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ORIGINAL PAPER

The effects of human attentional state on canine gazing behaviour: a comparison of free-ranging, shelter, and pet dogs

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Abstract

The ability of animals to communicate using gaze is a rich area of research. How domestic dogs (*Canis lupus familiaris*) use and respond to the gaze of humans is an area of particular interest. This study examined how three groups of domestic dogs from different populations (free-ranging dogs, pet dogs, and shelter dogs) responded to a human during three attentional state conditions: when the human was making eye contact (attentive), when the human was turned away (inattentive), and when the human exited the testing area. We found that dogs from different populations differed in their gazing behaviour. Free-ranging dogs responded to the human's change in attentional state by looking significantly less at the human in the inattentive condition compared to the attentive condition. Pet and shelter dogs did not differ in their gazing behaviour between these conditions. However, they gazed significantly more at the human in both the inattentive and attentive conditions compared to the free-ranging dogs and also spent more time in the proximity of the experimenter. This study suggests that life experience plays an important role in how dogs respond to the attentional state of a human.

Keywords Attentional state · Gazing · Free-ranging dogs · Shelter dogs · Pet dogs · Domestic dogs

Introduction

The ability of animals to acquire information or communicate using gaze is an intriguing area of study that has drawn the attention of researchers in diverse fields (Brainard and Fitch 2014; Kleinke 1986; Udell and Wynne 2008). One area of interest has been the role of gaze in cross-species communication, including the degree to which one individual is sensitive to the attentional state of the other. Research has indicated that domestic dogs (*Canis lupus familiaris*) attend to human gaze, and in many cases alter their behaviour according to gaze direction, for example, using human gaze to acquire information about where desired food or objects are located (Kaminski et al. 2013; Kaminski et al. 2009; Miklósi et al. 1998; Prato-Previde et al. 2007; Virányi et al. 2004). At least some populations of pet and working dogs have also been found to engage in perspective-taking behaviour (sometimes discussed in terms of Theory of Mind), including identification of individuals most receptive to providing food or affection (Bentosela et al. 2016; Jakovcevic et al. 2010; Ohkita et al. 2016; Udell et al. 2011; Udell and Wynne 2011a). In another study, pet dogs told by their owner to "lie down" would stay in this position for significantly longer when their owner was looking at them versus when the owner was distracted (either by reading a book, watching TV, or turning their back on the dog) or when the owner left the room (Schwab and Huber 2006). Likewise, dogs presented with a piece of food and asked to 'leave it' were shown to be more likely to do so if the human remained facing the dog tracking them with their

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gaze. When the commanding human sat in the room but began playing on a handheld computer, sat facing the dog but had their eyes closed, or sat facing away from the food with their back turned on the dog, the dogs were more likely to take the food (Call et al. 2003).

Pet dogs have also been shown to preferentially beg for food from someone looking at them as compared to someone who has their back turned or who is reading a book (Udell et al. 2011). Another study found that pet dogs that could not see the person's eyes (either due to the person being blindfolded or physically turned away from the dog) were more cautious when approaching the person and engaged in less begging behaviour compared to individuals whose body was oriented towards the dog (Gácsi et al. 2004). Pet dogs have also been shown to engage in "showing behaviour"—alternating their own gaze between a desired out-of-reach item and a human in the presence of an attending human, but not one who is inattentive (Miklósi et al. 2000).

The mechanisms underlying a dog's ability to detect attentional state differences in humans is a topic actively being explored, as an important aspect of social cognitive abilities of dogs. There are studies that suggest that a dog's morphology (Gácsi et al. 2009; Helton and Helton 2010), breeding (Jakovcevic et al. 2010), evolutionary history (Bentosela et al. 2016), lifetime experience (Barrera et al. 2011; Bhattacharjee et al. 2017; Jakovcevic et al. 2012), and even the method of altering human attentional state, e.g., back turned versus eyes occluded by an object (Udell et al. 2011), may all influence a dog's perspective-taking performance. However, to date, the majority of research in this area has focused on the gazing behaviour and responsiveness of pet domestic dogs, with some comparison to shelter dogs and wolves (Barrera et al. 2011; Jakovcevic et al. 2012; Kaminski et al. 2009; Udell and Wynne 2011a). While free-ranging dogs make up the majority of the domestic dog population (Coppinger and Coppinger 2001; Hughes and Macdonald 2013) and interact with humans regularly, much less is known about their social cognition, including how sensitive they are to human gaze and attentional state. Studies comparing domestic dogs across different populations, including pet, shelter, and free-ranging dogs, are necessary to identify the similarities and differences that exist between them. Such comparative research provides a critical foundation for investigating the role that differences in behavioural ecology, as well as other evolutionary and lifetime variables, play in the establishment of these behaviours.

Another relevant aspect of gaze behaviour is the duration of time that different canids spend looking at humans in the context of cognitive or social tasks and how much time canids spend in close proximity to attentive and inattentive humans. Several studies have suggested that domestic dogs engage in prolonged or extended gazing and proximity seeking towards humans compared to their non-domesticated counterparts. For example, pet dogs have been found to gaze longer at humans than wolves when confronted with an unsolvable problem, such as a food puzzle where the food is unobtainable (Miklósi et al. 2003), as well as in solvable puzzle box problems where a human is standing nearby (Brubaker et al. 2017; Udell 2015). In another study, when dogs and wolves were delivered food by a human from an elevated container, dogs continued to gaze at the human almost seven times longer on average than wolves, once the food delivery had stopped (was put on extinction) (Bentosela et al. 2016). Pet dogs have also been found to spend greater time in proximity to both attentive and inattentive humans compared to wolves and shelter dogs, although they typically spend significantly more time with humans when they are attentive (Bentosela et al. 2016; vonHoldt et al. 2017).

To some extent, this prolonged gazing behaviour and proximity seeking towards social companions may be a byproduct of genetic differences between dogs and wolves that occurred during the domestication process (vonHoldt et al. 2017). However, there is also evidence that a dog's environment and learning history may influence this behaviour. For example, both shelter dogs and pet dogs will gaze at a human's face when a reward is available but out of reach, however when the human is no longer delivering the out-of-reach food, shelter dogs extinguished their gazing behaviour faster compared to pet dogs, likely due to their lifetime experience or lack of a steady attachment figure in the shelter environment (Barrera et al. 2011). Although the history of shelter dogs can be difficult to obtain for research purposes, these dogs live in relatively unique conditions in which they have direct care and shelter provided by humans but do not have a steady attachment figure in a manner similar to pet dogs. However, these dogs can form attachment bonds fairly quickly and are known to engage in social behaviours with unknown humans (Barrera et al. 2010; Barrera et al. 2011; Gácsi et al. 2004; Gácsi et al. 2001; Udell et al. 2010). For this reason, the social behaviour of these dogs may be dictated by different underlying motivations (for example, seeking an attachment figure or acquiring social reinforcement in an environment where this is a more limited resource) compared to pet dogs, which already have an attachment figure in their human owner (Barrera et al. 2011).

Furthermore, studies comparing diverse dog populations on simple social tasks have sometimes provided insights that have challenged common thoughts about how certain social cues may function across different dog–human interactions. For example, in a study comparing free-ranging dogs', pet dogs' and wolves' response to an independently solvable puzzle box in the presence of a human, it was the free-ranging dogs (not the pet dogs) that spent the longest duration of time gazing at the human (Brubaker et al. 2017). However, the "type" of gazing that the free-ranging dogs engaged in was more varied than that of the pet dogs; some free-ranging

dogs appeared more submissive while others were more antagonistic, likely due to the varied life experiences of these dogs (Brubaker et al. 2017). Free-ranging dogs are often shunned by local communities due to concerns about hygiene and cleanliness, and humans can pose significant threats to the health and safety of these animals; however, this same population also relies on humans for food either indirectly through scavenging or directly by begging (Bhadra et al. 2015; Brubaker et al. 2017). It has also been shown that they build trust towards unfamiliar humans who pet them, rather than humans who give them food (Bhattacharjee et al. 2018). The gazing behaviour of dogs from different populations may thus serve different functions, such as detecting danger or potential conflicts (as is found in other species, see von Bayern and Emery 2009; Yorzinski et al. 2014), soliciting food/"begging", or the solicitation of/ increased motivation to engage in social contact with a human, even in the same experimental context, depending on environment or behavioural ecology of the dog under test. Therefore identifying the capacity for certain cognitive skills or behaviours within a species, as well as variability in such skills and behaviours across populations is necessary to understand the function and development of socio-cognitive traits.

Because humans can both provide valuable resources and also pose a significant threat to dogs living outside of direct human care, attending to human actions may be especially valuable to free-ranging dogs. This appears to be reflected in the duration of gaze towards humans in ambiguous situations in prior research (Bhadra et al. 2015; Brubaker et al. 2017). The degree to which free-ranging dogs alter their behaviour in the presence of an attentive versus inattentive human may also be different than that of pet or shelter dogs, due to the unique lifetime experiences and environmental pressures of each group; however, to date no research has examined the ability of free-ranging dogs to detect human attentional states. In addition, no studies have examined how the gazing behaviour of free-ranging dogs may differ or be similar to that of shelter dogs, which may share similar behaviours to these dogs given their lack of a human attachment figure and possible previous experience of shelter dogs that have lived as strays.

In the current study, free-ranging dogs', pet dogs', and shelter dogs' sensitivity to human attentional state was compared, using methods established by Jakovcevic et al. (2010). All dogs were presented with a small piece of chicken every 10 s for 50 s, followed immediately by a 2 min testing condition in which the experimenter stopped providing food and also did one of three things: turned their back on the dog, gazed directly at the dog, or left the testing area.

Based on previous studies, it was hypothesized that all dogs would adjust their behaviour according to the human attentional state, gazing less during the inattentive condition compared to the attentive condition. However, we predicted that cues of human attentional state might have higher importance for free-ranging dogs than the other two groups—both in terms of avoiding potentially threatening humans and identifying receptive humans to beg from. Additionally, this group would be more, or at least as, sensitive to attentional state as pet dogs but more sensitive than shelter dogs on this task, given their greater and diverse experience with humans as compared to the shelter dogs. As in prior studies (e.g., Jakovcevic et al. 2010), we predicted that pet dogs would show more gaze persistence than shelter dogs when faced with an attentive human who was no longer providing food. However, two possible predictions were made with respect to free-ranging dogs. Based on findings suggesting that this population is most likely to engage in prolonged gaze during ambiguous situations involving food (Brubaker et al. 2017), it seemed possible that dogs from this population might show the longest gaze persistence during the attentive condition, even when gaze behaviour was placed on extinction. Conversely, it seemed equally possible that free-ranging dogs would show a greater tendency to adjust foraging strategies when food is withheld. If this were the case, we would expect to see both the shortest gaze durations during extinction and the best attentional state discrimination by dogs of this population. Finally, it was predicted that pet and shelter dogs would spend more time in close proximity to or in contact with the human than the free-ranging dogs.

Methods

Subjects

Pet and shelter dogs recruited from the local community in Corvallis, Oregon (United States) and free-ranging dogs living on the streets in Kolkata, West Bengal (India) were used in this study. Pet dogs were required to have lived in their owner's house and legally owned by their owner for at least 1 year prior to testing. All dogs were estimated to be over the age of 1 year, while the reported age of pet dogs was an average of 6 years old (SE ± 0.5 years) and the average reported age of the shelter dogs was an average of 5 years old (SE ± 0.3 years), but the ages of shelter, free-ranging dogs and most of the pet dogs were necessarily estimates. There were 12 female and 12 male pet dogs, 10 female and 14 male shelter dogs, and 14 female and 10 male free-ranging dogs with a total of 24 dogs per group. An unfamiliar experimenter tested all dogs. Pet and shelter dogs were tested indoors (in the Human–Animal Interaction Lab testing room or in an isolated room in the shelter) and free-ranging dogs were tested outdoors, consistent with the general environment they were most acclimated to (Sen Majumder et al. 2014; Udell and Wynne 2011b). Free-ranging dogs were of

mixed breeds (commonly known as the Indian Pariah dog); pet dogs were a combination of mixed breeds and reported breeds (two Labrador Retrievers, one Jack Russell Terrier, one Bulldog, two Australian Shepherds, and one Bulldog); shelter dogs were largely mixed breed dogs with one known purebred (a Shar-Pei).

Methodology

Methods were adapted from Jakovcevic et al. (2010). Each dog experienced a 1-min acquisition condition followed immediately by a 2-min testing condition. During the acquisition condition, the dogs were given a total of five pieces of plain chicken (which totaled four grams per dog) from a container that was placed approximately two metres from the ground. The experimenter took a piece of chicken out of the container and gently tossed the chicken in the general direction of the dog once every 10 s regardless of whether the dog was looking at the experimenter or not. At the end of this condition, at least 5–6 pieces of chicken remained in the out-of-reach container. If any dogs walked away—leaving the camera frame—during the acquisition phase, they were disqualified from the study (however, this never occurred).

During the testing conditions, the experimenter stopped delivering food and did one of three things: face forward and gaze at the dog (the "attentive" condition), turn around and face away from the dog (the "inattentive" condition), or leave the testing area (the "control" condition) (see Fig. 1). The acquisition condition was always carried out immediately prior to each testing condition, and the order of the testing conditions was counterbalanced across subjects.

All conditions were video-recorded for future behaviour coding. The camera was positioned facing the experimenter approximately eight to ten feet away, depending on space availability. Duration (in seconds) of gazing at the food container, duration of gazing at the experimenter, time spent in close proximity (defined as within arms length of the experimenter) and time spent in far proximity (defined as outside of arm's length of the experimenter but within the camera frame) were coded for analysis. Time spent out of camera frame was also coded. Inter-rater reliability was measured by double coding 33% of the videos collected. Weighted Cohen–Kappa tests showed that reliability was high between coders for gazing duration ($k = 0.89$) and proximity ($k = 0.86$).

Statistical analyses

Data were not normally distributed; therefore, non-parametric statistics were used throughout. Kruskal–Wallis tests were used for group comparisons, Mann–Whitney U tests were used for post hoc analyses, and Wilcoxon signed rank tests were used for within-group comparisons. K-means clustering was also run to investigate dogs' proximity responses in the attentive condition. The value of K was considered as "3" for the clustering, since we categorized proximity measures as close proximity, far proximity, and out-of-camera frame (mentioned above). Bonferroni corrections ($p = 0.016$) were used for all post hoc comparisons. In all other cases, the alpha was set at $p = 0.05$. Statistics were run in R Studio.

Compliance with ethical standards

All owned subjects were volunteered by their owners or caretakers and remained in their care for the duration of the study. All free-ranging dogs were tested in their home environment (territories). Owners were not asked to deprive their dogs of food as part of this study or engage in any other activity that might compromise their welfare. Owners were free to withdraw their animal at any time, however, this never occurred. All procedures performed were in accordance with the ethical standards of Oregon State University and the Indian Institute of Science Education and Research Kolkata and with the laws of the United States and India. This study was approved by The Oregon State University Institutional Animal Care and Use Committee ACUP #4837.

Fig. 1 The experimental setup for each condition (attentive, inattentive, and control, respectively)

Results

Control condition—unaccompanied out-of-reach food container

Free-ranging dogs spent significantly more time gazing at the unaccompanied food container compared to pet dogs (exact Mann–Whitney *U* test, $Z = 2.94$, $p = 0.003$) and shelter dogs ($Z = 3.86$, $p < 0.001$); however, pet dogs and shelter dogs did not differ significantly in the amount of time they spent gazing at the food ($Z = 1.192$, $p = 0.294$).

Attentive condition

Significant differences were found between the different categories of dogs in the amount of time spent gazing at the human (Kruskal–Wallis Test, $p = 0.005$, Fig. 2) but not the food ($p = 0.217$) during the attentive condition. Significant differences were also found in the amount of time the dogs spent in close proximity to the experimenter (Kruskal Wallis, $p < 0.001$. *K*-means clustering revealed that free-ranging dogs formed a cluster in the far proximity category, while pet and shelter dogs' responses were greatly overlapping (Fig. 3). See Table 1 for means and standard errors for each group of dogs in the attentional phases.

Pet vs. free-ranging Pet dogs gazed significantly more at the human (exact Mann–Whitney *U* test, $Z = -2.64$, $p = 0.008$) during the attentive phase. Pet dogs spent significantly more time in close proximity of the human ($Z = -5.47$, $p < 0.001$) as compared to free-ranging dogs.

Shelter vs. free-ranging Shelter dogs gazed significantly more at the human (exact Mann–Whitney *U* test, $Z = -2.83$, $p = 0.004$) and spent significantly more time in close proximity of the human ($Z = -5.90$, $p < 0.001$) when compared to free-ranging dogs.

Shelter vs. pet Shelter dogs and pet dogs did not differ significantly in the amount of time spent gazing at the human (exact Mann–Whitney *U* test, $Z = 1.05$, $p = 0.301$) or in the amount of time spent in proximity of the human ($Z = 0.23$, $p = 0.83$) during the attentive condition.

Inattentive condition

Significant differences were found between groups in the amount of time spent gazing at the human (Kruskal–Wallis test, $p = 0.004$) but not the food (Kruskal–Wallis test, $p = 0.717$). Significant differences between groups were also found in the amount of time the dogs spent in close proximity (Kruskal–Wallis, $p < 0.001$) and far proximity (Kruskal–Wallis, $p < 0.001$) to the experimenter.

Pet vs. free-ranging Pet dogs gazed significantly more at the human (exact Mann–Whitney *U* test, $Z = -2.41$, $p = 0.015$) and spent significantly more time in the proximity of the human ($Z = -6.14$, $p < 0.001$) as compared to free-ranging dogs.

Shelter vs. free-ranging Shelter dogs gazed significantly more at the human (exact Mann–Whitney *U* test, $Z = -3.16$, $p = 0.001$) and spent significantly more time in the proximity of the human ($Z = -6.13$, $p < 0.001$) as compared to free-ranging dogs.

Shelter vs. pet Shelter dogs and pet dogs did not differ significantly in the amount of time spent gazing at the human (exact Mann–Whitney *U* test, $Z = -0.62$, $p = 0.543$) or in the amount of time spent in close proximity of the human ($Z = 0.45$, $p = 0.66$) during the inattentive condition.

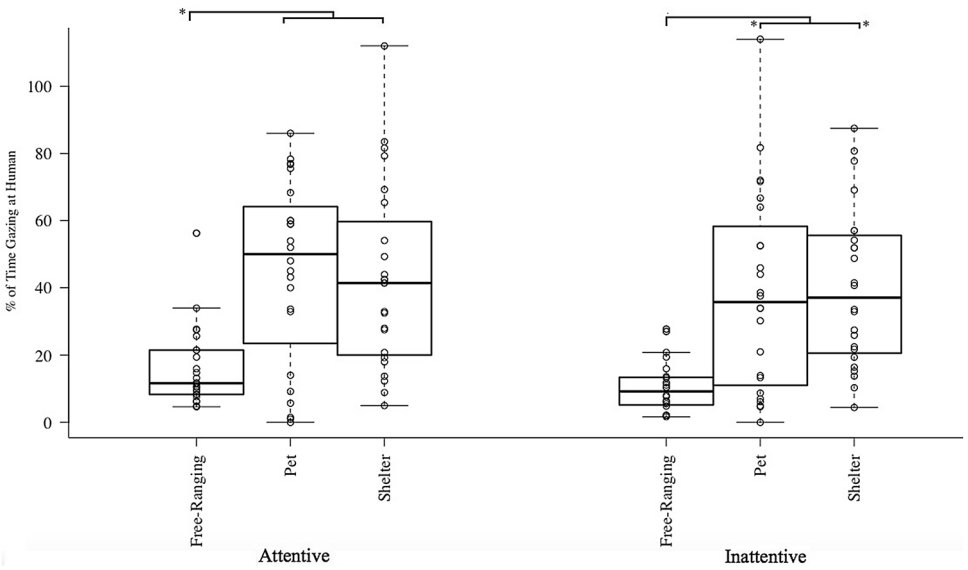

Fig. 2 Box and whisker plot showing the percent of time spent gazing at the human during the attentive and inattentive conditions (adjusted for time on camera). Horizontal line in the center of the boxplot indicates medians, and dots represent individuals. Significant findings between groups are noted

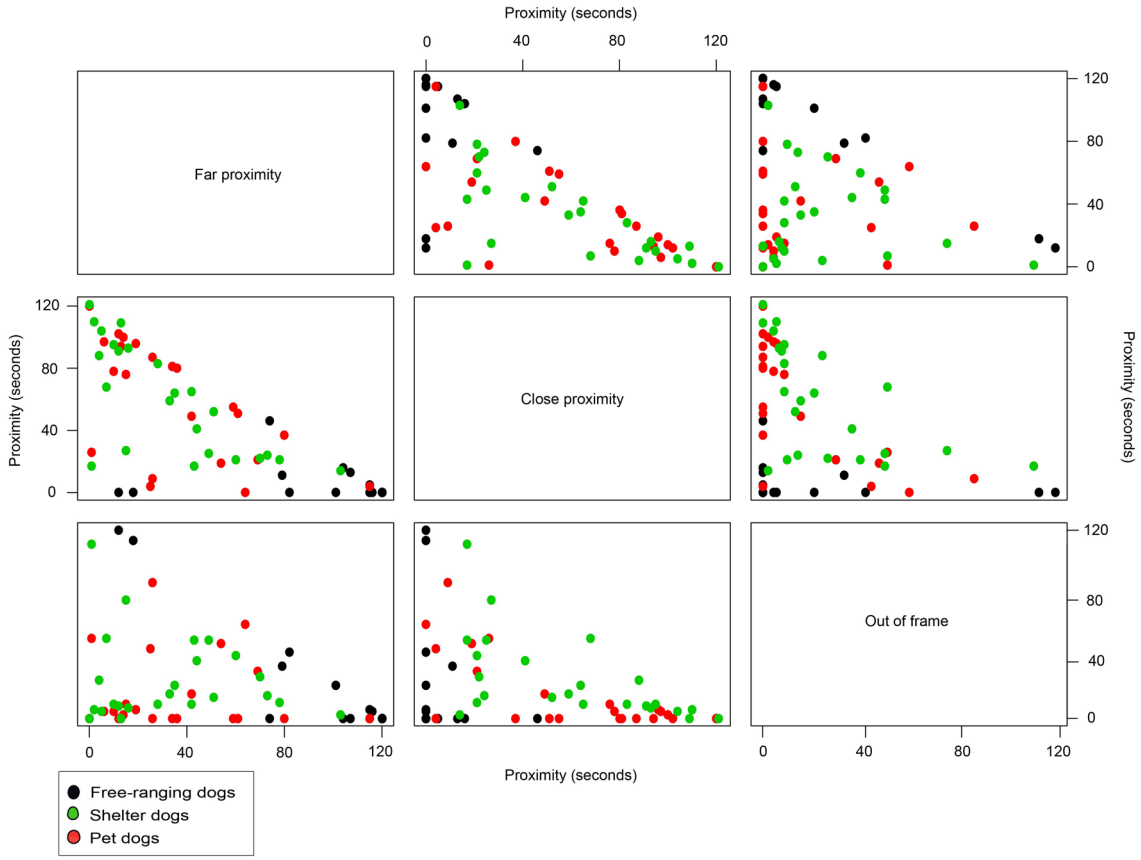

Fig. 3 Scatterplot matrix of the K-means cluster analysis showing the duration of proximity of free-ranging, shelter and pet dogs in the attentive condition. The graph illustrates a grid of scatterplots where each attribute ('far proximity', 'close proximity', and 'out of frame') is plotted against all others, and can be read by column or row with each plot appearing twice (allowing for consideration of the spatial relationships from two perspectives)

Within-group comparisons

All of the dogs (pooled) gazed at the food container for the least amount of time in the control condition, when there was no human present, compared to the attentive condition and inattentive condition (Kruskal–Wallis Test, exact two-sided $p < 0.001$). Free-ranging dogs did not differ in the amount of time spent gazing at the food during the attentive condition (Wilcoxon signed rank test, $V = 143$, $p = 0.891$) or the inattentive condition ($V = 86$, $p = 0.732$) as compared to the control condition. Pet dogs gazed at the food significantly more during the attentive condition ($V = 11$, $p = 0.010$) and inattentive condition ($V = 2$, $p = 0.006$) compared to the control condition. Shelter dogs also gazed significantly longer at the food during the attentive condition ($V = 1$, $p = 0.008$) and the inattentive condition ($V = 4$, $p = 0.011$) compared to the control condition (see Fig. 4).

As predicted, significant differences were found in the pooled amount of time the dogs spent gazing at the human, with the dogs gazing more during the attentive condition as compared to the inattentive condition (Wilcoxon Signed Rank Test, $V = 918$, $p = 0.04$). No significant differences were found when all dogs were compared for the amount of time spent gazing at the food during the attentive condition compared to the inattentive condition (exact Mann–Whitney test, $Z = 0.180$, $p = 0.859$).

Free-ranging dogs gazed significantly more at the human (Wilcoxon Signed Rank Test, $V = 226$, $p = 0.007$) in the attentive phase but did not significantly differ in their proximity to the human ($V = 11$, $p = 0.42$) in the attentive condition, as compared to the inattentive condition.

Pet dogs did not differ significantly in the amount of time spent gazing at the human (Wilcoxon Signed Rank Test, $V = 225$, $p = 0.031$) or in the amount of time spent in proximity to the human ($V = 134$, $p = 0.92$) in the attentive condition, as compared to the inattentive condition.

Shelter dogs also did not differ significantly in the amount of time spent gazing at the human (Wilcoxon signed rank test, $V = 138$, $p = 0.750$) or in the time spent in proximity to the human ($V = 146.5$, $p = 0.93$) in the attentive condition, as compared to the inattentive condition.

Table 1 Mean and standard errors of the percent of time free-ranging, shelter, and pet dogs spent engaging in the coded behaviours in each condition

	Attentive phase					Inattentive phase				
	Gazing at food	Gazing at human	Close proximity	Far proximity	Out of frame	Gazing at food	Gazing at human	Close proximity	Far proximity	Out of frame
Free-ranging dogs	1.8±0.5	16.1±2.4	3.8±2.1	103.5±6.3	12.8±6.2	1.4±0.3	10.3±1.5	1.9±1.9	97.1±7.9	21.0±7.9
Pet dogs	2.2±0.6	50±5.6	63.6±8.2	32.5±6.1	13.5±4.5	3.9±1.8	38.3±6.0	67.4±7.6	29.2±6.8	22.8±6.8
Shelter dogs	4.1±1.6	42.7±5.6	59.6±7.3	33.1±5.9	22.3±5.0	2.1±0.7	40.1±4.8	62.5±6.5	28.8±5.2	21.5±5.1

	Control	
	Gazing at food	Out of frame
Free-ranging dogs	1.3±0.4	37.3±8.4
Pet dogs	0.7±0.4	23.7±8.1
Shelter dogs	0.1±0.1	5.5±2.7

Discussion

Our results suggest that while all populations of dogs show some sensitivity to attentional state, the way they use this information to guide their behaviour differs based on their lifetime experiences. In general, the pet and shelter dogs spent more time in proximity to the unfamiliar experimenter compared to free-ranging dogs, supporting the notion that lifetime experience shapes the way in which these different populations socially behave around humans. The free-ranging dogs were the only population to treat an inattentive human as an equivalent to no human with respect to their interest in unreachable food. This could indicate that while all groups show begging behaviour in the presence of humans and unobtainable food, only pet and shelter dogs engage in significant levels of showing behaviour or social referencing—where gaze is also increased at the object of interest when human attention is available. Furthermore, these findings support our second prediction regarding free-ranging dogs: that this population appears to be the most sensitive to human attentional state cues in this context and is also the quickest to change foraging strategies when the human is no longer providing food.

As predicted, on average dogs adjusted their behaviour according to human attentional state, gazing less when a nearby human who had previously provided food was inattentive compared to when they were attentive. However, this is the first study of its kind that included comparisons with free-ranging dogs. The findings show that free-ranging dogs appeared to gaze for longer durations at the human when the human was attentive compared to when the human was inattentive. Shelter and pet dogs did not differ in their gazing behaviour in the inattentive and attentive conditions; in particular, shelter dogs did not change their gazing behaviour depending on the human's attentional state, while pet dogs showed a trend of gazing less when the person was inattentive. While seemingly counterintuitive, the behaviour of shelter dogs in this study is consistent with prior studies (Udell et al. 2011) and findings that shelter dogs will spend more time in proximity to an unfamiliar person than pet dogs even when the reinforcing nature of the interaction is unclear, e.g., when displaying fear behaviours towards them (Barrera et al. 2010). This could suggest social contact is of increased importance to this population given the relatively limited nature of social interactions with humans in a shelter. Alternatively, these dogs may have less lifetime experience with humans and thus may be unable to adjust their behaviour appropriately in response to social cues from humans.

Free-ranging dogs showed the most sensitivity to attentional state of humans, as they were the only individual group to gaze at the human for significantly longer

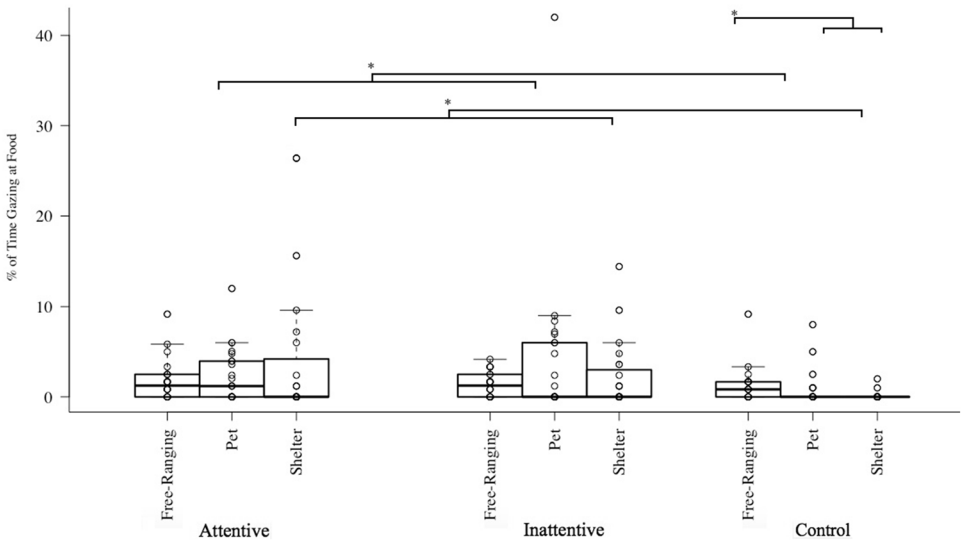

Fig. 4 Box and whisker plot showing the percent of time spent gazing at the food during the attentive, inattentive, and control conditions (adjusted for time on camera). Horizontal line in the center of the boxplot indicates medians, and dots represent individuals. Significant findings are noted

durations during the attentive condition compared to the inattentive condition on this task. They were also the only group to treat the inattentive human as equivalent to the absence of a human (control condition) with respect to the time they spent gazing at the unobtainable food in each of these conditions. Importantly, free-ranging dogs maintained far proximity to the human, while pet and shelter dogs maintained close proximity to the human, regardless of the human's attentional state. Given that free-ranging dogs are reliant on humans for survival but need to be vigilant for potential negative reactions from humans (Bhattacharjee et al. 2018; Paul et al. 2016), it is unsurprising that this population may be wary, compared to pet or shelter dogs, of approaching a human even when the human's back is turned. These dogs have been shown to adjust their point-following behaviour based on human reliability (Bhattacharjee et al. 2017), and comprehend human intentions through social cues (Bhattacharjee et al. 2018), further providing evidence of their particularly vigilant nature with regards to monitoring human behaviour.

Free-ranging dogs showed less gaze persistence towards the human once food provisioning had ended. Both pet and shelter dogs spent significantly more time than free-ranging dogs gazing at an attentive person who had stopped providing food. This supported our second prediction: free-ranging dogs appear to demonstrate a greater tendency to adjust foraging strategies when food is withheld as well as the best attentional state discrimination.

Some prior studies have shown more robust attentional state discrimination in pet and shelter dog populations (Barrera et al. 2011; Udell and Wynne 2011a). However, unlike previous studies, in this study the dogs did not have a choice between interacting with an attentive or inattentive human; instead they had the choice to socially persist or disengage with a single person who was attentive or inattentive. For pet and shelter dogs, a history of eventual provisioning or social contact with even a momentarily inattentive human might result in greater persistence when this person is the only social option. This is further supported by the fact that the pet and shelter dogs in this study spent more time in close proximity to the human compared to the free-ranging dogs, regardless of the testing phase. In fact, previous research has shown that pet and shelter dogs can be reinforced for gazing at a human regardless of whether food is available to them or not, perhaps due to the social attention they get from the task itself (Bentosela et al. 2008; Jakovcevic et al. 2010).

In contrast, the behaviour of free-ranging dogs appeared to be more directly linked to the likelihood of obtaining food in each condition. Given that these dogs are scavengers (Bhadra et al. 2015; Coppinger and Coppinger 2001), it is unlikely that they would continue to gaze at a human if it was not proving to be ecologically advantageous to them. Inattentive humans would be an unlikely source of available food in their niche, as would a human that had previously provided food but has stopped engaging in that behaviour. Interestingly, previous research has shown that free-ranging dogs will gaze more towards an attentive human than pet dogs or shelter dogs in a problem-solving scenario where a sealed container with food is provided to them (Bhattacharjee et al. 2017; Brubaker et al. 2017). In this case, the ambiguous nature of the situation appears to increase gaze persistence in this population, although it is unclear whether this is due to anticipation of further help, provisioning, or vigilance. Importantly, gazing towards humans may serve different purposes for these different populations; for example, free-ranging dogs may be more sensitive to human attentional state due to biological predispositions or may be more apt to follow attentional states for survival purposes. Future studies, including those that give free-ranging dogs a choice between an attentive and inattentive individual, may

shed additional light on the mechanisms underlying these behaviours.

Another interesting difference between the populations was the duration of time spent gazing at the food container. Free-ranging dogs on the whole spent the most time looking directly at the food container, whereas pet and shelter dogs spent more time looking at the human. Pet and shelter dogs spent significantly more time looking at the food in both human conditions (inattentive and attentive) compared to the control condition. Free-ranging dogs, on the other hand, spent roughly equivalent durations of time looking at the food in the control and inattentive conditions (conditions under which food would have to be obtained independently in a scavenging context) and less time looking at the food in the human attentive condition compared with control. This could suggest that the presence of a human who previously provided food from the out-of-reach container increased the salience of both stimuli for pet and shelter dogs, resulting in alternation of gaze behaviour (i.e., "showing behaviour" (Miklósi et al. 2000)). The free-ranging dogs, however, seem most sensitive to the condition under which food had previously been provided in this specific experiment and would be more likely to be provided again (when the human was attending) and showed attentional bias towards the ultimate source of the food—the human—instead of spending time looking at the food directly in the context of the attentive phase. Future research, particularly research that utilizes specialized equipment that can track gaze alteration and precise distance between the experimenter and the dog during the acquisition phase, could be used to further understand how food may be acting as a motivator for these dogs in the context of human interaction.

In the inattentive condition, free-ranging dogs spent the same amount of time looking at the food as in the control condition, whereas pet and shelter dogs spent more time looking at the food during the inattentive condition than during the control condition. Free-ranging dogs appeared to change their gazing behaviour towards the human depending on whether the human was physically available or not: they gazed more at the person during the attentive condition compared to the inattentive condition. However, like the other two groups of dogs, they did not increase their gaze towards the food during the inattentive condition. Interestingly, unlike the other groups, they also did not alter their gaze towards the food when the human was attentive, compared to when the human was absent. This may suggest that these dogs may be aware, at least to some extent, of a human's attentional state, and may be more vigilant about the human's behaviour when food is available but out of reach. However, given that they did not alter their gaze towards the food regardless of what the human was doing, this may suggest that these dogs are attending to the human as a means to obtain the food, and thus their interest in the food will be maintained regardless of whether the human is around or not. Shelter and pet dogs, in contrast, increased their gaze towards the food only when the human was in the room; anecdotally it was noted during the study that the shelter and pet dogs appeared distressed when left alone in the testing area (i.e., they whined, barked, paced, and/or panted excessively), suggesting that these dogs, in line with previous research, are particularly focused on the human during a problem-solving task (Miklósi et al. 2003; Udell 2015).

Conclusion

Previous research has shown that domestic dogs are capable of detecting human attentional states but that this ability can be influenced by a variety of factors, including the task itself, whether the dogs are in a shelter or not, and how the experimenter is looking away from them. This research largely supports those findings and additionally shows that free-ranging dogs can detect human attentional states when food is available but out of reach and respond in a way that suggests that these dogs may be primarily food oriented (they do not change their behaviour towards food but do change their behaviour towards the human based on the conditions that have predicted past food availability). Shelter and pet dogs showed less of a response to changes in the human's attentional state, perhaps indicating that the underlying mechanisms and motivations for these dogs' gazing behaviour are different (possibly more socially driven) than that of free-ranging dogs. This may be due to previous lifetime experiences and/or genetic factors that contribute to domestic dogs' social behaviours and gazing tendencies. Further research is needed with a variety of dog populations, such as free-ranging dogs with different levels of exposure to humans or working dogs that may have specialized training that could influence gazing behaviour in this context, to fully understand what factors contribute to a dog's ability to detect and respond to human attentional states.

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Author contributions Lauren Brubaker and Debottam Bhattacharjee designed the study; Lauren Brubaker, Prayas Ghaste, Piuli Shit, and Daisy Babu carried out the experiment. Lauren Brubaker and Debottam Bhattacharjee performed the analyses, drafted the manuscript and are the co-first authors on this manuscript. Anindita Bhadra and Monique Udell critically assisted with study design and helped draft the manuscript. All authors gave final approval for publication and agree to be held accountable for the work performed therein.

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