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Research

Roles for referential focus in effective and efficient canine signaling: Do pet and working dogs differ?

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ABSTRACT

Working dogs trained to be detection/sniffer dogs must work closely with their human partners. Pet dogs are also often asked to perform tasks, whether in a casual context (e.g., going for a walk) or as part of more formal activity (e.g., competitive sport). For the best performance outcomes, each partner must signal well to the other, and accurately read and respond to the other's signals. As part of a larger study comparing problem-solving behavior and information use in working dogs and pet dogs, we compared the detailed responses of 40 detection dogs and 80 pet dogs to verbal signals under two conditions: when the handler was facing the dog (front-facing condition) versus when the handler had his back to the dog, while giving a verbal request (back-facing condition). We hypothesize that: (1) both groups of dogs would be more accurate and faster in response when they could see the humans' faces and anterior bodies (front-facing condition) than in the back-facing condition; (2) dogs who did not respond immediately and correctly to the signal would exhibit behavioral signs of anxiety, uncertainty, and possibly distress, and such signals would be more common in the back-facing condition; and (3) the working dogs would be more consistent and successful as a group when compared to the pet dogs because working dogs have been specifically trained to do a job, in joint collaboration with humans who signal to them when and where to do the job and when they are successful. As such, clear signaling and response was already part of their practiced and tested daily life, and so should be reflected in their testing in this study. All testing was video recorded using the same test design and same order of tests. Neither pet nor working dogs were familiar with the test before initial testing, and neither was tested in a physical space that was familiar to them. Video analysis determined latency to response, time to completion of requested task, and identification of behaviors exhibited during the two conditions (human facing the dog/front-facing condition, or with the human's back turned to the dog/back-facing condition). Requests were given verbally using a normal tone of voice. Handlers were asked not to use hand signals. The three requests used were "sit," "down," and "stay". For most comparisons, dogs were slower to respond and took longer to complete each request when they were unable to see the handler's face (back-facing condition) (all $P < 0.05$). The behaviors exhibited when the working dogs could not see their handler's face were largely associated with seeking further information that would allow the dog to comply with the request. This pattern of response suggests that improvements in signaling behavior and understanding for both team members can and should be made and should lead to improvements in the dogs' welfare and better team performance. Pet dogs exhibited both information-seeking behaviors and those associated with anxiety when they could not see their owner's face, suggesting that working on efficient and accurate exchange of cues and responses would improve pet dog welfare and help to create a trusting relationship where anxiety about collaborative tasks is minimized.

Introduction

The domestic dog is able to use, and act on, signals given by humans. Signaling modalities may include head movement, direction of gaze (Soproni et al., 2001; Teglas et al., 2012), pointing

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gestures (Soproni et al., 2002; Scheider et al., 2013; Scandurra et al., 2018), body orientation (Soproni et al., 2002; Schwab and Huber, 2006), direct gaze (Bentosela et al., 2008; Duranton and Gaunet, 2016; Jakovcevic et al., 2010; Udell et al., 2010), and facial cues (Kaminski et al., 2017). Verbal signaling has also been studied (Dalibard 2009; Kaminski et al., 2004; Pongracz et al., 2005). Dogs are able to distinguish signal variants such as quality and volume of voice (Dalibard, 2009; Scheider et al., 2011) and positioning of gestures ranging from positioning of a single finger to broad arm movements (Soproni et al., 2002).

Seeking and focusing on the human face as a source of information has been widely studied in dogs (Barrera et al., 2011; D'Aniello et al., 2015; D'Aniello and Scandurra, 2016a; Gácsi et al., 2004; Passalacqua et al., 2011). If the human face is not in view or the eyes of the human are covered, dogs are less successful at performing the task the human requested (Gácsi et al., 2004). Puppies have been shown to briefly look at the human face to obtain help, although this appears to be a skill developed with time and additive social interactions with humans (Passalacqua et al., 2011), as is true for adult dogs (Duranton and Gaunet, 2016). The whole of the human face can be a source of information and attentional focus for dogs. Several functional magnetic resonance imaging studies have indicated that recognition of the human face results in activation of the temporal cortex of the canine brain (Berns et al., 2012; Berns and Cook, 2016; Cuaya et al., 2016; Dilks et al., 2015).

Dogs and humans often focus on the eyes, specifically. Gaze-averting may be a deferential display in dogs (Vas et al., 2005). Depending on emotional state and willingness to interact, dogs often engage positively in eye contact with humans, and humans use eye contact as a means to hold focus during training (McGreevy et al., 2012). In addition to "connecting" through eye contact, there is evidence that dogs can recognize facial expressions of humans. Dogs recognize and select photographs of their owner's smiling face over a blank (neutral expression) face (Nagasawa et al., 2011), and dogs produce more facial movements when an attentive human is facing them (Kaminski et al., 2017). In a study by Soproni et al. (2001), the dog's attention was engaged through eye contact, then voice, while the human faced the dog before using subsequent signaling involving pointing. Attention to the human's face and anterior body was considered necessary before the dog could accurately receive and act on subsequent signals.

The specific response that dogs exhibit to human cues may depend on their ontogenetic history, their exposure to and social history with humans (D'Aniello and Scandurra, 2016a; D'Aniello et al., 2017; Duranton and Gaunet, 2016; Soproni et al., 2001), and their conditioning to respond to various cues (D'Aniello et al., 2016b, 2017). Dogs performing agility tasks, a sport that requires attendance to the human for instructions about the layout of the course, were more likely to gaze longer at the human face when faced with an unsolvable task than were either search and rescue dogs, who work independently, or pet dogs (Marshall-Pescini et al., 2009). Dogs that have experienced closer social relationships with humans are more likely to appear to understand human gestural cues and body movements. Kenneled dogs are less likely to gaze at humans in unsolvable problems than are pet dogs (D'Aniello and Scandurra, 2016a), and pet dogs may learn to be more persistent in soliciting responses and actions from humans (Barrera et al., 2011). Shelter dogs with little opportunity for interspecific interactions with humans tend to watch human faces to a greater degree but are not as skilled at operating on signals sent to them by humans (D'Aniello et al., 2017).

In any communication system involving a goal of eliciting a response, there is a signaler and a receiver (Smith, 1981). The signaler may succeed in altering the receiver's behavior (e.g., getting them to move from a standing to a sitting position), but this outcome is dependent on several aspects of communication. The efficacy of communication depends on how clearly the signaler communicates, and on the ability and willingness of the receiver to attend to, receive, process, and respond to the signal. When the signal is clear and the receiver is willing to engage, and able to use and respond to the signal, the communication process is effective in terms of outcome and efficient in terms of time to response. However, when the signal is not clear or understood, the receiver may send reciprocal signals back to the original sender and may also act to seek information and clarity (Smith, 1981). This finding has relevance for the study reported here.

Humans use this signaling paradigm routinely with dogs. Attributions of outcomes to signals are seldom tested but Cook et al. (2016) demonstrated that dogs preferred a verbal signal ("praise") delivered by a familiar human to a food reward in a detour task. Yet the information that handlers or owners think they are signaling may not be the information on which the dog is acting when both verbal and nonverbal cues can be involved. Dogs are extremely good at integrating various signaling modalities and redundancies and recognize and act on subtle facial and body language cues (Mariti et al., 2017). If we are to have efficacious communication—signaling that is both clear and efficient—we need to know whether the state or condition under which the signal is given (e.g., facing the dog, facing away from the dog; sitting, standing) affects the outcome of the signal for the dog.

When the receiver is unable to use the signal given, for whatever reason, the response to the signal will not be as expected and the receiver may demonstrate attempts to gain information as to the signaler's intent. When dogs are unable to discern the meaning of a signal, they may become uncertain, anxious, or distressed. Behavioral signs that indicate anxiety or stress in dogs in varying contexts have been documented, particularly as they apply to assessing welfare (Beerda et al., 1997; Beerda et al., 2000; Casey 2002; Mariti et al., 2012; Overall, 2013; Rooney et al., 2007; Schilder and Van der Borg, 2004; Tod et al., 2005) and may include, but are not limited to, lip/nose licking, autogrooming, lifting of forepaw, lowered body posture, trembling, restless movement, stillness, scanning, head turning, hypersalivation, panting, decreased or increased appetite, defecating and/or urinating, digging, drinking, manipulating the environment, opening the mouth, various oral behaviors, stretching, urinating, vocalizing, exhibiting repetitive behaviors, and yawning.

Accordingly, we examined the response to three verbal signals, "sit," "down," and "stay" under two conditions, front facing (human facing with their entire body directly toward the dog) and back facing (human faces completely away from the dog with head back and limbs turned), for two groups of dogs with different relationships with humans: working dogs and pet dogs. Working dogs trained to be detection/sniffer dogs must work closely with their human partners. Pet dogs are also often asked to perform tasks, whether in a casual context (e.g., going for a walk) or as part of more formal activity (e.g., competitive sport). For the best performance outcomes, each partner must signal well to the other, and accurately read and respond to the other's signals.

We were interested only in how the dogs used the verbal information when they could see the signaler's face and anterior body, and when they could not. Because human gestures have been reported to appear more salient than words as cues for dogs (D'Aniello et al., 2016b) and because dogs use redundant verbal and physical signals to confirm the information they contain (Scandurra et al., 2018), this comparison allowed us to separate human facial and physical signals that acted as potentially redundant signals for dogs (the front-facing condition) from signals that were only verbal (back-facing condition).

We had three hypotheses. (1) We hypothesized that for both groups, regardless of signal, dogs would be more accurate and faster in response when they could see the human signalers' faces and anterior bodies (front-facing condition), which provided additional access to congruent nonverbal signals in this condition than when this information was lacking in the back-facing condition. (2) We also hypothesized that for dogs who did not respond immediately and correctly to the signal (e.g., those who were unsure of the signal or who had not truly learned the verbal signal), the behaviors exhibited would be those indicating (or related to) anxiety, uncertainty, and possibly distress (Beerda et al., 1997, 2000; Casey 2002; Mariti et al., 2012; Overall, 2013; Rooney et al., 2007; Schilder and Van der Borg, 2004; Tod et al., 2005), and that such signals would be more common in the back-facing condition because of the need to rely on global congruent signaling systems. (3) Finally, we hypothesized that the working dogs would be more consistent and successful as a group when compared to the pet dogs because working dogs have been specifically trained to do a job, in joint collaboration with humans who signal to them when and where to do the job and when they are successful. As such, clear signaling and response was already part of their practiced and tested daily life, and so should be reflected in their testing here.

Materials and methods

All dogs in this study were participating in a larger 13-item problem-solving test designed to identify how they used information from the environment, including human and nonhuman signals, to solve various problems across 4 cognitive domains (Table 1; Overall, 2013; Scheifele et al., 2016). Requesting dogs to "sit," "down," and "stay" under each of the two conditions, front facing or back facing to the dog, comprised tests 1 and 2, and were the only focus of this study. These tests involved cognitive domain 1.

The working dogs (N = 40 of 106 tested) were all trained, working detection dogs from three U.S. Department of Defense government contractor groups. These contractor working dogs had all been trained to detect drugs, weapons, or explosives using olfaction, although the vast majority worked to detect explosives. Some dogs were dual trained and also engaged in protection work. All working dogs were purpose-bred from a restricted number of breeds (primarily Belgian malinois, German shepherds, and Labrador retrievers) and obtained from vendors that sell working dogs. The working dogs were all adults from 20 months to 9 years (17 intact males, 17 intact females, 3 castrated males, 3 spayed females), trained to detect their targeted odorants when given a verbal and/or physical cue to "search" or "find it", and all were rewarded with a tennis ball or a tug toy when they indicated the appropriate substance. The pet dogs (N = 80) came from a variety of breeds (including mixed) and backgrounds (bred by owner, obtained as a puppy, obtained as a rescue, found), had various training histories (from no training to agility, flyball or nosework champions), and encompassed a wide range of ages, between 4 months and almost 14 years (7 intact males, 8 intact females, 38 castrated males, 27 spayed females). Of the 106 total working dogs enrolled in the comprehensive study, video analysis of canine signals for this part of the project was possible for only 40 of these dogs. The signals of all 80 pet dogs were clear on video. Breeds included in the study are found in Table 2.

All of the working dogs were handled by their trainers or handlers. All of the pet dogs were handled by their owners. Because the working dogs were operational, they were tested in their home facilities in a large, indoor space, not used for training. Pet dogs were all tested in the same large, indoor research space. Accordingly, the video conditions for seeing facial signals in the working dogs were more poorly lit than the conditions for the pet dogs. The indoor spaces for each respective group were unfamiliar to the subjects and no prior training exercises had taken place in those rooms for either group; thus, prior experience in a familiar setting was not a biasing condition.

All tests were done in the same order (front-facing condition first [Soproni et al., 2001]) and every attempt was made to standardize the positioning of equipment and handlers. Two researchers were present throughout and two video cameras were arranged so that at least one always had a clear angle for viewing the dog's behaviors. All handlers (owners, trainers, or occupational handlers) were asked to stand in the middle of a room that was gridded alternately at 1 meter (m) intervals and face the dog at about the distance with which they usually interacted with the dog. This distance was without exception within a meter but varied depending on the size and age of the dog. Because tone can affect response to a signal (Scheider et al., 2011), handlers were requested to use a normal, neutral tone of voice and to not use hand signals.

Table 1
Cognitive domain classification for testing dogs; note that domains 3 and 4 are often combined into a domain general for rodents and/or dogs (from Overall and Dunham, 2013 and Scheifele et al., 2016; adapted from Lezak et al., 2004; Strauss et al., 2006; Gabowitz et al., 2008)

1. Social/interactive learning/attention domain—communicating with monitoring and understanding others simple and complex visual learning (associational memory)
2. Physical/location memory/visual spatial domain—reasoning object permanence spatial reasoning
3. Executive function/learning and more complex memory domains (frontal lobes and integrated circuitry)—working memory sustained attention task perseverance inhibition and concept learning
4. Spontaneous behavior domain—sensory motor processes laterality odour/sound reactions/discrimination and responses to stressors including object exploration

Table 2
Numbers and breeds of dogs studied

Breed	# Pet dogs	# Working dogs
American eskimo	1	
American Staffordshire terrier	5	
Australian cattle dog	1	
Australian shepherd	8	
Basenji	1	
Bearded collie	2	
Belgian malinois		7
Bernese mountain dog	1	
Border collie	3	1
Borzoi	1	
Boxer	1	
Bull terrier	1	
Cavalier King Charles spaniel	1	
Cocker spaniel	1	
Corgi	3	
Doberman	1	
German shepherd dog	3	15
Golden retriever	5	3
Greyhound	3	
Jack Russell terrier	1	1
Keeshond	4	
Labrador retriever	14	13
Long-haired dachshund	1	
Mastiff	1	
Mixed breed	9	
Papillion	1	
Shetland sheepdog	1	
Shiba inu	1	
Standard poodle	1	
Tervuren	3	
Whippet	1	

Handlers were told that they could give the signals with the dog on-lead or off-lead (only the exceptional dog in each group was tested on-lead, for reasons of safety in the working dog group, and youth in the pet dog group) and that they could use food treats as rewards after successful performance, if they wished.

Signals were to be given in the order "sit", "down", and "stay" because this is the natural sequence most dogs use to lie down. "Sit" was defined as the hindquarters in contact with the floor as the forelimbs remained in extension with paws in contact with the floor. The rear quarter posture could be either symmetrical or asymmetrical. "Down" was defined as a recumbent posture with the sternum and hindquarters in contact with the floor and with hindquarters positioned either symmetrically or asymmetrically. "Stay" was defined as remaining in place, in any posture, for a minimum of 2 seconds as the handler/owner moved 1 meter away from the dog.

At the start of the test, handlers were asked to face the dog and verbally, without hand signals, ask the dog to "sit" (front-facing condition). If, after 10–20 seconds, the dog had not responded, the handler was allowed to repeat the signal. If the dog did not respond, the handlers were asked to move on to the next signal. Dogs had a total of 30 seconds to respond to each signal. The same rules for time, repetition, and hand signals were followed for the signals "down" and "stay". Following the condition where handlers faced the dog (front-facing condition), they were asked to repeat the entire process in the back-facing condition.

Measurements for each of the three tasks under both conditions included ultimate success and failure, latency to comply, and time to completion in seconds as indicated by review of video. Latency was defined as time in seconds from the first verbal request to the start of engaging in the task. Time to completion was defined as the amount of time in seconds to complete the task after the first request, within a maximum of 30 seconds. Success was defined as the correct response to the signal within the 30 seconds allotted. Failure was defined as no, or an incorrect response to the signal within the 30 seconds allotted.

The behavioral signals given by the dogs were identified by video analysis and are included in the ethogram in Table 3. Behavioral signals were assessed from the video using continuous sampling (Martin and Bateson, 2007). All behaviors were identified, defined, and counted. Because the time interval over which our measurements were taken was short, only behaviors listed in the

Table 3
Ethogram of the behaviors identified through video analysis of the signals the dogs gave in response to the three signal requests

Behavior#	Signal	Definition/description
1	Gazing upward toward handler's face	Moving the rostral portion of the head upward to direct the gaze toward handler's face or the back of the head
2	Moving to follow handler	Ambulating to follow the handler's movement away from the dog
3	Retracted ears	Ear pinna bilaterally retracted caudally against the head, exposing the inner ear lining to view
4	Yawning	Opening and closing of jaws without teeth exposed accompanied by muscle tension
5	Getting up	Rising from a sit or down position
6	Looking away from handler	Intentional turn of the head in a direction away from handler
7	Looking around or toward videographer/scanning	Head movement and gaze directed toward videographer and/or with the head/eye movement scanning the environment/room
8	Lowering the head/body	Flexion of the front and rear limbs and/or downward movement of the head to any degree without sternal contact with floor, i.e., crouching
9	Tail wag	Varying tail height, frequency, and oscillation amplitude
10	Lip lick	Tongue briefly seen outside of mouth, sweeping across lips/muzzle or up to nose
11	Sniffing handler	Odor investigation of the handler's hands or legs with rapid inhalations
12	Sniffing floor	Odor investigation of floor with rapid inhalations
13	Moving away from handler	Ambulating in any direction away from handler
14	In motion	Continuous movement of the feet/legs with ambulation in varying directions, absence of stillness
15	Wrong task	Dog offered a behavior not requested
16	Attention on inanimate focus (which could be noise)	Attention indicated by visual orientation toward an inanimate object or in the direction of a sound
17	Tail tucked	Ventral lowering of tail in close contact with perianal region
18	Nudging/licking handler's hand	Intentional movement of dog's nose or tongue to make contact with handler's hand
19	Gazing at/watching handler's hand movement	Sometimes with head movement to enable gaze as handler's hands moved
20	Raised forepaw	One forelimb moved dorsally to lift paw from contact with the floor while in a sit position—height from floor variable
21	Head/body shake	Voluntary rapid oscillation of the head and entire body, while the feet maintained contact with the floor
22	Worried/wrinkled facial expression	Facial muscles contracted to form skin wrinkles dorsal (superior) to the eyes in the frontal region of the cranium
23	Body tense/stiff	Movement generally inhibited due to muscle rigidity
24	Panting[a]	Rapid inhalation and exhalation with mouth open and tongue protruding rostrally at varying lengths. Saliva may or may not drip.
25	Barking for reward/treat	Barking (loud, sharp, rhythmic vocalization) while gazing at reward/treat in the owner's hand
26	Whining	High pitched vocalizations with mouth generally closed
27	Barking—other	Barking (loud, sharp, rhythmic vocalization) in any context other than for rewards in handler's hand
28	Looking down at floor	Head turned in downward gaze position toward the floor
29	Following hand into position	Coordinated head and body movement that tracks a human hand movement, typically into a "down" position
30	Head following hand lure (but not into desired position)	Movement of head to follow hand, but without completion of lowering body into "down" position
31	Jumping up handler	Raising of both the front limbs from the floor to make contact with handler's body, while the rear limbs maintained contact with the floor.

[a] Working dogs were tested in their operational kennel environments where the ambient temperature was recorded but not controlled. Because panting could have been due to thermoregulation, this was not a behavior that was evaluated as potentially associated with anxiety or distress for the working dogs. Pet dogs were tested in a constant environment with good ambient temperature control that did not require that they pant to thermoregulate. Panting was considered as a potential signal associated with anxiety or distress for pet dogs.

Table 4
Request completions, average latency, and average time to complete the request in seconds (s) for working dogs and pet dogs in both conditions (front facing and back facing) for each of the three signals

Request completions	Working dogs						Pet dogs					
	Front-facing condition	Average latency (s)	Average time to complete (s)	Back-facing condition	Average latency (s)	Average time to complete (s)	Front-facing condition	Average latency (s)	Average time to complete (s)	Back-facing condition	Average latency (s)	Average time to complete (s)
Sit	86/106[a] (81.1%)	1.36	2.21	59/106[d] (55.7%)	2.35	3.59	78/80[a] (97.5%)	1.58	1.72	63/80[d] (78.8%)	5.46	6.00
Down	44/106[b] (41.5%)	1.63	2.74	20/106[e] (18.9%)	2.20	3.45	78/80[b] (97.5%)	0.81	0.86	78/80[e] (97.5%)	1.04	1.13
Stay	6/106[c] (5.7%)	1.71	1.14	14/106[f] (13.2%)	1.75	2.29	78/80[c] (97.5%)	5.71	6.56	78/80[e] (97.5%)	5.71	6.56

Percentage of completions included parenthetically. Letters indicate statistical comparisons between groups for signal and condition for completion of behaviors, Chi square test for independence.
[a] $P < 0.00006$, $X^2 = 11.712$.
[b] $P < 0.00001$, $X^2 = 63.3284$.
[c] $P < 0.00001$, $X^2 = 155.2707$.
[d] $P < 0.00103$, $X^2 = 10.7697$.
[e] $P < 0.00001$, $X^2 = 111.0836$.
[f] $P < 0.00001$, $X^2 = 129.5897$ (all df = 1).

ethogram that occurred with frequency greater than 5% of the time across all dogs were analyzed because meaningful statistical comparisons for rare behaviors were not possible.

Behaviors were analyzed with respect to condition and group using R (R Development Core Team, 2009). Parametric procedures were used whenever the data met the assumptions of the test. Randomization (permutation) procedures (Good, 2005) were used to compute significance levels for all nonparametric comparisons to eliminate the need for distribution assumptions (e.g., normality). Tests of significance in comparisons of the frequency of behaviors under conditions where the handler was front facing versus back facing were conducted using binomial tests.

Results

Regardless of what we requested of the handlers of both working and pet dogs, most humans appeared to have difficulty in complying with the instruction to use only verbal signals and to do so at the frequency and timing suggested.

Analysis of latency and time to complete task

The data for latency and time to complete task and the frequency/percentage of completions for both working and pet dogs are found in Table 4. Most working dogs sat when asked to do so in the front-facing condition but did not lie down ("down") or "stay" when subsequently asked to do so. When comparing group outcomes for the requests in both conditions, pet dogs succeeded in executing all requests significantly more often than did the working dogs, regardless of the condition.

Latency(s) to comply with the "sit" request was significantly shorter when the working dogs could see the handler's face (front-facing condition) than when they could not (back-facing condition) ($P = 0.0008$) (Table 4; Figure 1). In contrast, there were no significant differences in latency when the dog could see the handler's face than when the dog could not (all $P > 0.05$) with either the "down" or "stay" requests (Figure 1). This result is affected by the low frequency with which the working dogs complied with the "down" and "stay" requests.

For the pet dogs, latency to comply was shorter for the front-facing condition only for the initial request to sit. Latency to comply for "down" was longer than for "sit" in both conditions. Latency to comply to "down" and "stay" requests did not differ by condition (Table 4; Figure 2).

Analysis of failure to complete task

Because so many working dogs did so poorly on these three tasks, we assessed their failure rates. For the "sit" request, working dogs failed at a significantly higher rate when they could not see the handler's face (back-facing condition) than when they could see the face (front-facing condition) ($X^2 = 7.8$, df = 1, $P = 0.0008$). In contrast, there were no significant differences in failure rates between the front-facing and back-facing conditions (all $P > 0.05$) with either the "down" or "stay" requests (Figure 3).

Analysis of behaviors exhibited during the task

The complete distribution of all 31 behaviors (Table 3) identified across all signals and conditions exhibited for working dogs and pet

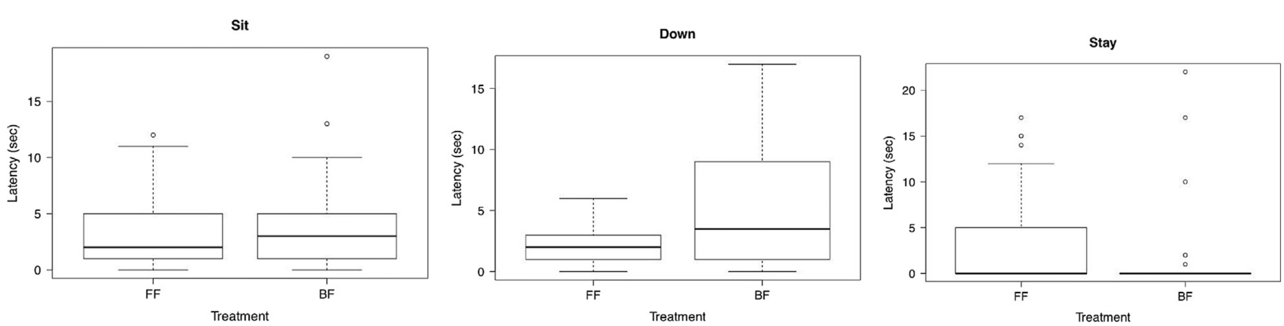

Figure 1. Latency to comply for the requests of "sit," "down," and "stay" in the front-facing condition and back-facing conditions in working dogs. The dots indicate extremes in the distribution, the median is indicated by the dark line, the box spans the interquartile range (IQR), and the whiskers indicate data that lie within 1.5 times the IQR for the upper and lower quartiles, respectively.

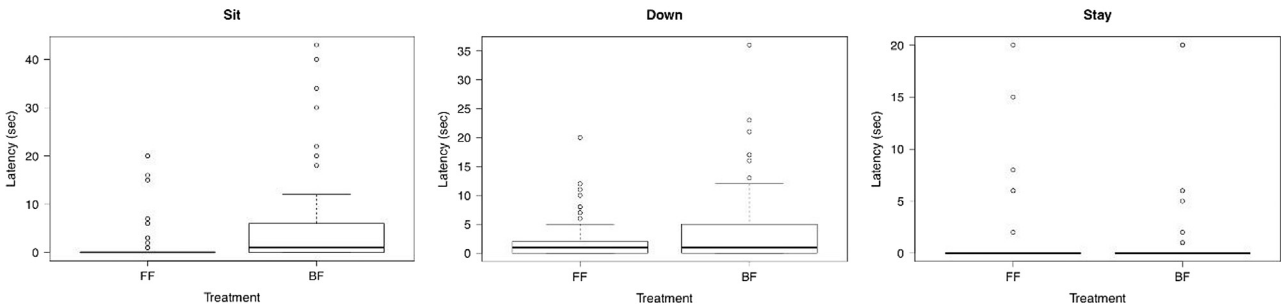

Figure 2. Latency to comply for the requests of "sit," "down," and "stay" in the front-facing condition and back-facing conditions pet dogs. The dots indicate extremes in the distribution, the median is indicated by the dark line, the box spans the interquartile range (IQR), and the whiskers indicate data that lie within 1.5 times the IQR for the upper and lower quartiles, respectively.

dogs is found in Figures 4 and 5, respectively. The distribution of all behaviors exhibited differs significantly between working dogs and pet dogs ($X^2 = 693.0117$, df $= 121$, $P < 0.0001$). In addition, there were highly significant differences ($X^2 = 163.6109$, df $= 55$, $P < 0.0001$) between the distributions of behaviors in working dogs when the handler was facing forward versus backward. Finally, there were also highly significant differences ($X^2 = 118.4629$, df $= 55$, $P < 0.0001$) between the distributions of behaviors in pet dogs when the handler was facing forward versus backward. Compared with pet dogs that had 31 behaviors in their ethogram, working dogs had only 24, suggesting a more impoverished communication repertoire (Figures 4 and 5). This is an important finding because it suggests an *a priori* decision of which behaviors to evaluate, for example, for signs of distress, may fail to adequately assay some populations of dogs.

An examination of which behaviors were never exhibited by group, condition and request is revealing (Table 5).

Pet dogs never lowered their head or body (a behavior often associated with stress or fear) or raised their forepaw (an intention signal often indicative of changing behaviors or uncertainty). Four behaviors were exhibited by pet dogs only in the front-facing condition and for one request only: they looked away from the handler for the down request, sniffed the handler for the sit request, tucked their tail for the stay request, and shook their head or body (often a sign of managing stress or uncertainty) for the sit request.

Unlike pet dogs, working dogs never barked for a reward/treat, whined, barked in nonreward situations, looked down at the floor, followed a hand into position, tracked a lure with their head, or jumped on the handler. Although the handlers of working dogs did use their hands to signal (despite being asked not to do so), they did not lure the dogs into position. Handlers are aware of lures and they use a hand lure to train dogs to sniff in certain locations at specific levels. The remainder of these behaviors is all attention-seeking behaviors which would be considered undesirable in working dogs. Working dogs yawned only in the back-facing condition for the down request and shook their head/body only in the front-facing condition for the down request.

We statistically compared the frequency of behaviors that occurred 5% or more of the time (Figures 6 and 7). This subset of behaviors defined by frequency was chosen to ensure comparison of data were unlikely to be artefacts of our short (up to 30 seconds) sample intervals.

Behaviors exhibited ≥5% of the time in response to the sit request for working dogs are listed in the following. Significant differences in behavior between the front-facing and back-facing conditions are indicated with an asterisk.

1* Gazing upward toward handler's face
2* Moving to follow handler
7* Looking around or toward videographer/scanning
9 Tail wag
10 Lip lick
22 Worried/wrinkled facial expression

Behaviors exhibited ≥5% of the time in response to the down request for working dogs are listed in the following. Significant differences in behavior between the front-facing and back-facing conditions are indicated with an asterisk.

1 Gazing upward toward handler's face
3 Retracted ears
7* Looking around or toward videographer/scanning
9 Tail wag
10 Lip lick
19 Gazing at/watching handler's hand movement

Behaviors exhibited ≥5% of the time in response to the stay request for working dogs are listed in the following. Significant

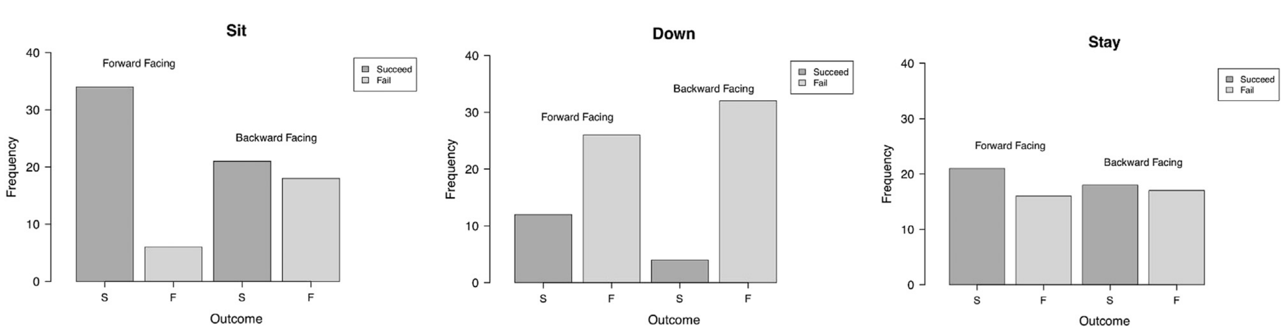

Figure 3. Failure frequency for the working dogs with respect to the requests of "sit", "down", and "stay" in the front/forward-facing and back/backward-facing conditions.

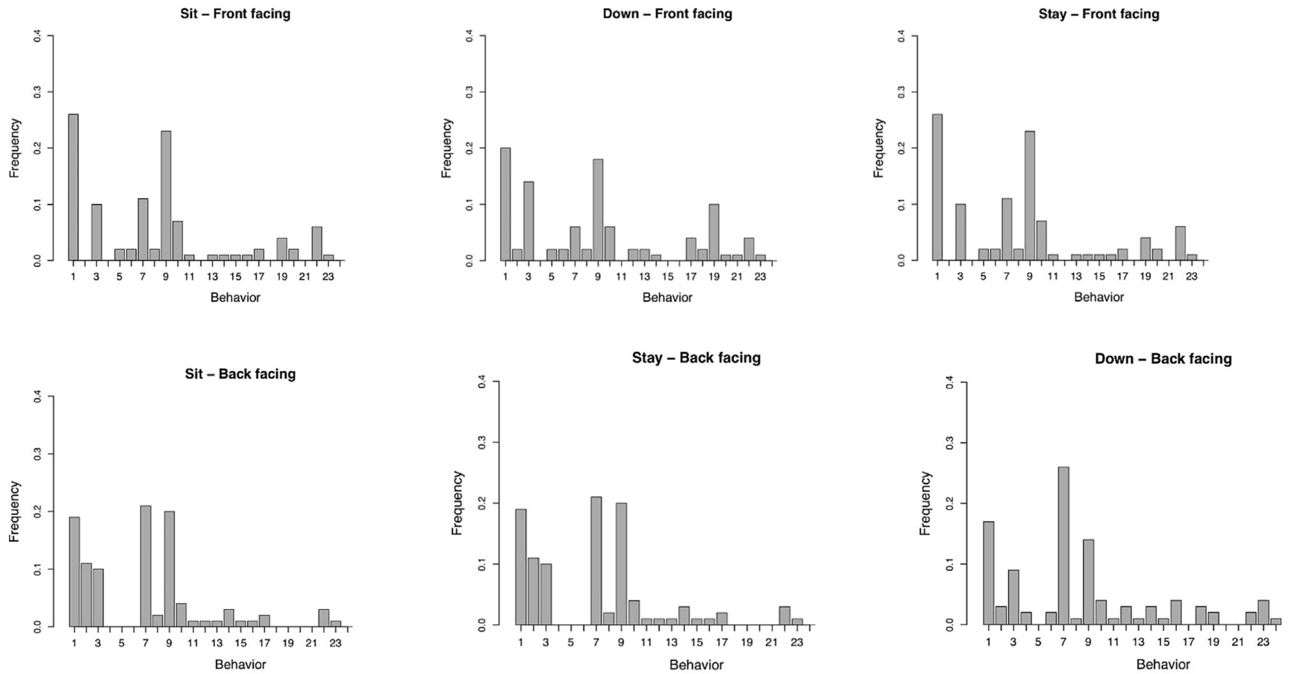

Figure 4. Frequency of occurrence of all identified behaviors for the working dogs with respect to the requests of “sit,” “down,” and “stay” in the front-facing condition and back-facing conditions. The numbers refer to the numbered behaviors in the ethogram in Table 3.

differences in behavior between the front-facing and back-facing conditions are indicated with an asterisk.

1 Gazing upward toward handler’s face
2 Moving to follow handler
3 Retracted ears
5 Getting up
7 Looking around or toward videographer/scanning
9 Tail wag
10* Lip lick
22 Worried/wrinkled facial expression

For the “sit” request, the only significant differences in observed behaviors with respect to condition for the working dogs were that dogs gazed at the handler’s face more in the front-facing posture ($X^2 = 4.23$, df = 1, $P = 0.039$) and attempted to follow the handler ($X^2 = 15.68$, df = 1, $P < 0.0001$) and looked around, scanning more in the back-facing posture ($X^2 = 6.15$, df = 1, $P = 0.013$) (Figure 6).

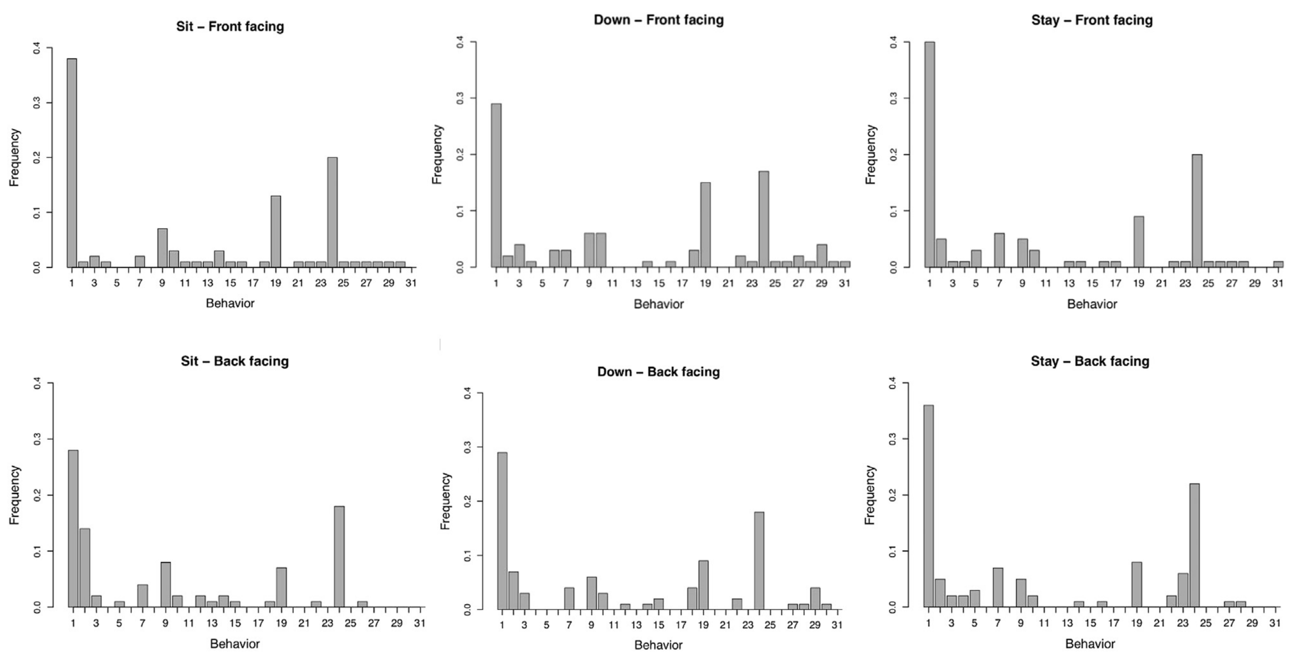

Figure 5. Frequency of occurrence of all identified behaviors for the pet dogs with respect to the requests of “sit,” “down,” and “stay” in the front-facing condition and back-facing conditions. The numbers refer to the numbered behaviors in the ethogram in Table 3.

Table 5
Behaviors not exhibited by group, condition, and request; X = behaviors not seen

#	Signal	Pet dogs						Working dogs					
		Sit front	Sit back	Down front	Down back	Stay front	Stay back	Sit front	Sit back	Down front	Down back	Stay front	Stay back
1	Gazing upward toward handler's face												
2	Moving to follow handler							X				X	
3	Retracted ears												
4	Yawning		X		X			X	X	X		X	X
5	Getting up	X		X	X				X		X		X
6	Looking away from handler	X	X		X	X	X		X				X
7	Looking around or toward videographer/scanning												
8	Lowering the head/body	X	X	X	X	X	X						
9	Tail wag												
10	Lip lick												
11	Sniffing handler		X	X	X	X	X			X			
12	Sniffing floor			X		X	X	X				X	
13	Moving away from handler			X	X		X						
14	In motion												
15	Wrong task			X		X	X			X			
16	Attention on inanimate focus (which could be noise)		X		X					X			
17	Tail tucked	X	X	X	X		X				X		
18	Nudging/licking handler's hand					X	X	X	X			X	X
19	Gazing at/watching handler's hand movement								X				X
20	Raised forepaw	X	X	X	X	X	X		X		X		X
21	Head/body shake		X	X	X	X	X	X	X		X	X	X
22	Worried/wrinkled facial expression												
23	Body tense/stiff		X		X		X						
24	Panting							X	X	X		X	X
25	Barking for reward/treat		X		X		X	X	X	X	X	X	X
26	Whining				X		X	X	X	X	X	X	X
27	Barking—other		X					X	X	X	X	X	X
28	Looking down at floor		X					X	X	X	X	X	X
29	Following hand into position		X			X	X	X	X	X	X	X	X
30	Head following hand lure (but not into desired position)		X			X	X	X	X	X	X	X	X
31	Jumping up handler	X	X		X		X	X	X	X	X	X	X

For the "down" request, the only significant difference was that the working dogs scanned more in the back-facing posture ($X^2 = 17.25$, df = 1, $P < 0.0001$). For the stay request, the working dogs licked their lips significantly more in the front-facing posture ($X^2 = 6.15$, df = 1, $P = 0.013$), an outcome that was unanticipated but suggests that this request when facing a handler may be unfamiliar.

Behaviors exhibited ≥5% of the time in response to the sit request for pet dogs are listed in the following. Significant differences in behavior between the front-facing and back-facing conditions are indicated with an asterisk.

1* Gazing upward toward handler's face
2* Moving to follow handler
9 Tail wag
19* Gazing at/watching handler's hand movement
24 Panting

Behaviors exhibited ≥5% of the time in response to the down request for pet dogs are listed in the following. Significant differences in behavior between the front-facing and back-facing conditions are indicated with an asterisk.

1 Gazing upward toward handler's face
2* Moving to follow handler
9 Tail wag
10 Lip lick
19* Gazing at/watching handler's hand movement
24 Panting

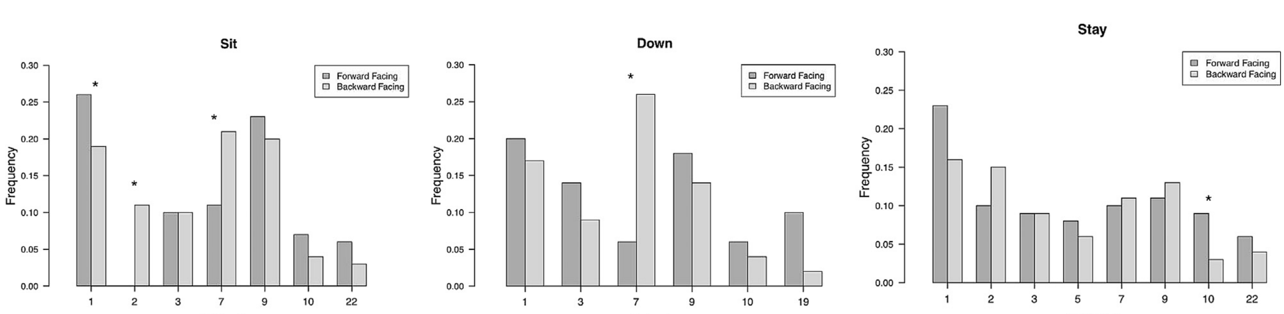

Figure 6. Frequency of occurrence of behaviors occurring ≥5% of the overall behaviors for working dogs with respect to the requests of "sit," "down," and "stay" in the front-facing condition and back-facing conditions. The numbers refer to the numbered behaviors in the ethogram in Table 3. Significant differences by condition are marked with an asterisk (binomial tests; $P < 0.05$). Pet dogs had a very different pattern of behavioral differences (Figure 7).

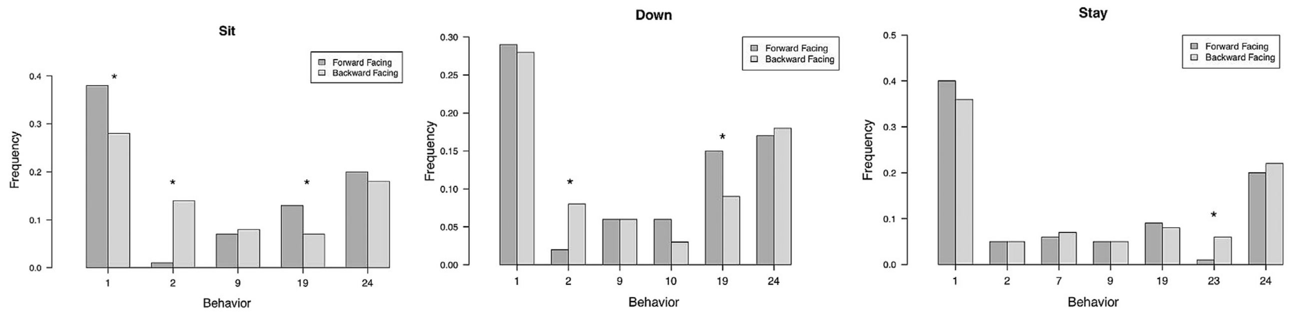

Figure 7. Frequency of occurrence of behaviors occurring ≥5% of the overall behaviors for pet dogs with respect to the requests of "sit," "down," and "stay" in the front-facing condition and back-facing conditions. The numbers refer to the numbered behaviors in the ethogram in Table 3. Significant differences by condition are marked with an asterisk (binomial tests; $P < 0.05$).

Behaviors exhibited ≥5% of the time in response to the stay request for pet dogs are listed in the following. Significant differences in behavior between the front-facing and back-facing conditions are indicated with an asterisk.

1 Gazing upward toward handler's face
2 Moving to follow handler
7 Looking around or toward videographer/scanning
9 Tail wag
19 Gazing at/watching handler's hand movement
23* Body tense/stiff
24 Panting

For the "sit" request, pet dogs gazed at the handler's face ($X^2 = 4.34$, df = 1, $P = 0.0372$) and watched the handler's hand ($X^2 = 4.33$, df = 1, $P = 0.0386$) significantly more frequently in the front facing, compared with the back-facing posture. The latter suggests that pet dogs may be expecting treats or rewards delivered by hand, and the former may indicate that concurrent, redundant facial and verbal signals are perceived to have enhanced salience. In the back-facing position, for the "sit" request pet dogs moved to follow the handler ($X^2 = 5.33$, df = 1, $P = 0.02102$), suggesting that they were soliciting additional cues to help them comply, other than the verbal request to "sit".

For the "down" request, pet dogs moved significantly more often to follow the handler in the back-facing position ($X^2 = 4.07$, df = 1, $P = 0.0438$), again, suggesting that they may be seeking additional information about the intent of the signal. In the front-facing position, pet dogs significantly more often gazed at/watched the handler's hand movements ($X^2 = 4.36$, df = 1, $P = 0.0369$) for the "down" request, suggesting that they anticipate a hand signal.

The only significant difference for behaviors that occurred 5% of the time or more often for the "stay" request in pet dogs was for the back-facing position, where dogs more often stiffened and became tense as they stayed ($X^2 = 7.97$, df = 1, $P = 0.0047$). This sign of stress suggests that dog may have used other nonverbal signals in the front-facing posture to confirm that they should stay and when they might be released.

There are some interesting patterns when we qualitatively compare the most common behaviors for pet and working dogs.

In terms of behaviors that signal dogs are seeking information, both pet and working dogs wagged their tails in both conditions for all requests, suggesting that they were willing to interact with the handler. Pet and working dogs both gazed upward toward the handler's face in both conditions and for all signals. Pet dogs moved to follow the handler in both conditions for all signals, whereas working dogs did not move to follow the handler in either condition for the down request, only. Interestingly, most of the working dogs did not comply with this request, suggesting that it may have been novel for them. Working dogs also scanned more than pet dogs, a behavior also associated with uncertainty, stress, or distress.

In terms of behaviors that are associated with uncertainty, stress, or distress, working dogs retracted their ears and licked lip in both conditions for "down" and "stay" but not sitting. Pet dogs did not retract their ears and licked lip only for the "down" request. Working dogs showed a worried/wrinkled facial expression for the "sit" and "stay" request in both conditions and scanned for all requests in both conditions. A worried/wrinkled expression was absent from the common behaviors of pet dogs, and they scanned only when requested to "stay", suggesting that they might be seeking more information but otherwise did not appear distressed. These major differences in patterns of behaviors between the pet and the working dogs with respect to this class of behaviors suggest that the working dogs were more stressed/distressed by these requests—regardless of condition—than were pet dogs.

Discussion

Whether a signal changes another's behavior may depend on many variables, including learning history, familiarity with the individual giving the signal, the signaler's skill level, environmental conditions and distractions, physical health, and emotional state.

These variables highlight the challenges of studying dog-handler interactions under "real world" field study conditions where standardization can apply to test design and instructions, only. Accordingly, our goal was not simply to determine the dogs' compliance. Instead, we sought to ask what behaviors the dogs exhibited in response to the verbal requests under two different conditions that altered information available. Signals were given when the human completely faced the dog and the dog could see the face and the front of the body, and when the human faced 180° away from the dog, and the dog could not see the human's face or the front of the body. In this context, the designations of "success" or "failure" indicate only whether the task was achieved at the end of the 30-second test period. Measures of how the dogs responded to the signal included latency to comply and time to completion. This study design allowed us to examine how the dogs in the two broad groups used and sought information.

It is important to highlight two major findings about how dogs responded to human signals. First, working dogs and pet dogs differed significantly in the distribution of behaviors exhibited and the number of behaviors exhibited, with working dogs exhibiting fewer behaviors across all conditions and signals. Second, both pet and working dogs differed significantly in the distribution of behaviors exhibited when the front-facing and back-facing conditions were compared. These findings mean that dogs are using verbal signals in the context of other, nonverbal sources of information, and that the combined sources of information shape their responses, and that the ultimate response pattern depends on the dogs' work history (here, pet or odorant detection dogs). Accordingly, we cannot make assumptions about dogs' responses to signals without considering these factors.

Our first hypothesis that dogs in both groups would perform better in the front-facing condition was confirmed for the "sit" request for both groups of dogs. All dogs were more accurate and faster when they could see the handler giving the "sit" request. Most working dogs did not lie down ("down") or "stay" when subsequently asked to do so. Pet dogs succeeded in executing all requests significantly more often than did the working dogs, regardless of the condition, and were faster at executing all requests in the front-facing condition, when compared to the back-facing condition, as hypothesized.

The second hypothesis that dogs that were unable to respond would show signs of anxiety or distress was not confirmed for the working dogs but was confirmed for pet dogs. Working dogs appeared uncertain and distressed about cues, regardless of condition, with a complex pattern of behaviors. Working dogs gazed at the handler's face significantly more often in the front-facing condition for the "sit" cue, only. Working dogs scanned significantly more often in the back-facing position for the "sit" and "down" requests, but not for the "stay" request, but very few dogs succeeded in the "stay" request. At this point in the requests, most working dogs just seemed confused. Working dogs moved to follow the handler significantly more often in the back-facing condition for the "sit" request, only. Working dogs also licked their lips significantly more often in the front-facing conditions for the "stay" signal. The lack of other condition dependent significant behaviors for the "stay" signal suggests the working dogs did not know what the "stay" cue meant or they were uncertain that they should comply.

These dogs did not exhibit behaviors associated with stress more frequently when the handler faced away from the dogs, but they sought to monitor the handler's behavior and signals given by hands. We requested that handlers not use hand signals, which did not entirely eliminate them. The pattern of working dogs' behaviors suggests that they habitually monitored handlers' postures for signaling information. That these dogs moved to follow the handler in the back-facing condition for the signal with which they did best—"sit"—may confirm a role for the working dogs seeking nonverbal signals from the handler. Dogs have been shown to perform better and faster to a combination of gestures and verbal cues (Scandurra et al., 2018), a redundancy pattern that minimizes errors. Human gestures appear more salient than words as cues (D'Aniello et al., 2016b). Canids are more likely to recognize an object that is moving than one that stands still (Miller and Murphy, 1995), which may improve attention and more closely follows normal canine visual perception if there is some type of body movement on the part of the human signaler. However, it is important to remember that these working dogs were kennel dogs, and as such may not look at human faces as often as pet dogs do (D'Aniello and Scandurra, 2016a; D'Aniello et al., 2017).

Pet dogs gazed at the handler's face and moved to follow the handler significantly more often in the front-facing condition for the "sit" request, but in the back-facing position, pet dogs showed behaviors associated with soliciting more information about the goal of the request (e.g., moving to follow the handler significantly more often in the back-facing condition for the "sit" and "down" signals). This latter behavior may suggest that the dogs had learned their cues with hand signals and/or used hand signals to confirm the verbal cue.

The third hypothesis that working dogs would be more consistent and successful as a group when compared to the pet dogs was rejected. Working dogs were less successful as a group in responding to the signals and were less consistent across signals. Interestingly, although pet dogs succeeded in executing the request significantly more often than did the working dogs, regardless of the condition, working dogs who responded to the request did so more quickly than did the pet dogs. This finding is potentially important because it strongly suggests that the working dogs have been selected for quick reactions, regardless of the situation they face. In the absence of a strong signaling relationship, this pattern of behavior may render these dogs a challenge to train reliably to cues, especially if their attention is not first focused on the handler.

It is interesting that dogs in both the pet and working groups appeared to have sought physical cues, but working dogs moved to seek information from faces and hands. Pet dogs that live in close association with their human companions may have the opportunity to develop a better understanding of communicative gestures (D'Aniello and Scandurra, 2016a). Detection dogs are often taught to begin a search with a physical hand gesture that leads them to the area to be searched so it is possible that these dogs sought the signal with which they may have been most familiar. Reid (2009) posits that dogs' enculturation with humans, who have opposable thumbs and who deliver care by means of hands, has a direct effect on canines becoming acutely tuned to body movement and human attentional state.

The differing distribution of behaviors exhibited by pet dogs when compared with working dogs undergoing the same testing procedure is important. Compared with pet dogs, working dogs exhibit a depauperate repertoire of signals, especially with respect to signals where dogs solicit direct interaction from people. The patterns of behaviors exhibited and the overall repertoire of behaviors may be influenced by the dogs' rearing, learning, and performance environments, which may enhance some behaviors, while dampening others. Here, it is possible that working dogs failed to exhibit some behaviors because they were either not acknowledged or rewarded as part of training, or deliberately discouraged. Regardless, knowledge of the underlying distribution of behaviors exhibited by dogs in different functional environments must inform the choice of behaviors used in assays of behavioral markers or important population and individual differences will be missed.

The differences in profiles between working and pet dogs strongly suggest that the working dogs were less practiced with, and less knowledgeable of, the verbal cues, although they made efforts to gain additional information about what was desired from their handlers. The extent to which the working dogs did not respond to the verbal cues was surprising, however, as they work closely with handlers in their daily life. The work of detection is primarily the dog's responsibility but getting the dog to the area of interest and directing the dog is the handler's responsibility. For these contractor dogs, there was wide variation in response.

When these dogs were successful, they had faster rates of response and smaller latencies than did pet dogs, suggesting that there has been some selection for dogs to exhibited heightened reactivity to cues. We do not know if the same variation and range in response occurs in purpose-bred, rather than purchased contractor dogs, but this is an important issue. Clear signaling allows rapid and appropriate response. Working dogs, like those we studied, may improve in task compliance were they develop a more effective signaling relationship with their handler. There is evidence that such relationships matter. Military working dogs that went home with their handlers had decreased problematic aggression and were more sociable than dogs that remained only in the kennel environment (Lefebvre et al., 2007). Familiarity with handlers enhances cue performance in working dogs, even when cues are given by strangers (Scandurra et al., 2017). Such outcomes may contribute to coherence and success of working dog teams. Given their diminished signaling repertoire, compared to pet dogs, and their heightened reactivity to signals, working dogs may benefit from repeated evaluations using a standardized, field-portable test for incipient signs of anxiety associated with their ability to respond to signals and perform their task.

Conclusions

McGreevy et al. (2012) discusses the concept of "inattentional blindness". Inattentional blindness involves the notion that we are less likely to see something we are looking at if our attention is not focused on it (Mack, 2003). Humans should attend to the signals dogs convey, especially if they are reciprocal to signaling by humans. Canine signals, as shown in this study, can indicate when the dog does not understand or misunderstands what the human is trying to convey.

Lack of clarity in signaling and decreased comprehension of signals affects a dog's emotional state and has implications for welfare (Beerda et al., 1997, 2000; Casey 2002; Deldalle and Gaunet, 2014; Harvey et al., 2016; Mariti et al., 2012; McGreevy et al., 2012; Overall, 2013; Rooney et al., 2007; Schilder and van der Borg, 2004; Tod et al., 2005). The humans' ability to observe and perceive body language signals as part of reciprocal communication allows them to assess the dog's emotional state. Lack of awareness of subtle signaling indicating uncertainty, anxiety, or distress in the dog may result in inappropriate or ineffective human signaling and failure of the desired outcome. Failed signals may perpetuate compromised emotional welfare and detract from a cooperative relationship. In considering dyadic interactions between humans and canines, a goal of "social synchrony," in which behavior between bonded partners interacting with each other can be coordinated (Pirrone et al., 2017), could result in greater success in achieving the intended outcome. Successful dual signaling between humans and dogs should also reduce the risk of compromised emotional and cognitive states.

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Ethical considerations

IACUC approval was provided by both the US DoD Army Medical Research and Materiel Command and the University of Pennsylvania privately owned pet protocol.

Authors' contributions

The idea for this article was conceived by Karen L. Overall. The experiments were designed by Karen L. Overall and Arthur E. Dunham. The experiments were performed by Karen L. Overall and assistants. Data were collected and videos analyzed by Karen L. Overall and Deborah Bryant. The data were analyzed by Arthur E. Dunham and Karen L. Overall. The article was written by all the authors.

Conflict of interest

Karen L. Overall is the Editor-in-Chief of Journal of Veterinary Behavior: Clinical Applications and Research. Another editor, Christel Moons, was appointed to manage all steps of this submission to ensure that the highest ethical standards were upheld by the Journal.

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