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ORIGINAL PAPER

Dogs steal in the dark

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Abstract All current evidence of visual perspective taking in dogs can possibly be explained by dogs reacting to certain stimuli rather than understanding what others see. In the current study, we set up a situation in which contextual information and social cues are in conflict. A human always forbade the dog from taking a piece of food. The part of the room being illuminated was then varied, for example, either the area where the human was seated or the area where the food was located was lit. Results show that dogs steal significantly more food when it is dark compared to when it is light. While stealing forbidden food the dog's behaviour also depends on the type of illumination in the room. Illumination around the food, but not the human, affected the dogs' behaviour. This indicates that dogs do not take the sight of the human as a signal to avoid the food. It also cannot be explained by a low-level associative rule of avoiding illuminated food which dogs actually approach faster when they are in private. The current finding therefore raises the possibility that dogs take into account the human's visual access to the food while making their decision to steal it.

Keywords Domestic dog · Social cognition · Perspective taking · Competition

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Introduction

Domestic dogs (*Canis familiaris*) are good at reading humans' attentional states. Dogs distinguish situations in which a human looks at them attentively from situations in which a human looks away, sits with her back turned or has her eyes closed (Call et al. 2003). In this study, a human experimenter placed a piece of food on the ground, ordering the dog not to take it, and then varied her attention systematically. Dogs stole significantly less food when the human had her eyes open compared to all other conditions. This finding has been replicated from other groups using the same context (Schwab and Huber 2006) as well as in other, more cooperative, contexts (Gácsi et al. 2004; Virányi et al. 2004; Udell et al. 2011). In the Gácsi et al. (2004) study, dogs were confronted with a situation where they had to decide which of two individuals they would beg from. They chose the attentive over the inattentive human.

Taken together these findings suggest that dogs have some sensitivity to cues of attention (e.g. visibility of the eyes), but as yet it is not clear whether this constitutes a flexible understanding of *seeing*. Bräuer et al. (2004) showed that dogs steal more food when they are hidden from a human's view by a large compared to a small barrier. This finding, however, could be best explained by an 'out-of-sight, out-of-mind' kind of rule and does not necessarily mean that dogs understand that because of the large barrier, the human could not see them steal the food. Another finding of that study was that dogs stole less food when the barrier between them and the human had a small window and was therefore ineffective in obstructing the human's vision. However, this finding could also be explained by dogs' sensitivity to other stimuli (e.g. seeing the human's body parts) instead of dogs' understanding of the human's visual access to the food (Kaminski et al. 2009).

Recently, Kaminski et al. (2009) published a study in which they suggested that domestic dogs understand something about a human's perspective. In this study, dogs were presented with a situation in which a human and the dog sat facing each other. Between the dog and the human were two barriers; one barrier was opaque the other barrier was transparent. Behind each of the two barriers was a toy. Both toys were visible from the dogs' perspective while from the human's perspective only the one behind the transparent barrier was visible. The human then asked the dog to 'Fetch!' without designating a specific object in any way. The dogs preferred the object behind the transparent barrier more in a condition where the dog and human were facing each other than in a condition in which the human sat opposite, but with her back turned (and therefore without visual access to either of the objects), or a condition during which the human sat on the same side as the dog (and therefore could see both objects equally well). This finding suggests that it is not only the visibility of the human's eyes which may provide a cue for the dog, but that dogs, like other animals tested in a similar setting, may actually understand something about the human's perspective (Bräuer et al. 2004; Kaminski et al. 2009). However, alternatively dogs may prefer the object behind the visible barrier more when the human is turned towards them, and therefore, the human's eyes are visible because then they can sustain visual contact with the human's eyes while fetching the toy (Kaminski et al. 2009).

Therefore, all evidence to date could be explained by dogs reacting to specific stimuli rather than having an understanding of seeing in others. One way to test if dogs really are engaging in perspective taking or are simply reacting to specific cues would be to set up a context in which the social cues, for example the visibility of the human's eyes, alone cannot determine the human's visual access to the food or a situation during which the contextual information and the social cues are in conflict. One such context would be a situation in which the human's visual access to, for example, a piece of food is determined by the intensity of the light in the room.

Evidence that intensity of light affects the behaviour of competitors comes from a study by Dally et al. (2004) with western Scrub Jays (*Aphelocoma californica*). The authors conducted a study to investigate whether the jays could understand that the level of light potentially reduced the transfer of visual information to competitors. Each jay was allowed to cache non-degradable food in two trays; one was well lit, whereas the other was in the shade. In one condition, the birds cached in private and in the other they were observed. When observed, the jays preferentially cached in the shaded tray, whereas both trays were used equally when caching occurred in private. The authors argue this is evidence that, in a competitive situation with others, intensity of light around the cache site plays a role, which could be evidence that jays understand what others can and cannot see (Dally et al. 2004).

In the current study, we set up a situation to determine whether dogs understand that in darkness the human's vision is impaired and she has difficulty in seeing the dog stealing a piece of food. The human always forbade the dog from taking a piece of food from the floor. The intensity of the light in the room was then varied and so was the part of the room that was illuminated. Depending on the condition, it was the human's face that was illuminated, or the area where the food was located, or both areas, or neither. The question was whether dogs were more likely to take the food in one situation rather than the other. If dogs understand something about the human's visual access to the food, we would expect them to steal less food when the area around the food is illuminated. However, if dogs' behaviour is mainly driven by their visual access to the human (e.g. some kind of 'out-of-mind, out-of-sight' strategy), we would expect dogs to take the piece of food more often when the human's face is illuminated compared to when it is not.

Study 1

The purpose of Study 1 is to see if intensity of light affects dogs' strategy in a competitive situation with a human over food.

Methods

Subjects

Twenty-eight dogs (14 females and 14 males) of various breed and ages participated in this study and were included in the data analysis. Four dogs had to be excluded because they never took the food. Additionally, one dog had to be excluded due to an experimental error and another one because he refused to continue with the test during his first session. All subjects were living as pet dogs with their owners in a medium-sized city in Germany and received the normal obedience training typical for domestic dogs. All dogs were chosen from a database of the Max Planck Institute for Evolutionary Anthropology. Owners were never present during the test and were not informed about the purpose of the study before the end of the last session, to avoid possible training between the testing days.

To be chosen for the study, dogs had to be at least 1 year old, interested in food and be comfortable without their owners even in a room of complete darkness. Females were not tested during oestrus.

Materials and methods

The data collection took place from February 2009 to July 2009. Testing took place in quiet rooms of the MPI EVA in Leipzig (8.70 m × 4.00 m × 2.85 m). Windows were covered with black polythene sheet, so no light could illuminate the room from outside. Water was available ad libitum throughout the test. Each session was videotaped on a mini-DV tape with a Sony night-view camera (DCR-HC 62 E). An infrared illuminator (Ecoline®, wavelength: 850 nm, 12 V, 2.5 W) was used to get better recordings with the camera. This light was only visible to the camera and did not illuminate the room. The experimenter sat at a predetermined spot. Two lamps (60 W spot lights) were positioned two metres apart from each other, on a horizontal plane halfway between the experimenter and the food. They were fixed on 0.70-m-high wooden poles and could be switched on and off with two remote controls. One of the lamps was directed towards the experimenter and the other at the spot where the food was placed during the test. The spot for the food was marked with reflective (but not phosphorescent) tape and was located 2 m in front of the experimenter. All dogs wore a reflective collar around their necks during the whole test making it easier to detect their movements and their approaches to the food. The illuminance of the different areas in the room during each condition were measured using digital Luxmeter (BEHA type: 93421). In the condition during which both areas were dark, illuminance was 0.1 lux around both areas. When only one spot (either food or human) was illuminated the illuminance in the illuminated area was 112 lux and in the non-illuminated area was 2 lux. When both areas were illuminated the illuminance around both areas was 112 lux.

The dogs had to pass a pre-test to participate in the study. This was conducted to ensure that the dogs' understood the commands used by the experimenter. After the experimenter and the dog entered the room the experimenter took a piece of food showed it to the dog and walked to the predetermined location. Then the experimenter called the dog's name to get his attention. While saying 'Aus' or 'Nein' (German: 'Do not take it!') with a strong, low-pitched voice she put the food on the ground at the marked position. The command was repeated as often as required—until the dog stopped trying to eat the food. Then the experimenter slowly walked backwards and sat on the ground at the predetermined location. The trial ended after 60 s had elapsed without the dog taking the food. After the 60 s had elapsed, the dog was encouraged to take the food with the words 'Geh ab!' or 'Jetzt nimm's!' (German for 'You can take it now!').

If the dog attempted to take the food during the pre-test, the experimenter intervened (e.g. by repeating the command again) and the 60 s started again.

In the test situation, after the experimenter and the dog entered the room, the experimenter took a piece of food showed it to the dog and switched off the ceiling lights. Both experimental lamps were switched on and the experimenter walked to the predetermined location and called the dog's name to get its attention. While saying 'Aus' or 'Nein' (German for 'Do not take it!') with a strong, low-pitched voice she put the food on the ground at the marked spot. While doing this, the experimenter's gaze alternated between the food and the dog. The experimenter ensured that the dog was always attentive while giving the command. Then the experimenter slowly walked backwards and sat down on the ground at the predetermined spot. The trial started when the lamps were switched on or off by remote controls, depending on the condition (see Fig. 1).

Food Dark/Human Dark	Both lamps were switched off so it was completely dark in the testing room
Food Dark/Human Light	The lamp directed at the food was switched off, while the lamp directed at the experimenter was switched on
Food Light/Human Dark	The lamp directed at the food was switched on, while the lamp directed at the experimenter was switched off
Food Light/Human Light	Both lamps were switched on

During the trials the experimenter sat still the entire time, irrespective of whether the dog did or did not take the food, and looked at a predetermined spot on the opposite wall. The trial ended after 120 s had elapsed after which the experimenter stood up and took the food (if it was still there) without looking at the dog. After a 10 min break the dog began the next trial.

Conditions were presented in a within-subject design and each dog received 4 trials in each condition, totalling 16 test trials altogether. Dogs received the trials in 4 sessions with one session/day, and each condition occurring only once per session. Conditions were counterbalanced for each dog across sessions and presented semi-randomized with the stipulation that the order of conditions changed every day. At the end of each testing day, the experimenter re-established her authority by repeating one trial of the warm-up phase in which dogs had to obey the command to not take the food for 60 s. This was done to avoid the dogs learning to ignore the command not to take the forbidden food because no punishment was used during the test trials.

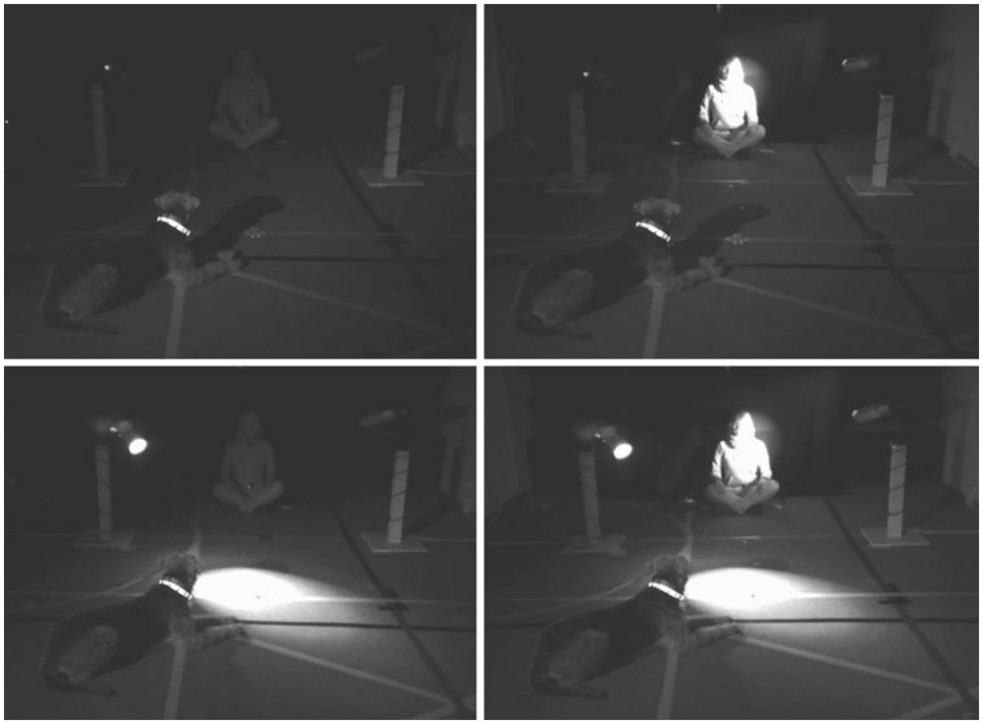

Fig. 1 The *figure* presents the four different conditions of Study 1. *Photographs* are captions from videotape and therefore represent the video capture with the night-view camera: From *left* to *bottom right*: *Food Dark/Human Dark,Food Dark/Human Light,Food Light/Human Dark*, *Food Light/Human Light*

Scoring

All data were coded from the video material by the same person (AP). We coded whether or not the dogs took the food, the latency from the moment the trial started until food retrieval, and the direction from which the subject approached the food (facing the experimenter or from the experimenter's side).

An independent observer who was not familiar with the purpose of the study scored a randomly selected sample of the original video material for reliability purposes. Twenty-nine per cent of the 'take food data' and 24 % of the 'direction and latency data' were coded. The level of agreement for taking the food was 100 % because it could be determined without ambiguity. Reliability for approach direction was excellent (Cohen's $\kappa = 0.97$, $N = 96$, $P < 0.001$). For the latency data, a Pearson correlation was used for agreement of continuous data (Lorenz 1996). Reliability for latency was excellent ($r = +1.00$, $N = 57$, $P < 0.001$).

The data for the amount of 'food taken' as well as for 'direction of approach' were not normally distributed, so we used non-parametric statistics (Friedman analysis of variance by ranks and Wilcoxon signed-rank tests). The data for the latencies were normally distributed, so we performed parametric statistics on this measure. We visually inspected plots of residuals versus expected values. Those indicated no obvious violations of the assumptions of an ANOVA, which was accordingly conducted.

Results

We first looked at the mean number of trials in which the dogs took the food across conditions (Table 1). Whether or not the dogs took the food depended on condition as there was a significant difference between conditions (Friedman test: $N = 28$, $\chi^2 = 48.42$, $df = 3$, $P < 0.001$). Post hoc Wilcoxon signed-rank tests showed that dogs took the food significantly more often in the *Food Dark/Human Dark* condition compared to all other conditions (Wilcoxon signed-rank test: *Food Dark/Human Light*: $T^+ = 0.0$, $N = 17$, $P < 0.001$; *Food Light/Human Dark*: $T^+ = 7.5$, $N = 20$, $P < 0.001$; *Food Light/Human Light*: $T^+ = 0.0$, $N = 24$, $P < 0.001$) and significantly less often in the *Food Light/Human Light* condition compared to all other conditions (Wilcoxon signed-rank test: *Food Dark/Human Dark*: see above; *Food Dark/Human Light*: $T^+ = 0.0$, $N = 15$, $P = 0.001$; *Food Light/Human Dark*: $T^+ = 4.5$, $N = 15$, $P = 0.001$). There was no significant difference between *Food Light/Human Dark* and *Food Dark/Human Light* conditions (Wilcoxon signed-rank test: $T^+ = 24.0$, $N = 13$, $P = 0.106$).

Table 1 Number of food pieces taken (out of four possible) by each subject in the four different conditions of Study 1

Subject	Condition			
	Food Dark/Human Dark	Food Dark/Human Light	Food Light/Human Dark	Food Light/Human Light
Baska	4	3	3	3
Luna	4	4	3	3
Luna (2)	3	3	2	1
Alina	3	2	2	2
Pepe	4	4	4	3
Amy	4	3	3	1
Wolf	1	1	2	1
Richard	4	3	3	3
Juri	4	4	4	3
Chico	4	4	3	1
Rocky	4	3	3	1
Thyson	4	4	4	4
Kimi	1	1	0	0
Lucie	4	3	3	3
Jazz	2	1	1	1
Merlin	2	1	0	0
Loki	3	2	3	2
Alma	3	2	1	2
Baghira	3	3	3	3
Asta	2	1	2	0
Max	4	2	1	0
Rudi	4	4	2	0
Jerry–Lee	3	1	1	1
Zosi	4	4	4	4
Jack	4	3	1	1
Stoffel	4	3	3	0
Bacardi	4	3	4	3
Ronja	3	2	2	0
Mean	3.32	2.64	2.39	1.64
Median	4	3	3	1
Quartile 1	3	2	1.75	0.75
Quartile 3	4	3.25	3	3

There were no gender differences in how often dogs took the food in any of the four conditions.

In a second step, we looked at latency as a measure and compared how long it took subjects to take the food in the four different conditions (see Fig. 2). Only dogs that took the food in at least one trial in every condition were included in the latency analysis. A repeated measures ANOVA with the factors *Food illuminated* (Yes vs. No) or *Human illuminated* (Yes vs. No) showed that dogs took the food significantly faster when it was not illuminated ($F_{1, 19} = 8.88$, $P = 0.008$), whereas whether or not the human being was illuminated did not affect the dogs' behaviour ($F_{1, 19} = 2.57$, $P = 0.13$). There were no significant interactions.

In a last step, we looked at the dogs' approach route. Only the dogs that took the food in at least one trial in every condition were included in the analysis. In all conditions, the dogs approached the food significantly more often coming from the direction of the door (from which they could see the face of the experimenter) than from the opposite direction (*Food Dark/Human Dark*: $T^+ = 143.0$, $N = 19$, $P = 0.037$; *Food Dark/Human Light*: $T^+ = 190.0$, $N = 21$, $P = 0.006$; *Food Light/Human Dark*: $T^+ = 158.5$, $N = 19$, $P = 0.004$; *Food Light/Human Light*: $T^+ = 184.0$, $N = 21$, $P = 0.008$). There were no significant differences in direction of approach across conditions (Friedman test: $N = 21$, $\chi^2 = 5.57$, $df = 3$, $P = 0.14$).

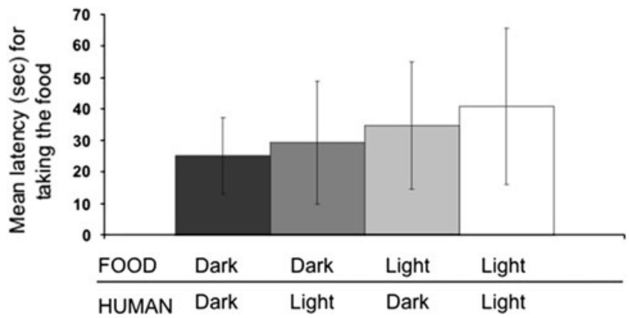

Fig. 2 Mean latency until dogs' stole the food in the different conditions of Study 1

To see if the dogs learned anything during the study, we analysed the dogs' food stealing behaviour in the very first session. Cochran's Q revealed an overall effect when comparing the number of food pieces taken across conditions (Cochran's $Q = 15.27$, $P = 0.01$). McNemar tests were used for pairwise comparisons between all four conditions. Even by the first session, the dogs took the food piece significantly more often in the *Food Dark/Human Dark* condition than in any of the other three conditions (mean = 0.71; compared to condition *Food Dark/Human Light*: mean = 0.5, $P = 0.031$; *Food Light/Human Dark*: mean = 0.43, $P = 0.008$; *Food Light/Human Light*: mean = 0.36, $P = 0.002$). However, no significant differences in the number of dogs taking the food between conditions *Food Light/Human Light* and *Food Dark/Human Light* ($P = 0.29$) as well as between *Food Light/Human Light* and *Food Light/Human Dark* ($P = 0.69$) could be observed. When comparing the *Food Dark/Human Light* to the *Food Light/Human Dark* condition there was also no significant effect ($P = 0.69$).

The number of trials in which dogs took the food per condition was not significantly different between sessions ($\chi^2 = 0.03$, $df = 1$, $P = 0.88$). So, no learning effect was found.

Discussion

The results show that the level of illumination in the room affected the dogs' behaviour. One could argue that because of dogs' different visual system they may not differentiate between the different levels of illumination in the room as they may see well in darkness. Unfortunately, there is absolutely no empirical evidence on how well dogs see in the dark. Every statement made is just guesswork based on the relative amount of 'rods' and 'cones' found in the retina [see for a review Miller and Murphey (1995)]. However, the behaviour of the dogs in the current study clearly shows that dogs differentiate the conditions based on the type of illumination in the room.

The dogs took the food significantly more often when both locations (food and human) were in darkness compared to all other conditions. When there was only one location illuminated, irrespective of whether it was the human or the food, the dogs stole the food equally often. Dogs also hesitated significantly longer in taking the food when it was illuminated (and therefore visible) than when it was not, while whether the human was illuminated or not had no effect on the dogs' behaviour.

Whether these results indicate that dogs understand that a reduced level of illumination hinders the human's visual access to the food and therefore increases the chances of theft is as yet unclear. It is unlikely that the dogs simply forgot that the human was in the room when she was not illuminated. If that were the case, we would not expect the dogs to differentiate between whether or not the food was illuminated. Instead, we would expect the dogs to steal the food as soon as the human was not illuminated and was therefore out of sight ('out-of-sight, out-of-mind strategy').

Also, the results cannot be explained by the dogs' refraining from taking the food because they could see the human's body parts (e.g. the eyes). If that were the case, we would expect the dogs to generally differentiate the conditions during which the human is illuminated from those during which she is not. However, there is the possibility that the dogs did not react to the social situation at all, but simply associated light around the food as an aversive stimulus, which inhibited them from taking the food once they had heard the forbidding command. We therefore conducted a follow-up study in which we varied the illumination around the food and had the human leave the room after giving the command not to take the food.

Study 2

In this study we varied the illumination around the food, but the human left the room after giving the command not to take the food. This was to see if dogs simply treated light around the food as a signal to avoid it.

Subjects

Twelve dogs (six females and six males) of various breed and ages participated in this study (see Table 1). All dogs were naïve to the test and had not participated in Study 1.

Materials and methods

The materials and design of this study were similar to the ones used in Study 1. Testing took place in the same room with an identical setup. As in the *Food Dark/Human Dark* and the *Food Light/Human Light* condition of Study 1 the illuminance levels were measured as 0.1 lux around both areas for the non-social dark condition and 112 lux around both areas for the non-social light condition.

The general procedure of the pre-test and experimental phase was identical to that used in Study 1, except that in the experimental phase the experimenter left the room after placing the food and ordering the dog not to take it. The trial started as soon as the experimenter turned away from the dog and left the room. After the experimenter left the room there were two possible conditions:

Non-social dark — The lamps were switched off such that it was completely dark inside the testing room. This was analogous to the *Food Dark/Human Dark* condition of the main study

Non-social light — The lamps were switched on. This was analogous to the *Food Light/Human Light* condition in the main study

Conditions were presented in a within-subject design with every dog receiving 4 trials in both conditions, totalling eight trials altogether. Trials were presented in two sessions of four trials each, with each condition occurring twice per session in a randomized order. After the first session was finished, authority was re-established analogously to the procedure used in Study 1.

Scoring

All data were coded from the video material by the same person (AP), and again we coded the mean amount of food taken in the two different conditions as well as the latency until good retrieval. An independent observer who was not familiar with the purpose of the study scored a randomly selected sample of the original video material for reliability purposes. Twenty-five per cent of the 'take food data' and 27 % of the 'direction and latency data' were coded. The level of agreement for taking the food was 100 % because it could be determined without ambiguity. For the latency data, a Spearman's rho for nonparametric correlations was used to test agreement of continuous data (Lorenz 1996). The reliability score for latency was excellent ($r = +0.95$, $N = 24$, $P < 0.001$). The data for 'food taken' as well as for 'latency to approach' were not normally distributed, so we performed nonparametric statistics (Wilcoxon signed-rank tests).

Results

The dogs took the food in almost all cases. Of the 12 dogs tested, 2 dogs did not take it in two trials (one dog in the *Non-social dark* condition and 1 in the *Non-social light* condition) and 2 dogs did not take it once (both in the *Non-social dark* condition). There was no significant difference between the two condition in the mean number of trials in which dogs took the food (Wilcoxon signed-rank test: $T^{+} = 4.5$, $N = 12$, $P = 0.41$).

In terms of latency to take the food, a comparison of the two conditions showed that the dogs took the food significantly faster when it was illuminated (condition *Non-social Light*: mean = 6.33 s, SD ± 3.97) compared to its being in the dark (condition *Non-social Dark*: mean = 9.37 s, SD ± 6.70; Wilcoxon signed-rank test: $T^{+} = 7.0$, $N = 12$, $P = 0.012$).

Discussion

The results of this study indicate that dogs' behaviour cannot be explained by a purely associative account of generally avoiding illuminated food. This is supported by the fact that in the current, non-social condition, dogs take the illuminated food even faster than the non-illuminated food.

One question that remains is to what extent dogs base their decision on the overall intensity of light in the room or the specific illumination of one or the other location. In the third study, we therefore systematically controlled for the intensity of light in the room. This was ensured as both lamps were always switched on, but, depending on the condition, one lamp was then turned away from (or towards) one or the other location, such that this location was then illuminated or in darkness.

Study 3

Subjects

Forty-four dogs (22 females and 22 males) of various breed and ages participated in Study 3 and were included in the data analysis (see Table 1). Eleven dogs had to be excluded because of never taking the food. Additionally, four dogs had to be excluded due to being too anxious to participate and three dogs because of not passing the pre-test. Only dogs that were naïve to the test and had not taken part in Studies 1 or 2 participated in this study. The dogs were randomly assigned to one of two groups.

Materials and methods

The materials and design of this study were similar to the ones used in Study 1 with the only difference that now the lamps could be turned in different directions as they were placed on a rotatable platform and had a rope attached to them with which they could be pulled in one or the other direction.

The pre-test of this study was done analogously to the one in Study 1 and again the dogs had to pass this pre-test to participate.

The procedure of the experimental phase was also identical to that used in Study 1 with the exception that the illumination level in the room never changed. Instead the lamps were either moved towards the food (or human) or moved away from the food (or human). The lamp was turned in one of the two possible directions by the experimenter pulling on a cord (with her right hand) attached to the lamp.

For one group of dogs, the experimenter always sat in the light and the illumination level around the food was varied (Both lamps were always switched on):

Human Light

Food Dark E was illuminated and the spotlight on the ground was directed away from the food

Food Light E was illuminated and the spotlight was directed at the food, so it was also illuminated

For the other group of dogs, the experimenter always sat in the *dark* and again the illumination level around the food varied:

Human Dark

Food Dark E was in the dark and the spotlight on the ground was directed away from the food

Food Light E was in the dark, but the food was illuminated

Every dog received eight test trials in total, four in the *Food Dark* condition and four in the *Food Light* condition. To balance potential order effects of the presentation of the conditions, an equal number of dogs started with one of the four (above mentioned) conditions. The illuminance of the different areas in the room during each condition was again measured. In the condition in which the human sat in the dark, illuminance was 2 lux around the human and 112 lux around the food when the lamp was directed at the food and 2 lux when the lamp was directed away from the food. In the condition during which the human sat in the light, illuminance was 112 lux around the human and 112 lux around the food when the lamp was directed at the food and 2 lux when the lamp was directed away from the food.

Every dog received four test trials per condition, with each condition occurring twice per session. Thus, two sessions were needed for each dog. Conditions were counterbalanced for each dog and presented in a semi-randomized order with the stipulation that the same condition could not occur in more than two consecutive trials.

After each session, dogs received the same training to re-establish the experimenter's authority, as in Study 1.

Scoring

All coding was done from videotape by the same person (AP). Again, we coded mean number of food pieces taken as well as latency until food retrieval. All data were normally distributed, so parametric statistics were used. We visually inspected plots of residuals versus expected values. Those indicated no obvious violations of the assumptions of an ANOVA.

Results

We first looked at the mean number of trials in which the dogs took the food. An overall ANOVA was conducted with the within-subject factor *Food illuminated* (Yes vs. No) and the between-subject factor *Human illuminated* (Yes vs. No). Results showed that whether the food was illuminated or not had no effect on the dogs' behaviour ($F_{1,42} = 0.94$, $P = 0.34$), nor did illumination of the human ($F_{1,42} = 2.39$, $P = 0.14$), and there was no interaction between the two factors ($F_{1,42} = 0.94$, $P = 0.34$).

We then looked at latency to food retrieval and again conducted an overall ANOVA with the within-subject factor *Food illuminated* (Yes vs. No) and the between-subject factor *Human illuminated* (Yes vs. No). Results showed that the dogs hesitated longer before taking the food when the food was illuminated than when it was not ($F_{1,37} = 5.99$, $P = 0.019$). Whether the human was illuminated or not had no effect ($F_{1,37} = 2.11$, $P = 0.16$) and there was no interaction between the two factors ($F_{1,37} = 1.78$, $P = 0.19$).

Discussion

The results of this study replicate the finding of Study 1. The dogs hesitated longer before taking the food when the food was illuminated than when it was not. They did so irrespective of seeing the human. The new finding here is that it is not only the general intensity of light around the food area that makes the dogs hesitate longer. Dogs' decision when to steal the food is actually based on the specific location being illuminated. This again indicates that dogs do not react to the human as an aversive stimulus, which, once visible, keeps them from disobeying. The second finding is that there was no significant difference between conditions on the amount of trials in which dogs actually took the food. This is different from Study 1 where the illumination level around the food also affected the amount of food pieces taken. This supports the hypothesis that for the dogs' decision to actually *take* the food, the level of intensity of light in the room is more important than the location illuminated.

General discussion

Taken together, the results suggest that dogs take into account the intensity of light in the room when competing over food. The dogs steal significantly more food when it is dark compared to when it is light. However, dogs' behaviour while stealing forbidden food also depends on the type of illumination in the room. Whether or not the human is illuminated does not affect dogs' behaviour. Seeing the human and particularly the human's eyes is important information for dogs. This is supported by research showing that dogs steal significantly more food when the human's eyes are closed as opposed to open or the human is oriented towards the food or oriented away from it (Call et al. 2003; Schwab and Huber 2006). The current study, however, provides evidence that when deciding to steal food, dogs do not take the sight of the human (or the human's eyes) simply as an aversive stimulus, which, once visible, keeps them from stealing the food.

Interestingly, the current study shows that what does affect dogs' behaviour is the level of illumination around the food. This also cannot be explained by a very low-level associative rule like, for example, always avoid illuminated food, as dogs actually approach illuminated food faster when they are in private. One possible high-level explanation could be that dogs understand that when the food (and therefore the area around it) is illuminated, the human can see them approaching and stealing the food. The current finding therefore raises the possibility that dogs take into account the human's visual access to the food while making their decision to steal it. This would be in line with research for other species, which indicates that intensity of light might help for the purposes of determining when the other individual can or cannot see things (Dally et al. 2004).

Research to date supports the hypothesis that dogs, like other mammalian species, understand when another individual's line of sight is blocked. The current findings support the hypothesis that this evidence cannot just be explained by low-level accounts, such as seeing a human's body parts as an aversive stimulus. Dogs also seem to react appropriately in more cooperative contexts where they have to decide whom to beg from: the human whose vision is obstructed, or the human who can see them (Cooper et al. 2003; Gácsi et al. 2004).

However, dogs' understanding of seeing in humans seems to be limited and not as flexible as that of other species. This is because dogs do not seem to understand what a human has seen in the recent past (Kaminski et al. 2009). In that study, dogs distinguished which toy to bring to the human based on the human's current visual access to those toys. Upon the command to fetch, the dogs fetched a toy which was visible to the human through a transparent barrier significantly more in a condition where the experimenter and the dogs sat opposite each other than in a control condition where the dog and the human sat on the same side and thus had comparable visual access to both toys (Kaminski et al. 2009). However, in another condition of the same paradigm, two toys were placed behind opaque barriers such that the experimenter, sitting opposite the dog, had no visual access to either of the toys, while the dog saw both toys equally well. The experimenter then watched the placement of one toy, but not the other—thus she was knowledgeable about the location of one toy but ignorant about the location of the other. Interestingly, upon the request to fetch, the dogs did not distinguish between the two toys, contradicting the hypothesis that they can distinguish between knowledge and ignorance in other individuals (Kaminski et al. 2009).

Therefore, it seems as if dogs' understanding of others' visual access may be limited to the present and may not go beyond Level 1 perspective taking. This is in contrast to other species. Chimpanzees, for example, not only understand when another's line of sight is currently blocked or when they are not in a position to see things (Bräuer et al. 2007; Hare et al. 2000; Kaminski et al. 2004; Liebal et al. 2004; Melis et al. 2006), but also understand knowledge and ignorance in others (Hare et al. 2001; Kaminski et al. 2008). The same is true for more distantly related species, like, for example, Scrub Jays, which, like chimpanzees, seem to understand others' past as well as current visual access (Dally et al. 2004, 2005, 2006; Emery and Clayton 2001). This has led to the hypothesis that these species may have a flexible understanding of others' psychological states, in particular an understanding of seeing in others (Call and Tomasello 2008). On the evidence of the present and other studies, we would not argue for that degree of flexibility in dogs, but more research is needed to identify the mechanisms behind dogs' behaviour.

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