Behavioural Processes 85 (2010) 77–79

Contents lists available at ScienceDirect

Behavioural Processes

journal homepage: www.elsevier.com/locate/behavproc

Rapid Report

Physical size matters in the domestic dog's (*Canis lupus familiaris*) ability to use human pointing cues

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ARTICLE INFO

Article history:
Received 22 February 2010
Received in revised form 20 May 2010
Accepted 21 May 2010

Keywords:
Breed
Communication
Dog
Dog–Human Interaction

ABSTRACT

Researchers have reported differences between breeds of dogs in their ability to utilize human gestures (Wobber et al., 2009). These reports could either be the result of underlying differences in inherent communication abilities or differences in physical capacities amongst breeds. One physical difference between breeds which may make a difference in using visual cues is relative size. Larger dogs should, all other things being equal, have greater inter-ocular distances and this may improve their visual abilities for some tasks. This hypothesis was tested in the present study by comparing the performance of larger (>22.7 kg) and smaller (<22.7 kg) dogs on a pointing choice task. Larger dogs did perform better on this task than smaller dogs ($P = .03$). Researchers need to be careful when making comparisons between breeds to first consider physical differences before assuming any inherent cognitive differences.

1. Introduction

Helton (2010) argues that when researchers advance plausible differences in cognitive and behavioural abilities existing amongst breeds of domestic dogs (*Canis lupus familiaris*), that they need to first rule out task-relevant physical differences. The domestic dog has reasserted its position in the behavioural and biological sciences (Hare and Tomesello, 2005; Miklosi, 2007). The recent mapping of the canine genome has, for example, opened the possibility of using the domestic dog to unravel the mysteries of behavioural genetics (Iron et al., 2003; Mosher et al., 2007). Dogs are the most phenotypically diverse species (Lark et al., 2006). The dog, therefore, provides an excellent opportunity to uncover the links between genes and phenotypes, including behavioural phenotypes. Behavioural scientists should not however overlook that an earlier generation of scientists also noticed the immense potential of the domestic dog to unravel the mysteries of behavioural genetics.

In regards to breed differences in cognitive and behavioural abilities, Scott and Fuller (1965, p. 258) noted after a long series cognitive tests conducted on Basenjis, Beagles, Cocker Spaniels, Fox Terriers, and Shetland Sheepdogs, "...we can conclude that all breeds show about the same average level of performance in problem solving, provided they can be adequately motivated, *provided physical differences and handicaps do not affect the tests*, and provided interfering emotional reactions such as fear can be eliminated." When making breed comparisons on a test, researchers need to take care that physical differences and handicaps do not affect the test, as breeds obviously do differ physically (Coppinger and Coppinger, 2001). The physical size range in dogs is immense for a single species, with specimens ranging from the diminutive toy breeds like the Yorkshire Terrier weighing less than 1 kg to the giant Mastiff, weighing as much as 150 kg. Dogs differ in many other physical characteristics in addition to absolute size.

Dogs also differ in shape and these shape differences correlate with other physiological features. McGreevy et al. (2004), for example, have demonstrated differences, in the visual physiology of more dolichocephalic (long skulled) and more brachycephalic (broad skulled) dogs. This distinction is based on calculated cephalic index, a ratio between skull width and length. Cephalic index correlates with the distribution of ganglion visual cells in dogs' retinas. High ganglion cell densities mark areas in the retina that have high resolution. More dolichocephalic dogs have horizontal bands of high ganglion cell density. More brachycephalic dogs have something more analogous to a human fovea, a circular zone in the center of the retina. Gacsi et al. (2009) have recently demonstrated that more brachycephalic dogs are superior to more dolichocephalic dogs in using human gestures to find objects. This is consistent with the increased central vision available to brachycephalic dogs due to their fovea-like visual sensory physiology and increased ocular overlap, which is due to their more forward facing eye position.

Greater sensitivity to the obvious and sometimes non-obvious physical differences amongst breeds, like size and head shape, may improve research on dogs and other animals. Given recent

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doi:10.1016/j.beproc.2010.05.008

research demonstrating differences in relatedness between different breeds of dogs and wolves, researchers have been quick to exploit this information to test theories regarding the origins of dogs' communication abilities. Wobber et al. (2009), for example, investigated breed differences in the ability of dogs to use human communicative visual signals to locate hidden food. Wobber and colleagues compared four breeds: Siberian Huskies, Shepherds (Belgian and German), Basenjis, and Toy Poodles. Their choice of breeds was motivated by the desire to test different ideas regarding the origins of dogs' communicative abilities. The first idea they tested was whether being genetically closer to wolves, which recent genetic research indicates Siberian Huskies and Basenjis are in comparison to Shepherds and Poodles, influences dog performance in their communication paradigm. The second objective was to test whether being bred to work specifically with people which they argued based on breed organizations' classifications Siberians Huskies and Shepherds are in comparison to Toy Poodles and Basenjis, influences dog performance in their communication paradigm. Wobber and colleagues did find that Siberian Huskies and Shepherds performed better than Toy Poodles or Basenjis. They, therefore, argued that being bred to work with people may have selected for improved communication abilities in some dog breeds. While this could be true, an obvious issue in this study and its interpretation is the complete confound of physical size with their being bred-to-work-with-people factor (see Helton, 2010).

Shepherds and huskies are physically larger than Basenjis or Toy Poodles. Larger dogs are likely to have greater inter-ocular distances and may have altered degrees of ocular overlap as their skulls are larger and, perhaps, differently shaped. Greater inter-ocular distances should increase depth perception (stereopsis) and may thereby, improve the dog's ability to detect visual cues. While the role inter-ocular distance plays in human depth perception has been disputed (Banister and Blackburn, 1931; Clark and Warren, 1935; Mead, 1943), researchers should keep in mind that the range of head shapes in dogs is much greater than is typical in people. Binocular vision does improve vision over monocular vision for both short and long distances (Allison et al., 2009). As the distance between the eyes becomes progressive smaller, eventually to the limit of the mythical Cyclops, visual ability will be reduced as it converges on monocular vision (see Changizi and Shimojo, 2008). This is based on physical optical constraints. For example, as Allison et al. (2009) indicate the binocular disparity (δ) associated for a given depth difference (Δd) increases proportionally with the inter-ocular distance (I) and inversely with the square of the viewing distance (D), disparity can therefore by approximated by the formula: $\delta \approx [\Delta d \times I]/D^2$. Both Toy Poodles and Basenjis have smaller heads with closer inter-ocular spacing (I) than Huskies and Shepherds, therefore on a visual task, a difference in performance would not be surprising.

A recent study by Gacsi et al. (2009) presents performance of a multitude of dogs on the human pointing test, and while they did not measure the dog's inter-ocular distances, they did report the dog's breed. While individual dogs will deviate from their breed's standard, we can use these breed standards to roughly classify the dogs into small and large breeds. Large breeds are those greater than 50 lbs (22.7 kg), whereas small breeds are less than 50 lbs (22.7 kg). Thus, Helton's (2010) proposition that size matters in the dog's ability to use human gestures can be tested. The hypothesis is that larger dogs will be superior to smaller dogs on the pointing task.

2. Materials and methods

The data for dogs was extracted from Gacsi et al. (2009). One hundred and four dogs were included in the present analysis as their breed standards could be determined. In Gacsi et al. (2009) the dogs were briefly trained to retrieve food from a baited bowl. In the test condition, the dogs were held by their owners while the experimenter baited one of two bowls out of sight. The experimenter then placed the two bowls in front of the dog at the same time. The experimenter then stood at a distance 2–2.5 m from the dog with folded arms. After establishing eye contact with the dog, the experimenter made a momentary pointing gesture toward the baited bowl with an outstretched index finger. The pointing gesture was made for less than a second and then the experimenter brought his or her arms back to a folded position. The dog was released by the owner only after the experimenter's hand returned to the crossed position. Whichever bowl the dog first approached was considered the dog's choice. The test was repeated 20 times for each dog with the bowl baited, right or left, determined randomly. The total numbers of correct decisions were recorded for each dog.

3. Results

Total data set. For the initial analysis all 104 dogs were separated into large (>50 lbs or 22.7 kg) and small (<50 lbs or 22.7 kg) breeds. Generally a dog >50 lbs is considered a large dog. Since the actual individual dogs' weights or sizes were not recorded and dogs are likely to deviate from their breed standards, the breed standard weights were not analyzed. Instead the dogs were grouped into larger or smaller breeds. For example, while an individual Chihuahua may be large for its breed, it will still not be as large as a small German shepherd. This resulted in 61 large and 43 small dogs. The distribution of the number of correct decisions was significantly different from a normal distribution based on both the Kolmogrov–Smirnov test ($P < .01$) and the Shapiro–Wilk test ($P < .01$). Therefore, the difference between large and small dogs was tested with a one-tailed Mann–Whitney test. The large dogs ($Mdn = 14$) made significantly more correct decisions than small dogs ($Mdn = 12$), $U = 1031.5$, $N = 104$, $P = .03$

Brachycephalic dogs removed. Because brachycephalic dogs have distinctive retinal physiology and brachycephalicy may intercorrelate with size, the 23 brachycephalic dogs were removed from the data set and the analysis was repeated with the non-brachycephalic dogs. The difference between large and small dogs was tested with a one-tailed Mann–Whitney test. The large dogs ($Mdn = 13.5$) made significantly more correct decisions than small dogs ($Mdn = 12$), $U = 567.0$, $N = 79$, $P = .03$. In order to further explore this difference, an alternative grouping was employed that split the data set into three size categories, small (26 dogs, <27 lbs), medium (31 dogs, between 27 and 67.5 lbs) and large (22 dogs, >67.5 lbs). The difference between the small and medium dogs was tested with a one-tailed Mann–Whitney test. The medium dogs ($Mdn = 14$) made significantly more correct decisions than small dogs ($Mdn = 12$), $U = 263.5$, $N = 57$, $P = .01$. The difference between the small and large dogs was tested with a one-tailed Mann–Whitney test. The large dogs ($Mdn = 13.5$) did make significantly more correct decisions than small dogs ($Mdn = 12$), $U = 188.5$, $N = 48$, $P = .02$. The large dogs ($Mdn = 13.5$) did not, however, make significantly more correct decisions than medium dogs ($Mdn = 14$). These results are displayed in Fig. 1

4. Discussion

As predicted, larger dogs as a group perform better on the pointing gesture task than smaller dogs ($P = .03$). As McGreevy et al. (2004) and Gacsi et al. (2009) indicate the relationship between size and performance is also likely to be influenced by the differences in retinal physiology occurring in brachycephalic dogs. Excluding brachycephalic dogs from the analysis does not, however, alter the general finding presented here that larger dogs perform better

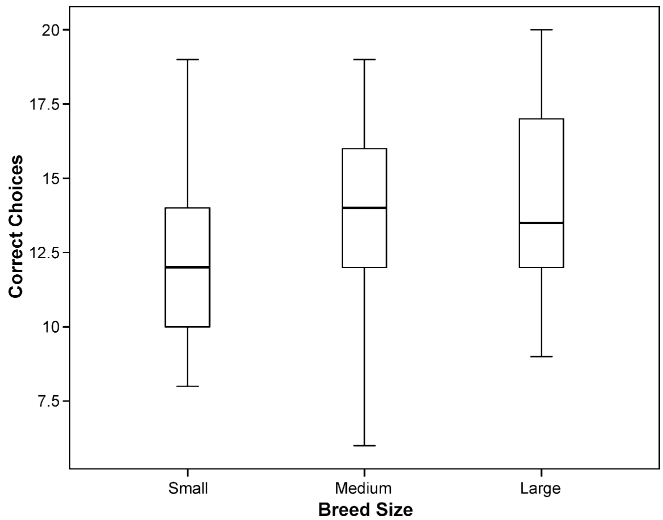

Fig. 1. Box plots showing the relationship between size of dog (small < 27 lbs; medium 27–67.5 lbs, and large > 67.5 lbs) and correct choices out of 20 total possible on the pointing-task with brachycephalic dogs removed.

on the pointing gesture task than smaller dogs. A closer analysis of the relationship between size and performance, excluding brachycephalic dogs, indicates the primary influence of size on performance occurs on the small end of the continuum (see Fig. 1). One limitation of the present study was that there was no means to determine how closely the dogs in the study were represented by their breed standard, nor could we determine the dogs' actual inter-ocular spacing. In the analyses presented here we hoped to avoid this dilemma by simply grouping the dogs into small and large, or small, medium, and large categories. Any finer grain analysis was implausible with the data available. We strongly encourage researchers in the future to collect inter-ocular spacing information when investigating breed differences in visual performance.

There at least three possible and not mutually exclusive explanations for the result that size relates to performance on a pointing task. The first explanation is the one proposed by Helton (2010) and presented in the introduction regarding the physical differences between large and small dogs. Larger dogs will generally have greater inter-ocular distances than smaller dogs. Greater inter-ocular distances should improve stereopsis and the use of other depth cues. Binocular vision does improve visual perception over monocular vision (Allison et al., 2009). These benefits reduce, however, as the inter-ocular distance shortens (Changizi and Shimojo, 2008). A difference on a task requiring vision between large and small dogs should not, therefore, be surprising.

A second plausible explanation is that larger dogs simply have more consistent experience with human gestures than smaller dogs or the consequences of the gestures are more strictly enforced with larger dogs. This is also not inconceivable. The tolerance of disobedience in larger dogs is undoubtedly different than for smaller dogs. A small dog which ignores the command to get off the couch, perhaps issued simultaneously with a vocal command and pointing gesture, is probably not as likely to be disciplined as a larger dog which ignores the command. A disobedient large dog is a greater relative threat or danger, than a disobedient small dog. As Wynne et al., 2008 suggest reinforcement experience on these pointing tasks probably matters. Differences in reinforcement experiences could explain the great diversity in performance results detected across dogs.

The third explanation is the one proposed by Wobber et al. (2009) that larger dogs are bred to work with people, whereas they argue smaller dogs are typically just companions and not bred to work with people. The difference in ability would therefore be the result of some direct genetic influence on communication skills. There may have been selection differences for communication abilities or modes of communication across breeds; for example, there may have been selection for more quiet or more vocal communication for different breeds. Wobber and colleagues claim, however, that smaller dogs are typically just companions and not bred to work with people needs justification.

Undoubtedly people will differ in their preference for the three plausible explanations provided above. They are not mutually exclusive and all may contribute to the diversity of performance observed amongst dogs. The last of the three, the breed genetic difference in communication skills, however, should not be advanced until the two other possibilities have been ruled out first. Bigger breeds of dogs are obviously different than smaller breeds of dogs. These size differences may impact perceptual abilities. In order to further explore these visual differences, perhaps, researchers could test dogs in binocular and monocular (with eye-patches) viewing conditions on the pointing task. Regardless, these types of tests should be done first. Whenever differences within a species or even between a species are found, our first goal should be to look for an obvious (or even non-obvious) physical explanation (see McGreevy et al., 2004). Only after all these physical possibilities have been eliminated should we then move to differences in experiences (reinforcement histories), and then only last, possible inherent cognitive differences. Hopefully, this is not taken as a particular criticism of Wobber's et al. (2009) work, but only a general statement to researchers who are making breed or species comparisons to start at the beginning: physical explanations first.

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