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BRIEF REPORT

Inverse Sex Effects on Performance of Domestic Dogs (*Canis Familiaris*) in a Repeated Problem-Solving Task

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The authors investigated differences between female and male pet dogs in physical cognition using an object manipulation task. Subjects (24 females and 23 males of different breeds) had to open a box in order to obtain a food reward during 3 consecutive trials, and latency times before success were measured. Males were significantly more successful in opening the box during the first trial. However, this sex difference was inversed when successful individuals were retested. During the following 2 trials, females were more successful than males, indicating that they were able to improve their skills more quickly once they had managed to succeed for a first time. Sex-specific dynamics in repeated problem-solving tasks might be an important contributor to individual differences in cognitive performance of pet dogs.

Keywords: sex difference, pet dog, dog cognition, physical cognition, object manipulation

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Females and males differ in several aspects of their cognitive abilities to solve physical problems (Healy, Bacon, Haggis, Harris, & Kelley, 2009). For example, it has been shown that men perform better in mental rotation or navigation, whereas women outperform men in object location memory tasks (Andreano & Cahill, 2009; Caplan, Crawford, Hyde, & Richardson, 1997). Similar differences are also found in many nonhuman animals, for instance in rodents (Hawley, Grissom, Barratt, Conrad, & Dohanich, 2012; Jonasson, 2005). These differences are still not fully understood and are subject to controversial discussions. One of the widely accepted explanations is the "range size hypothesis," proposing that males are under high selection pressure to remember landmarks as they have larger home ranges than females, thus leading to an improvement in their physical and spatial cognitive abilities (Healy et al., 2009). However, in some other taxa such as canids, home range does not appear to differ between males and females (e.g., Kamler & MacDonald, 2014). And in free-ranging dogs (*Canis familiaris*) sex does not influence home range size (Daniels, 1983) or dispersal distance (Pal, Ghosh, & Roy, 1998) either. Moreover, little is known about the presence or absence of the above-mentioned sex-specific cognitive differences in the domestic dog (Marshall-Pescini, Barnard, Branson, & Valsecchi, 2013; Miklósi, 2007; Passalacqua, Marshall-Pescini, Merola, Palestrini, & Prato Previde, 2013). This is particularly surprising because various aspects of dog cognition were intensively studied during the last decades (reviewed in Bensky, Gosling, & Sinn, 2013). A recent study focusing on this subject showed that female dogs were more likely than males to respond to violations of the expected size of an object (Müller, Mayer, Dörrenberg, Huber, & Range, 2011). But to

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the best of our knowledge, so far no study has focused on whether female and male dogs differ in their success to solve a physical cognitive problem.

In this article, we proposed to explore this understudied field, testing for sex differences in the domestic dog using a problem-solving task, defined as "the use of a novel means to reach a goal when direct means are unavailable" (Seed & Call, 2010). To this end, subjects had to repeatedly open a box in order to obtain food and we studied their performance with respect to latency time until success. Based on the results of studies in other mammalian species (Healy et al., 2009), we expected that male dogs will outperform females during a repeated problem-solving task as applied here. Furthermore, we studied whether this purported male advantage was constant across time, that is, when initially successful animals were retested in consecutive trials.

Method

Subjects and Experimental Setting

We tested 47 pet dogs (24 females and 23 males) of 28 different breeds or mixed breeds, with sex ratio balanced across breeds (see Table S1 in the online supplemental materials). Subjects were between 1- and 8-years-old (on average: 3.7 years; no significant age differences between males and females: $t = .26$, $p = .79$), and did not show any signs of visual or physical impairment. Owners participated on a voluntary basis and were recruited via the Internet and by personal communication. As verified by interviews with the owners, all dogs were naïve to the kind of problem-solving task used in this study.

Experiments were conducted in a closed and silent room (5.0 × 4.6 m). The experimenter was always the same woman for all dogs (see Figure S2 in the online supplemental materials). Owners were present during the experiments, but remained silent, immobile and did not directly look at their dogs. Furthermore, owners wore dark sunglasses to avoid giving any gaze cue to the dogs during the trials. During the experiments, dogs wore their usual collars or harnesses.

The apparatus consisted of a wooden box (15 cm × 15 cm × 5 cm), not fixed to the ground. A food reward was hidden inside the box (a handful of mince and cooked chicken meat), which was then closed by a plastic cover. A handle (3 cm × 3 cm cylindrical plastic stick) fixed on the top of the cover, allowed the dogs to remove it (with mouth or front paw) in order to get the reward.

General Procedure and Data Collection

The procedure consisted of two consecutives phases:

1. Familiarization phase: The owner, the dog and the experimenter entered the room and the dog got unleashed in order to allow it to explore the room and to get familiar with the experimenter.

2. Testing phase: The owner and the dogs were on their predefined location (see Figure S2 in the online supplemental materials time until success within each trial were noted.time until success within each trial were noted.), with the empty apparatus (i.e., no reward inside) placed on the floor in front of them. The experimenter attracted the dog's attention and let it smell the reward she had in the hand. Then she put the meat inside the box, and put the cover on it to close the apparatus, with clear and large gestures, to ensure that the dog could observe and be interested in it. Finally, the experimenter went to her own predefined location and asked the owner to unleash the dog. This was repeated three times (Trials 1–3). The experiment was terminated (whether or not the dog was successful in opening the box) after 120 s during Trial 1, and after 60 s during Trials 2 and 3. The dog was leashed at the end of a trial and waited 30 s between each trial.

All trials were video recorded and videos were analyzed by the same experimenter. For all trials, analysis began when the dog was unleashed. From this moment on, latency time before first contact with the box, the dogs' success in opening the box (yes/no) and the latency time until success within each trial were noted. See online supplement materials for details on validation of accuracy of video analysis.

Statistical Analysis

Analyses were done using the program R, version 3.0.1 (R Core Team, 2013). Differences between females and males with respect to the latency time in approaching the box were tested by linear mixed-effects models (LMM). Sex differences with respect to the time to open the box were tested using Cox proportional hazards regression models. By the latter analysis, we adjusted for the censored character of the data, that is, that some of the dogs did not manage to open the box during the respective trials. See the online supplemental materials for details.

To test for sex-specific differences in the success in opening the box across time (see Figure 1), we considered data from all individuals during the first trial. This was done in order to test for sex-specific differences in success in a novel problem solving task. During the following trials, we only considered individuals for analysis, which were successful during at least one of the previous trials. This was done in order to test whether the probability of repeated success (i.e., in an already mastered problem-solving task) differs between females and males. Thus sample size decreased between trial one and the following trials, however slightly increased between Trial 2 and Trial 3, as some animals were successful during Trial 2 but not during Trial 1.

Results

Latency to Approach the Box

The latency of approaching the object did not differ between females and males and was not affected by the reproductive status (neutered/intact) or the age of the dogs, either when considering all individuals or only focusing on dogs which were successful during the respective trial ($p > .05$). Furthermore, there was no significant interaction between sex and trial, indicating that there were no sex specific differences among trials ($p > .10$).

The latency of approach differed significantly across trials (LMM: $\chi^2_2 = 7.60$, $n = 141$, $p = .022$) when considering all individuals. Post hoc comparisons revealed that latencies during

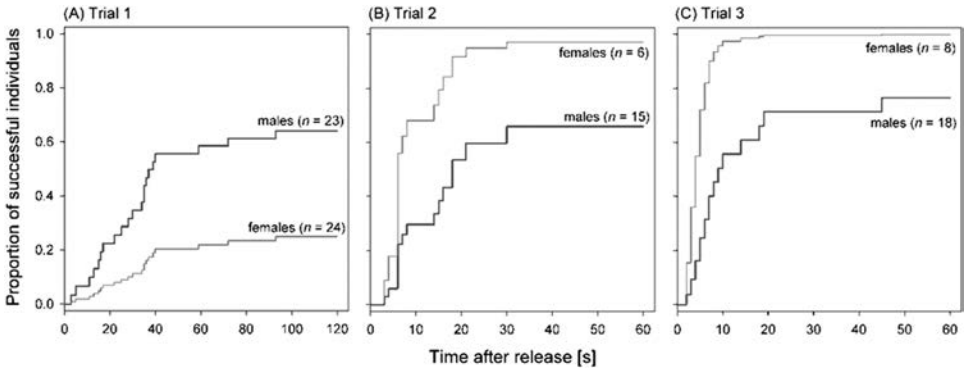


Figure 1. Kaplan-Meier curves showing the increase in the proportion of successful females and males during repeated trials. Differences between females and males were significant during all trials; but note the inversed effects between the first and the following trials. Sample sizes increase from the second to the third trial, as we considered all individuals for analysis during the repeated trials, which were successful in one of the previous trials. See text for details on statistics. See the online article for the color version of this figure.

the third trial (on average 7.9 s ± 4.1 $CI_{90\%}$) were significantly higher than during the first trial (4.8 s ± 4.3 $CI_{90\%}$); $\chi^2_2 = 5.39$, $p = .020$) and during the second trial (5.2 s ± 3.5 $CI_{90\%}$); $\chi^2_2 = 6.16$, $p = .013$). The first and second trials did not differ ($\chi^2_2 = .16$, $p = .70$). These differences among trials disappeared when only considering subjects, which were successful during the respective trial (Trial 1: 1.5 s ± .7 $CI_{90\%}$; Trial 2: 1.3 s ± .2 $CI_{90\%}$; Trial 3: 1.3 s ± .2 $CI_{90\%}$;$\chi^2_2 = .32$, $p = .85$).

Opening the Box

First trial. During the first trial males were significantly more successful than females in opening the box (Cox proportional hazards regression: $\chi^2_2 = 7.67$, $n = 47$, $p = .006$; Figure 1A). Note that this kind of model integrates the latency time as well as the probability of success as dependent variable for analysis. There were no significant effects of the dogs' age and reproductive status ($\chi^2_2 = .08$, $p = .77$) with respect to their success ($\chi^2_2 = .11$, $p = .74$) and also no significant interactions among the three predictor variables ($p > .10$).

Repeated trials. The sex-dependent performance was inversed when successful subjects were repeatedly tested in a second and third trial. During Trial 2 ($\chi^2_2 = 4.10$, $n = 21$, $p = .043$; Figure 1B) as well as during Trial 3 ($\chi^2_2 = 7.40$, $n = 26$, $p = .007$; Figure 1C) the proportion of successful females was significantly higher than the proportion of successful males. Again, there were no significant effects of age and of reproductive status, and also the interactions between the 3 predictor variables were not significant ($p > .05$).

Discussion

Although sex differences in physical problem-solving skills have been intensively studied in various mammalian species (Seed & Call, 2010), to our knowledge this is the first study reporting differences between females and males in problem-solving abilities in the domestic dog. Most importantly, our results indicate inversed sex-specific differences in success across repeated trials. During the first trial, males outperformed females and such a male advantage in physical cognition is in line with previous findings in other mammals (Benson-Amram, Weldele, & Holekamp, 2013; Healy et al., 2009). This initial difference was unlikely due to females' lower degree of motivation because both sexes did not differ in their latency to approach the box in any of the trials. We suggest that male dogs were less affected by the experimental setting as studies on dog temperament using nonsocial objects have frequently reported comparatively higher boldness scores in males in such situations (Starling et al., 2013).

Different nonexclusive mechanisms might be considered in order to explain this observed sex difference (Müller et al., 2011). First and as already mentioned, sex-specific selection might have led to different cognitive abilities. It is possible that such difference was selected and present in dogs' and wolves' common ancestor. And even if no evidence exists that different selective pressures, home range size or breeding strategies have shaped male and female pet dogs' behavior in a contrasting way (Miklósi, 2007), sex-specific cognitive abilities might originate from the dog's ancestral species. Second, sex-specific environment during ontogeny might have induced different cognitive capacities of adult females and males. And indeed, sex-specific differences in early developmental environment are for example reported in humans, since children of different gender are frequently raised in a different way according to cultural traditions (Wood & Eagly, 2012). As many owners consider their dogs as family members (Archer, 1997), a "social gender consideration," that is, differences in the way owners might interact with female and male dogs, could be potentially relevant here. Third, sex difference in cognition might also be a by-product of other sex-dependent differences, such as hormone levels (Kimura, 1999). For example, a study in men indicates that increased testosterone levels have differential effects on spatial abilities and verbal fluency (O'Connor, Archer, Hair, & Wu, 2001). But in general, the interaction between testosterone levels and cognitive abilities is far from being clear.

Most importantly, when retesting individuals that were initially successful, females outperformed males during these successive trials. Such a higher performance in female dogs as compared with males has been already reported in previous studies, although

never in the context of repeated trials (Müller et al., 2011; Rooijakkers et al., 2009). We propose that this inversed sex effect across time could be due to sex-specific differences in the way of remembering the successful strategy of problem solving. Indeed, such differences in learning performance between males and females in social as well as in nonsocial contexts have been described in primates. For example, female rhesus monkeys (*Macaca mulatta*) outscored males in a learning task related to the utilization of local markers (Herman & Wallen, 2007). Moreover, studies in humans indicate that females remember precise object or local features better than males (Lejbak et al., 2009; Voyer et al., 2007). We propose that similar sex-specific processes could be present in the dog.

Although this study only focuses on a single task, it provides a significant piece of evidence emphasizing the existence of sex-specific differences in problem-solving skills in the domestic dogs. Most importantly, the study reveals that the direction of differences between males and females is not necessarily stable across repeated trials. We hope that our findings will stimulate others to include such interactive changes across time in the study of cognitive abilities in mammals and birds.

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