experimenter returned her to the starting point, while the other experimenter entered the room and changed the stimuli. However, the subject could not see any manipulation of the stimuli since an opaque barrier was placed in front of her by the experimenter who was near the cat.

In the test phase, we adopted an extinction procedure used in other species with cognitive tasks that require a training phase (Chiandetti and Vallortigara 2008; Sovrano et al. 2007): neither bowl held food and no further reinforcement was therefore provided. Such a procedure was similar to the previous training, except that a new set of stimuli (with paired areas) was used. A total of 60 trials had been planned (six overall sessions, two per day, ten trials per session). However, since the cats' motivation to select a bowl in the absence of reinforcement was likely to decrease with an increasing number of trials, a criterion was agreed upon whereby the trials in which subjects spent longer than 5 min reaching any bowl should be discarded. The number of trials that fell within this category differed for each cat (17 Nerina, 4 Wilde, 24 Wieso, and 27 Suesse).

The cats' ability to discriminate between the two quantities was initially analysed by χ^2 tests on the frequency of choices between the groups; subsequently, one-sample t tests on the proportion of accuracy were performed to see whether cats were globally able to solve both training and test phases. Statistical tests were carried out with SPSS 15.0.

Results

Training: can cats learn how to distinguish between two quantities?

Subjects easily learned to associate food and stimuli (Fig. 2), preferentially selecting the bowl placed below the reinforced quantity (Nerina, $\chi_{(1)} = 17.640$, $P < 0.001$; Wilde, $\chi_{(1)} = 33.640$, $P < 0.001$; Wieso, $\chi_{(1)} = 27.040$, $P < 0.001$; Suesse, $\chi_{(1)} = 19.160$, $P < 0.001$). Thereby, we observed an overall ability to distinguish between the two quantities when the proportion of correct choices was analysed (mean ± SD: 0.758 ± 0.034; one sample t test, $t_{(3)} = 15.132$, $P < 0.001$). A subsequent analysis showed that the overall proportion of correct choices in the first half of the training (1–5 sessions) statistically differed from the proportion of correct choices in the following trials (6–10 sessions; paired t test, $t_{(3)} = -6.794$, $P = 0.007$).

Test: do cats use non-numerical cues to solve the task?

Two cats successfully discriminated the reinforced quantity when the overall area between the two stimulus sets was equated (Nerina, $\chi_{(1)} = 10.256$, $P < 0.001$; Suesse,

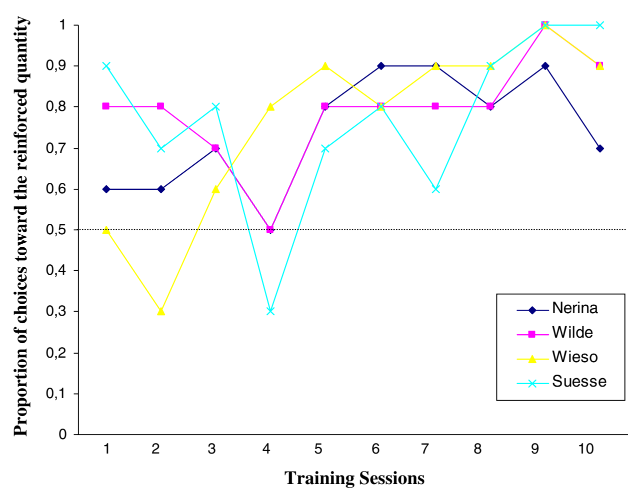

Fig. 2 Proportion of correct choices of the four subjects during the 10 training sessions

Table 1 Overall percentage of correct choices during training and test phase for each cat

Subject	Reinforced toward	Percentage of correct choices during	
		Training (%)	Test (%)
Nerina	3	71	74
Wilde	3	79	46
Suesse	2	77	82
Wieso	2	76	61

$\chi_{(1)} = 9.308$, $P = 0.002$) whereas no significant choice was found for the other two subjects (Wilde, $\chi_{(1)} = 0.286$, $P = 0.593$; Wieso, $\chi_{(1)} = 1.778$, $P = 0.182$, Table 1). An overall analysis indicated that the cats did not correctly choose the reinforced quantity when the area was controlled for (0.633 ± 0.126; $t_{(3)} = 2.111$, $P = 0.125$).

A subsequent analysis on the proportion of correct choices of the first session (10 trials) revealed that subjects' performance at the beginning of the extinction procedure (Nerina, 71% correct choices, $\chi_{(1)} = 1.286$, $P = 0.257$; Wilde, 50% correct choices, $\chi_{(1)} = 0.000$, $P = 1.000$; Suesse, 70% correct choices, $\chi_{(1)} = 1.600$, $P = 0.206$; Wieso, 60% correct choices, $\chi_{(1)} = 0.400$, $P = 0.527$) was positively correlated with the proportion of correct choices of the following trials ($r = 0.994$, $P = 0.006$).

Discussion

The present work is intended to be a preliminary study of cats' numerical competence. We demonstrated that cats can easily discriminate between different quantities of dots. The ability to select the largest quantity may be used in different ecological contexts, and feeding behaviour, in which animals try to maximise the amount of food, represents one of the most important situations. To date, apart from the McComb et al. study (1994) and a subsequent investigation on African lions (Heinsohn 1997), this work represents the only experimental evidence on rudimentary quantity discrimination abilities in felines.

Results of the training phase clearly showed that cats can learn how to distinguish between two groups of elements differing in numerosity. The fact that cats' performance was more accurate in the second half of the training phase demonstrates how quantity discrimination in this task was learned over the trials and was not spontaneously achieved by the subjects, as has instead been found in other species (Hauser et al. 2000; Uller et al. 2003).

On the other hand, results of the test phase provided evidence that subjects did not strictly use numerical information but rather seemed to analyse the quantity of area of the dots, as has also been observed in non-human primates (Tomonaga 2008). The fact that cats' performance during the first trials of the test was very similar to what was exhibited in the following trials strongly supports the idea that the reduced motivation resulting from the extinction procedure cannot be the basis for the minor accuracy of subjects' response when the area was controlled for.

It is not possible at present to exclude the possibility that cats can use other non-numerical variables (such as the sum of their contours and the density of the elements) that cannot be fully matched when we control for the area. Regardless of the exact perceptual cue involved, non-numerical information seems to be spontaneously preferred to numbers in a quantity discrimination task, as previously observed in other vertebrates such as human infants (Feigenson et al. 2002), apes (Beran et al. 2008), monkeys (Stevens et al. 2007) and fish (Agrillo et al. 2008).

The trend exhibited by the subjects during the training demonstrates that our procedure may be successfully used in further studies on cats' cognition, particularly to extend research into felines' numerical competence. For instance, the next step of the project will involve a training procedure where the range of the possible non-numerical cues (such as area, contour, brightness and density of the elements) will be fully investigated. Once we understand the exact mechanism employed by cats to distinguish between two quantities, continuous variables will be matched from the start of the initial training phase. Further research employing the methodology presented here will therefore address whether or not cats possess the ability to discriminate between two quantities by counting each element.

However, we have now provided clear evidence on quantity discrimination in felines. The literature on the capacity for discriminating among sets containing different numbers of objects, previously reported in human babies, several non-human mammals, birds and fish is therefore extended to include the domestic cat as well.

Acknowledgments The authors would like to thank the two anonymous referees for their comments and useful suggestions. The reported experiments comply with all laws of the country (Italy) in which they were performed.

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