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Free-ranging dogs match a human's preference in a foraging task

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Abstract

Social learning is a mechanism used by many species to efficiently gain information about their environment. Although many animals live in an environment where members of other species are present, little is known about interspecific social learning. Domesticated and urbanized species provide the opportunity to investigate whether nonhuman animals can learn from heterospecifics such as humans, who are integral parts of their social landscape. Although domestic dogs *Canis familiaris* have been intensively researched for their ability to learn from humans, most studies have focused on dogs living as pets. However, free-ranging dogs represent the majority of the world's dog population, they live alongside humans, scavenge on human refuse, and are subject to natural and sexual selection. Thus, free-ranging dogs with extensive exposure to humans and their artifacts provide the opportunity to investigate interspecific social learning in a naturalistic setting, where learning from humans might be a benefit for them. Here we tested individual free-ranging dogs in a between-subject design: Dogs in the control group could spontaneously choose between two novel and differently patterned food-delivering boxes. In the experimental group, instead, dogs could first observe an unfamiliar human approaching and eating from 1 of the 2 boxes. We provide the first evidence that free-ranging dogs match the choice of an unfamiliar human. These results show that at least simple forms of interspecific social learning might be involved in dogs' success in living alongside humans in a complex urbanized environment.

Key words: *Canis familiaris*, dogs, domestication, foraging, free-ranging dogs, social learning, urbanization.

Humans have a huge impact on the world, modifying environments at a speed that has no equal. Understanding how nonhuman species adapt to this continuously changing world has become a central topic both at a scientific and societal level. With the high speed of human-induced landscape alteration, behavioral plasticity can enable a species to rapidly acquire novel behaviors, beneficial in their newly altered environment (Sih 2013; Sol et al. 2013; Thompson et al. 2022). Behavioral plasticity can take the form of learning, both at the individual and at the social level (Mesoudi et al. 2016).

Acquiring information about environmental stimuli from others (i.e., social learning) can be cheaper and faster than engaging in direct trial-and-error interactions typical of individual learning (Laland 2004; Kendal et al. 2005). Especially for species living in a human-dominated environment, it would be advantageous to learn not only from conspecifics but also from humans (Goumas et al. 2020; Feist et al. 2023). This would be particularly true for those species depending on human resources (e.g., food and shelter) for their survival (Sol et al. 2013; Sarkar and Bhadra 2022). Studying the impact, which humans have on the behavior of animals (whether domesticated or not) living in urbanized environments is not only relevant for the understanding of how species adapt (and thrive) in a human-dominated landscape, but it can also provide insights into the cognitive mechanisms underlying interspecific social learning (Goumas et al. 2020). Domestic dogs *Canis familiaris*, in particular pet dogs, have been intensively studied as a model for interspecific social learning. Twenty years of research on pet or pack-living hand-raised domestic dogs has shown them to acquire socially different types of information from humans (Pongrácz 2014): food location (Range and Virányi 2013), body movement imitation (Huber et al. 2009, 2018, 2020; Fugazza and Miklósi 2015), object manipulation (Range et al. 2007, 2011) and reaction to unfamiliar humans (Duranton et al. 2017). However, pet or pack-living hand-raised dogs receive very intense socialization with humans since early puppyhood, and their attention to humans as well as the copying of their actions could have been reinforced through previous interactions with their owners or other familiar humans (Pongrácz 2014). Free-ranging dogs, instead, do not receive such intense socialization (Marshall-Pescini et al. 2017; Horn et al. 2022) and they represent the majority of dogs in the world (Hughes and Macdonald 2013).

Free-ranging dogs are not restricted in their movements and mating choices, and they are genetically distinct from purebred dogs and show larger genetic variability (Pilot et al. 2015). They are opportunistic foragers mostly scavenging off

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human refuse (Bhadra and Bhadra 2014; Butler et al. 2018) and thus subjected to a highly variable (both temporally and spatially) environment constantly under human influence (Gommper 2014). As such, they continuously face novel human artifacts, which might bring an advantage to them (e.g., by containing palatable food, Lazzaroni et al., 2019; Sarkar et al., 2019). Moreover, although their activities are not controlled by humans, especially free-ranging dogs, which live as village dogs (Pal 2001; Butler et al. 2018) interact with humans in various ways (Majumder et al. 2014; Paul et al. 2016; Bhattacharjee et al. 2020), thus they might be particularly attentive to what humans do, especially in a foraging context.

To date, free-ranging dogs have been shown to pay attention to humans (Brubaker et al. 2019), to adjust their behavior based on their previous experiences with humans (Bhattacharjee and Bhadra 2022), and to interact with novel objects potentially concealing food (Lazzaroni et al. 2019; Sarkar et al. 2019). However, to the best of our knowledge, no study has investigated whether free-ranging dogs pay attention to human behavior and adapt their foraging choices based on what humans do.

In this study, we focused on what was considered to potentially be highly relevant information for free-ranging dogs' survival, i.e., where to find food, and we set up a task, which would not require highly complex social learning abilities (e.g., stimulus enhancement, Heyes 1994; Whiten 2023). More specifically, we aimed at investigating whether having witnessed a human eating from 1 of 2 novel feeding sources, free-ranging dogs would be influenced in their subsequent choice of which resource to approach. Thus, we tested free-ranging dogs in a between-subject design, where dogs in the experimental group witnessed a human interacting with 1 of 2 differently looking boxes; whereas dogs in the control group were directly exposed to the 2 boxes without having previously witnessed a human demonstration.

Based on the fact, which free-ranging dogs rely on human resources for their survival (Bhadra and Bhadra 2014; Butler et al. 2018) and that they have been shown to pay attention to humans (Brubaker et al. 2019; Bhattacharjee and Bhadra 2022), we hypothesized, which they would match their preferences to the one displayed by a human when facing a novel foraging source. More specifically, we predicted that: 1. free-ranging dogs would be more likely to approach a new foraging apparatus after having seen a human interacting with it (experimental group) than when nobody was observed interacting with it (control group); 2. in the experimental group, free-ranging dogs would match the previously observed choice of a human demonstrator for 1 of 2 apparatuses above chance; and interact with the human-chosen apparatus for longer than the non-chosen one whereas 3. in the control group, no preference for a specific apparatus would be observed, and dogs would interact for an equal amount of time with the 2.

Materials and Methods

Subjects

We tested $N = 156$ adult free-ranging dogs living in small villages in Morocco (Sous-Massa region). Dogs in the area live within human settlements, they live in proximity to humans, and they use human refuse as the main food source. These dogs are genetically close to eastern European mongrels (Range and Marshall-Pescini 2022), who are not an admixture of different breeds (Pilot et al. 2015).

Dogs were tested on the streets and their movements were not restricted. Moreover, although we aimed at testing only dogs which were found alone, in some cases humans, other dogs, or other animals (e.g., cats) were approached during testing. In some cases, subjects needed to be excluded from the analyses: If they left before the end of the 30 s demonstration, if it was unclear whether the subject watched the demonstration, if other dogs or members of other species (i.e., cats and humans) interfered before they could make a choice, or if errors in the experimental procedure occurred. Hence, the final sample comprised $N = 99$ subjects ($N = 43$ in the No Demonstration group (21 females and 22 males) and $N = 56$ in the Demonstration group (18 females, 33 males, and 5 of unknown sex)).

Equipment

All subjects were exposed to the same equipment. Two boxes (H 60 cm × W 40 cm × L 30 cm) covered with a laminated fabric of different colors (i.e., 1 yellow and 1 blue with a flower pattern, Figure 1). Each box contained an automatic feeder (PetSafe® Treat&Train™) that could be activated independently with a remote control. At the bottom of the box, an opening allowed the subject to access the food being delivered by the automatic feeder. When the button on the remote was pressed, dry dog food (~5 pieces) came out from the feeder at the bottom of the box.

Design and experimental procedure

Two experimenters (E1 and E2) drove by car around villages to locate dogs alone, in the morning between 6 AM and 11 AM. Visited areas and villages were chosen in a semi-randomized way, with different villages being visited each week. Dogs could be easily identified individually, hence none of the subjects was tested more than once (this was later also checked from the videos). As finding the same dog in the same location a second time is difficult, we adopted a between-subject design. Hence, subjects were randomly assigned to 2 groups: A subject could either witness a human demonstration (Demonstration group) or not (No Demonstration group). The sex of the subject was noted by E2 or later from video recordings. Once a subject was identified, a hand-held video camera was turned on and placed in or on top of the car (depending on the positioning of the dog in relation to where the car was parked). Then, both E1 and E2 stepped out of the car, took 1 box each (color of the box randomized across tests) from the boot of the car, walked 5 m away from the car, and simultaneously placed the boxes on the ground 2 m distance from one another at ~10 m from the subject. The location was chosen so that the 2 boxes were placed between the car and the subject. The opening at the bottom of the box was placed in the direction of the car so that it was possible to see whether the subject ate from the box. A few kibbles were present at the bottom of each box at the beginning of the trial but for $N = 14$ dogs (note: To ensure that the absence of the food at the start of the trial did not affect the results, we included the presence/absence of food at the start of the trial in the analyses, see below).

Then, depending on the group assignment, both E1 and E2 (No Demonstration group) or only E2 (Demonstration group) walked back to the car. In the Demonstration group, E1 remained close to the box they had carried, clapped twice, and whistled to get the dog's attention. As soon as the dog started to pay attention to E1, E1 kneeled next to the box

Figure 1. Equipment and set-up used in the present study. Two boxes were placed 2 m away from each other, at ~10 m from a subject. In the figure, the unfamiliar human kneels and pretends to eat from 1 of the 2 boxes for 30 s (Demonstration group). Photo credits: Giulia Cimarelli.

and pretended to eat from it. E1 did so for 30 s. After that, they stood up and walked back and entered the car. $N = 21$ dogs approached the experimental setting before the 30 s of demonstration were over. When this happened, E1 stood up and walked back to the car as soon as the subject was 3 m away from 1 of the boxes. Whenever the dog approached 1 of the boxes within 10 cm, E2 pressed a button to release the kibbles in the feeder. If the subject remained within 10 cm from the box, food (~5 kibbles) was released as soon as the subject finished ingesting the previously delivered food. The experiment stopped after 5 min or if the dog walked more than 100 m away from the boxes.

Behavioral analysis

The videos of the experiment were analyzed using Loopy (Loopbio, Vienna, Austria) by M.J. A second coder (G.C.) coded 20% of the videos to assess inter-rater reliability. We analyzed whether the dog approached at least 1 box to within 10 cm and which box (yellow vs. blue) the dog approached first. The 2 coders obtained a 100% agreement for both variables. Moreover, we analyzed the duration of interaction with each box (sniffing and touching the box) throughout the experiment, as an additional measure of potential preference for 1 of the 2 boxes. The inter-rater reliability was excellent for both analyzed variables: Interaction duration with the blue box (ICC = 0.93, $F = 25.9$, $P < 0.001$), and interaction duration with the yellow box (ICC = 0.98, $F = 79.6$, $P < 0.001$).

As in some cases ($N = 21$), dogs in the Demonstration group approached the experimental setting before the end of the demonstration (hence, when E1 was still close to the box), we also counted how many dogs chose the correct box depending on whether they approached the box whereas E1 was still engaged in the demonstration and hence close to the box (ie., before the 30 s elapsed) or at the end of the 30 s of demonstration (i.e., when E1 was no longer present in proximity to the experimental setting) and how many dogs followed E1 to the car once E1 left the experimental setting. We did so to assess whether dogs' motivation to approach the correct box was potentially based on the desire to interact with the human rather than with the box itself.

Statistical analysis

Data were analyzed using R (v. 4.2.1) (R Core Team, 2021). To test whether the likelihood of approaching at least 1 box and the subjects' choice depended on having witnessed a human demonstration, we conducted Generalized Linear Models (GLM, binomial family, *glm* function, lme4 package) with group (Demonstration vs. No Demonstration) as main predictor. Sex (male vs. female) and the presence of food at the start of the trial (yes vs. no) were included as control predictors (hence, their significance was not considered). A null model lacking the main predictor was also run and compared with the full model using a likelihood ratio test (chi-square test, *Anova* function) to reduce the likelihood of committing a Type 1 error. If the null–full model comparison was significant, then a likelihood ratio test was performed to investigate the effect of the predicting variable (chi-square test, *drop1* function). Over-dispersion of the full model was assessed and it was found to be acceptable (*over.disp* function).

Moreover, we carried out a binomial test to assess whether dogs in each group chose the correct box above chance. The correct box was either the box approached by *E* in the Demonstration group or the randomly chosen yellow box in the No Demonstration group. A box was randomly chosen as the correct box in the No Demonstration group to be able to compare choices between the 2 groups. To assess whether dogs chose the correct box with the potential motivation to interact with the human rather than with the box itself, we ran a Fisher's Exact test to compare the number of dogs who approached the correct box depending on whether they approached during the demonstration (i.e., before the 30 s of demonstration were over) or after (Demonstration group only).

To test whether having witnessed a human demonstration influenced the amount of time that the subjects spent interacting with each box, we ran a General Linear Mixed Model (LMM, lme4 package, *lmer* function) with the interaction between group and box as the main test predictor and the duration of interaction with each box as response variable (log-transformed to meet model assumptions). We used a mixed model, with the identity of the subject as a random effect, to control for pseudo-replication (each subject could have interacted with both boxes, hence the dataset comprised 2 rows per individual, each representing the duration of interaction with 1 of the 2 boxes). Sex (male vs. female) and the presence of food at the start of the trial (yes vs. no) were included as control predictors (hence, their significance was not considered). A null model lacking the main predictor was compared with the full model using a likelihood ratio test (chi-square test, *Anova* function) to reduce the likelihood of committing a Type 1 error. If the null–full model comparison was significant, then a likelihood ratio test was performed to investigate the effect of the predicting variables (chi-square test, *drop1* function). The full model's assumptions were checked by plotting residuals vs. fitted values (homogeneity of variance) and by means of qqplots of the models' residuals (normality). Both returned acceptable results. To investigate the difference between each level of the predictors involved in the interaction, we used the function *emmeans* (package emmeans), adjusting for multiple testing using the Tukey method. As the time spent interacting with the first approached box could have depended on the fact that dogs were provided with food when in proximity to a box (independently from the identity of the box), hence reinforced to stay at the first box, we further analyzed whether dogs spent generally more time interacting with the first box approached (paired-samples Wilcoxon test) and whether the time spent interacting with the correct box approached as first was dependent on group assignment (2-samples Wilcoxon test), to distinguish between a preference for interacting with the first approached box from a preference for interacting with the demonstrated box influenced by the demonstration. Only $N = 77$ dogs were included in the analysis of the interaction duration with the box as in 22 cases ($N = 14$ in the No Demonstration group and $N = 8$ in the Demonstration group) environmental disturbance occurred after their first approach/choice. Plots were drawn using the function *ggplot* (package ggplot2).

Results

Approaching at least 1 box

Overall, 64.64% (64/99) dogs approached at least 1 box: 67.44% (29/43) dogs in the No Demonstration and 62.5% (35/56) dogs in the Demonstration group. We did not find that dogs' likelihood of approaching 1 of the 2 boxes was influenced by having witnessed a human demonstration (GLM, $\chi^2 = 0.16$, $df = 1$, $P = 0.16$). In the Demonstration group, of the 35 dogs who approached at least 1 box, $N = 21$ approached whereas E1 was still performing the demonstration, whereas the remaining 14 approached after the 30 s of demonstration. According to the procedure, when these 21 dogs approached the experimental setting, E1 stood up and moved back to the car. Among these 21 dogs, none followed E1 back to the car.

Box choice

Among those dogs who made a choice ($N = 29$ in the No Demonstration group and $N = 35$ in the Demonstration group), 44.83% of the dogs in the No Demonstration group chose the yellow box (dummy coded as the correct box), which was at chance level (13/29, binomial test: $P = 0.71$). In the Demonstration group, 91.43% of dogs chose the box approached by the demonstrator (32/35, binomial test: $P < 0.0001$). The likelihood of choosing the correct box was significantly higher in the Demonstration group than in the No Demonstration group (GLM, $\chi^2 = 14.49$, $df = 1$, $P < 0.0001$, Figure 2). In the Demonstration group, 21 dogs approached a box during the demonstration, with 20 of them choosing the demonstrated box (95.24%, binomial test: $P < 0.001$). Amongst the 14 who approached after the demonstration, 12 chose the correct box (85.71%, binomial test: $P = 0.01$). The likelihood of approaching the correct box did not differ between those dogs who approached the correct box during or after the demonstration (Fisher's Exact test: $P = 0.55$).

Interaction duration with each box

We found a significant effect of the interaction between the group and box when analyzing the duration of interaction with the box (LMM, $\chi^2 = 19.45$, $df = 3$, $P = 0.0002$). The dogs who received a demonstration interacted with the correct box significantly more than dogs who did not receive it (No Demonstration group, correct vs. control box: estimates ± $SE = 0.14 \pm 0.24$, $t = 0.58$, $df = 70$, $P = 0.56$; Demonstration group, correct vs. control box: estimates ± $SE = 0.74 \pm 0.19$, $t = 3.85$, $df = 70$, $P < 0.001$, Figure 3). Overall, dogs interacted more with the first box approached than with the second one (paired-samples Wilcoxon test, $V = 1$, $P < 0.001$), but dogs of the Demonstration group interacted for longer with the correct box they first approached than the No Demonstration group (two-samples Wilcoxon test, $W = 961$, $P < 0.001$).

Opportunistic observations of intra-specific influence

In $N = 21$ cases ($N = 16$ in the No Demonstration group and $N = 5$ in the Demonstration group), a second dog witnessed the first subject interacting with 1 of the 2 boxes and approached 1 of the 2 boxes as second. Although it was not the primary goal of the present study, we coded whether these dogs chose to approach the same box as their partner. $N = 17/21$ (80.95%) dogs chose the same box as their partner, which was above chance (binomial test: $P = 0.007$). Even after excluding those dogs of the Demonstration group (who might have also witnessed E1s demonstration), the second dogs of the No Demonstration group matched their partners' choice above chance ($N = 14/16$, 87.5%, binomial test: $P = 0.004$).

Discussion

The aim of the present study was to investigate whether free-ranging dogs' foraging choices are influenced by humans.

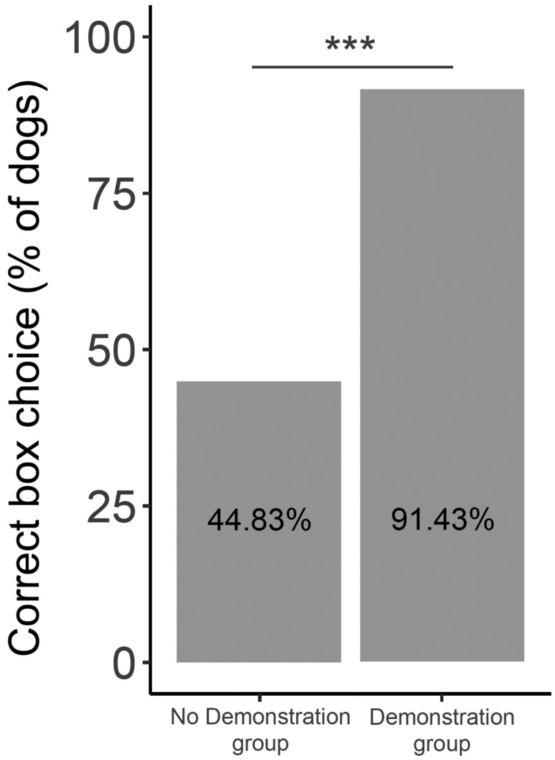

Figure 2. Percentage of dogs approaching the correct box as first in the 2 groups. ***$P < 0.001$.

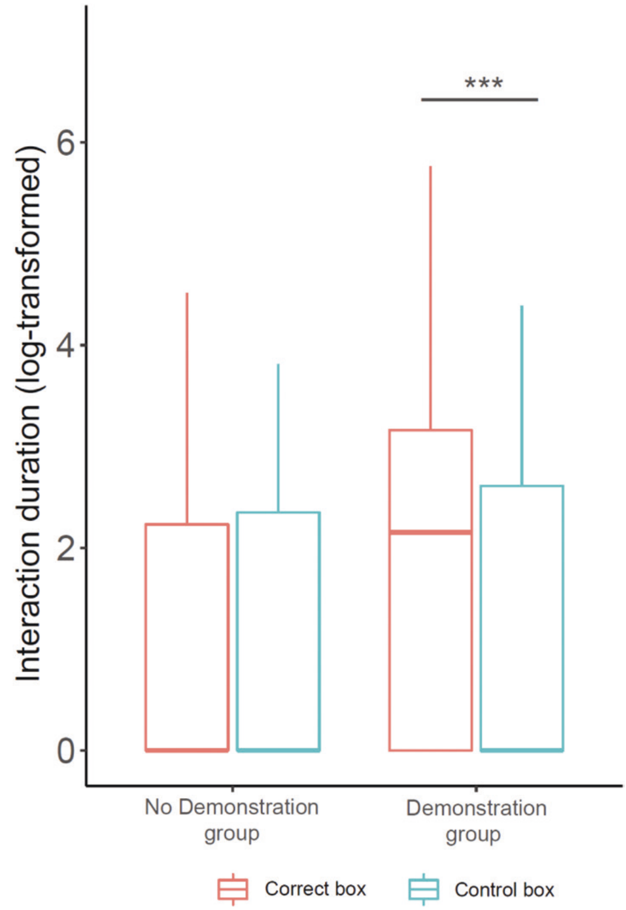

Figure 3. Interaction duration (in s, log-transformed) with each box for dogs of the 2 groups. Median and interquartile range (IQR; represented by the box), 25th percentile + 1.5 IQR, and 75th − 1.5 IQR (represented by the lower and the upper whiskers, respectively). ***$P < 0.001$.

By using a 2-choice task and a between-subject design, we tested whether free-ranging dogs living on the streets of Southern Morocco would match their preference for a feeding box previously approached by an unfamiliar human. In line with our main hypothesis, we found that more than 90% of the tested free-ranging dogs chose the box preferred by a human and interacted with it for longer than with the control box, whereas they chose randomly and interacted for a comparable amount of time with the two boxes when they did not witness a human demonstration. Although one could argue that the time spent interacting with the demonstrated box was an artifact of having approached it as first (hence, dogs might have stayed at the first approached box simply because they were rewarded with food if they stayed in proximity to it), we could show that dogs of the Demonstration group spent more time close to the first approached box, confirming that the human demonstration had an effect not only on the first choice but also on the time dogs interacted with the approached box. Taken together, these results show that indeed free-ranging dogs are influenced by humans in their foraging choices, even if their socialization with humans is low.

The present results are not surprising given the fact that pet dogs have been shown to pay attention to a human demonstrator and to copy their actions accurately (Pongrácz 2014; Fugazza and Miklósi 2015; Huber et al. 2018). It would be reasonable to assume that free-ranging dogs possess the same cognitive skills as pet dogs, but to date, only a few studies have directly compared pet dogs and free-ranging dogs in terms of problem-solving (Brubaker et al. 2017; Lazzaroni et al. 2020) and sensitivity to different human facial expressions (Lazzaroni et al. 2023). Hence, it is still unclear to what extent dogs with different selection histories and experiences with humans share similar cognitive and motivational capabilities (Horn et al. 2022). The present study provides the first evidence that also free-ranging dogs adjust their behavior depending on what an unfamiliar human does, thus they can learn features of their environment from humans. The mechanism behind the present form of copying was likely stimulus or local enhancement (Heyes 1994; Whiten 2023). In fact, dogs needed to move towards the apparatus or location in which the human was seen, to be able to obtain food. Future studies will be needed to understand how precisely free-ranging dogs can copy human and conspecific actions. Still, with this study, we can confirm that in a simple enhancement task, dogs do pay attention to a human and match their preferences for 1 of 2 novel feeding sources.

Although previous studies with this population have shown that the dogs are interested in human artifacts (Lazzaroni et al. 2019, 2020), considering the size of the boxes and their novelty, we were unsure whether dogs would show a motivation to approach them. Instead, contrary to 1 of our predictions, dogs were equally likely to approach at least 1 of the boxes, whether the experimenter interacted with it or not. In fact, most dogs approached at least 1 of the 2 boxes (almost 65% of the dogs), showing that even if novel, the 2 boxes elicited curiosity in most dogs. Considering that dogs who did not witness the human demonstration chose either box at random, we could exclude potential pre-existing preferences for

1 of the 2 stimuli based on external characteristics (pattern/color). It is possible that having witnessed the 2 experimenters carrying the boxes to the experimental location was enough to elicit the curiosity of the dogs tested, even if no experimental demonstration followed. Although practically challenging, it would be interesting to test whether such boxes would be approached by a similar number of dogs if they were positioned in dogs' territories without, which dogs could witness humans transporting them.

One could argue that dogs chose the demonstrated box because they were looking for proximity to the human demonstrator, rather than using the information provided by the human demonstration to obtain food from 1 of the boxes. However, considering that none of the dogs followed the human to the car (when the experimenter ended the demonstration) and that the dogs' choice for the correct box did not differ between dogs who approached during the demonstration (while the human was still close to the box) and those who approached when the human had already left the experimental setting, we argue that dogs did not approach the experimental setting with the motivation to interact with the human, but rather that they observed the human preference for 1 of the boxes and adjusted their behavior accordingly. Taken together, these elements support the idea that free-ranging dogs pay attention to what humans do (Brubaker et al. 2019; Bhattacharjee and Bhadra 2022), and this then influences their choices. Hence, in the present setting, free-ranging dogs used the unfamiliar human as a source of information rather than someone with whom to interact.

In the present study, dogs had never previously interacted with the demonstrator, thereby showing a general reliance on humans for information, at least in the present context. A previous study has shown that free-ranging dogs living in India flexibly adjust their attention to a human, depending on their previous experience with them (Bhattacharjee et al. 2018). In that study, dogs stopped responding to human communicative cues if they experienced beforehand that they were not reliable. It is possible that the free-ranging dogs tested in the present study might have already had a generally positive association between the presence of humans and palatable food. Future studies could investigate whether such choices are influenced by previous experience, by having multiple trials and comparing conditions in which the presence of a human may or may not reliably predict the presence of food. Although such a situation may not reflect the general experience of free-ranging dogs living in an environment in which leftovers are generally disposed of openly (i.e., thrown directly on the ground or in easily accessible and open trash cans), different trash management strategies in different areas of the world (e.g., by the presence of inaccessible trash cans, Johnson et al. 2018) could lead to a variation in selective attention towards humans.

Testing free-ranging dogs on the streets poses methodological challenges as these live in a semi- or urbanized environment where other dogs, humans, and other animal species live. In the present study, this meant that only about 60% of tested dogs could be included in the final analyses. However, an uncontrolled environment can also provide the opportunity to witness spontaneous behaviors and social interactions. Indeed, in the present study, we could observe that most dogs (more than 80%) approaching the experimental setting as a second (i.e., after a first tested dog had made a choice) chose the same box the partner interacted with. These results provide preliminary evidence for social influence in a foraging task at an intraspecific level. To date, experiments conducted with pet dogs or hand-raised captive dogs have shown that dogs can acquire information from conspecifics (e.g., Range et al. 2007; Miller et al. 2009; Pongrácz 2014). However, in most studies, the dog used as a demonstrator was unfamiliar to the subject, as most pet dogs are housed individually, and training of different dog demonstrators requires more time and resources for researchers. Instead, free-ranging dogs live in groups where individualized affiliative relationships and cooperation to defend their territories can be measured (Bonanni et al. 2010; Cafazzo et al. 2010), thus allowing researchers to investigate the role that social relationships play in the likelihood of learning from a demonstrator dog and to analyze what information dogs learn from one another (Coussi-Korbel and Fragaszy 1995; Laland 2004). The present observations show intraspecific influence in free-ranging dogs in a foraging task and call for future studies investigating intraspecific social learning in dogs living in groups.

The current study provides the first evidence of at least simple forms of social learning in free-ranging dogs, setting the stage for future studies potentially investigating how individual experiences, different human attitudes towards free-ranging dogs (hence, behaviors toward them), hunger levels, personality, information type, context, etc. influence dogs' likelihood of learning socially, their levels of copying fidelity, and the relevance of intra and interspecific social learning for dogs' survival.

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Ethical statement

Ethical approval for this study was obtained from the Ethical Committee for Animal Veterinary Science and Public Health of the University Hassan II Rabat, Morocco (Protocol number: CESASPV_2023_04). All procedures applied in the present study were noninvasive and in accordance with the European Union Directive on the protection of animals used for scientific purposes (EU Directive 2010/63/EU). The participation of subjects was completely voluntary. No subject was restricted in their movements nor forced to interact with the experimental setting.

Conflict of interests

Nothing declared.

References

Bhadra A, Bhadra A, 2014. Preference for meat is not innate in dogs. *J Ethol* **32**:15–22.

Bhattacharjee D, Bhadra A, 2022. Adjustment in the point-following behaviour of free-ranging dogs: Roles of social petting and informative-deceptive nature of cues. *Anim Cogn* **25**:571–579.

Bhattacharjee D, Mandal S, Shit P, Varghese MG, Vishnoi A et al., 2020. Free-ranging dogs are capable of utilizing complex human pointing cues. *Front Psychol* **10**:2818.

Bhattacharjee D, Sau S, Bhadra A, 2018. Free-ranging dogs understand human intentions and adjust their behavioral responses accordingly. *Front Ecol Evol* **6**:232. doi: 10.3389/fevo.2018.00232.

Bonanni R, Valsecchi P, Natoli E, 2010. Pattern of individual participation and cheating in conflicts between groups of free-ranging dogs. *Anim Behav* **79**:957–968.

Brubaker L, Bhattacharjee D, Ghaste P, Babu D, Shit P et al., 2019. The effects of human attentional state on canine gazing behaviour: A comparison of free-ranging, shelter, and pet dogs. *Anim Cogn* **22**: 1129–1139.

Brubaker L, Dasgupta S, Bhattacharjee D, Bhadra A, Udell MAR, 2017. Differences in problem-solving between canid populations: Do domestication and lifetime experience affect persistence? *Anim Cogn* **20**:717–723.

Butler J, Brown W, du Toit J, 2018. Anthropogenic food subsidy to a commensal carnivore: The value and supply of human faeces in the diet of free-ranging dogs. *Animals* **8**:67.

Cafazzo S, Valsecchi P, Bonanni R, Natoli E, 2010. Dominance in relation to age, sex, and competitive contexts in a group of free-ranging domestic dogs. *Behav Ecol* **21**:443–455.

Coussi-Korbel S, Fragaszy DM, 1995. On the relation between social dynamics and social learning. *Anim Behav* **50**:1441–1453.

Duranton C, Bedossa T, Gaunet F, 2017. Do shelter dogs engage in social referencing with their caregiver in an approach paradigm? An exploratory study. *Appl Anim Behav Sci* **189**:57–65.

Feist F, Smith K, Graham P, 2023. Inter-species stimulus enhancement: Herring gulls *Larus argentatus* mimic human food choice during foraging. *Biol Lett* **19**:20230035. doi: 10.1098/rsbl.2023.0035.

Fugazza C, Miklósi A, 2015. Social learning in dog training: The effectiveness of the do as I do method compared to shaping/clicker training. *Appl Anim Behav Sci* **171**:146–151.

Gommper ME, 2014. The dog-human-wildlife interface: Assessing the scope of the problem. In: Gommper ME, editor. *Free-Ranging Dogs and Wildlife Conservation*. Oxford (UK): Oxford University Press, 9–54.

Goumas M, Boogert NJ, Kelley LA, 2020. Urban herring gulls use human behavioural cues to locate food. *R Soc Open Sci* **7**:191959.

Heyes CM, 1994. Social learning in animals: Categories and mechanisms. *Biol Rev Camb Philos Soc* **69**:207–231.

Horn L, Cimarelli G, Boucherie PH, Slipogor V, Bugnyar T, 2022. Beyond the dichotomy between field and lab: The importance of studying cognition in context. *Curr Opin Behav Sci* **46**:101172. doi: 10.1016/j.cobeha.2022.101172.

Huber L, Popovová N, Riener S, Salobir K, Cimarelli G, 2018. Would dogs copy irrelevant actions from their human caregiver? *Learn Behav* **46**:387–397.

Huber L, Range F, Voelkl B, Szucsich A, Virányi Z et al., 2009. The evolution of imitation: What do the capacities of non-human animals tell us about the mechanisms of imitation? *Philos Trans R Soc B: Biol Sci* **364**:2299–2309.

Huber L, Salobir K, Mundry R, Cimarelli G, 2020. Selective over imitation in dogs. *Learn Behav* **48**:113–123.

Hughes J, Macdonald DW, 2013. A review of the interactions between free-roaming domestic dogs and wildlife. *Biol Conserv* **157**:341–351.

Johnson HE, Lewis DL, Lischka SA, Breck SW, 2018. Assessing ecological and social outcomes of a bear-proofing experiment. *Jour. Wild. Mgmt*. **82**: 1102-1114.

Kendal RL, Coolen I, van Bergen Y, Laland KN, 2005. Trade-offs in the adaptive use of social and asocial learning. *Adv Study Behav* **35**:333–379.

Laland KN, 2004. Social learning strategies. *Learn Behav* **32**:4–14.

Lazzaroni M, Marshall-Pescini S, Manzenreiter H, Gosch S, Přibilová L et al., 2020. Why do dogs look back at the human in an impossible task? Looking back behaviour may be over-interpreted. *Anim Cogn* **23**:427–441.

Lazzaroni M, Range F, Bernasconi L, Darc L, Holtsch M et al., 2019. The role of life experience in affecting persistence: A comparative study between free-ranging dogs, pet dogs and captive pack dogs. *PLoS ONE* **14**:12–14.

Lazzaroni M, Schär J, Baxter E, Gratalon J, Range F et al., 2023. Village dogs match pet dogs in reading human facial expressions. *PeerJ* **11**:e15601.

Majumder SS, Chatterjee A, Bhadra A, 2014. A dog's day with humans-time activity budget of free-ranging dogs in India. *Curr Sci* **106**:874–878.

Marshall-Pescini S, Cafazzo S, Virányi Z, Range F, 2017. Integrating social ecology in explanations of wolf–dog behavioral differences. *Curr Opin Behav Sci* **16**:80–86.

Mesoudi A, Chang L, Dall SRX, Thornton A, 2016. The evolution of individual and cultural variation in social learning. *Trends Ecol Evol* **31**:215–225.

Miller HC, Rayburn-Reeves R, Zentall TR, 2009. Imitation and emulation by dogs using a bidirectional control procedure. *Behav Process* **80**:109–114.

Pal SK, 2001. Population ecology of free-ranging urban dogs in West Bengal, India. *Acta Theriol (Warsz)* **46**:69–78.

Paul M, Sen Majumder S, Sau S, Nandi AK, Bhadra A, 2016. High early life mortality in free-ranging dogs is largely influenced by humans. *Sci Rep* **6**:1–8.

Pilot M, Malewski T, Moura AE, Grzybowski T, Olenski K et al., 2015. On the origin of mongrels: Evolutionary history of free-breeding dogs in Eurasia. *Proc R Soc B* **1820**:20152189.

Pongrácz P, 2014. Social learning in dogs. In: Marshall-Pescini S, Kaminski J, editors. *The Social Dog: Behaviour and Cognition*. Elsevier. doi: 10.1016/B978-0-12-407818-5.00009-7.

R Core Team, 2021. R: A Language and Environment for Statistical Computing. Vienna: R Foundation for Statistical Computing. URL https://www.R-project.org/.

Range F, Huber L, Heyes C, 2011. Automatic imitation in dogs. *Proc R Soc B* **278**:211–217.

Range F, Marshall-Pescini S, 2022. The socio-ecology of free-ranging dogs. In: Range F, Marshall-Pescini S eds. *Wolves and Dogs: Between Myth and Science*. Cham: Springer, 83–110. doi:10.1007/978-3-030-98411-3_4.

Range F, Virányi Z, 2013. Social learning from humans or conspecifics: Differences and similarities between wolves and dogs. *Front Psychol* **4**:1–10.

Range F, Viranyi Z, Huber L, 2007. Selective imitation in domestic dogs. *Curr Biol* **17**:868–872.

Sarkar R, Bhadra A, 2022. How do animals navigate the urban jungle? A review of cognition in urban-adapted animals. *Curr Opin Behav Sci* **46**:101177. doi: 10.1016/j.cobeha.2022.101177.

Sarkar R, Sau S, Bhadra A, 2019. Scavengers can be choosers: A study on food preference in free-ranging dogs. *Appl Anim Behav Sci* **216**:38–44.

Sih A, 2013. Understanding variation in behavioural responses to human-induced rapid environmental change: A conceptual overview. *Anim Behav* **85**:1077–1088.

Sol D, Lapiedra O, González-Lagos C, 2013. Behavioural adjustments for a life in the city. *Anim Behav* **85**:1101–1112.

Thompson MJ, Capilla-Lasheras P, Dominoni DM, Reale D, Charmantier A, 2022. Phenotypic variation in urban environments: Mechanisms and implications. *Trends Ecol Evol* **37**:171–182.

Whiten A, 2023. Cultural evolution in the science of culture and cultural evolution. *Phys Life Rev* **45**:31–51.