Czech University of Life Sciences Prague

Faculty of Agrobiology, Food and Natural Resources

Ph.D. Thesis:

The degree of communication between humans and dogs, wolf-dogs and wolves in association with the genetic background as a model for application to farm animals

Andrea Sommese, Ph.D. Candidate

Supervisor: Professor Luděk Bartoš, Sc.D.

Specialist supervisor: Associated Professor Helena Chaloupková, Ph.D.

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STATEMENT

I hereby declare that I have completed this thesis by myself using the cited literature. I agree with utilization of included information on condition of the correct citation. This Ph.D. thesis, neither its substantial part, was not submitted to gain another or the same academic title.

In Prague: November, 2020 Andrea Sommese, Ph.D. candidate

CONTENT

1. General introduction

Communication is necessary for every social interaction because all of them are based on the exchange of information. Animals have evolved different ways to pass messages using, for example, optical, acoustic or chemicals signals. Often those signals play a delicate and important role when it comes to sexual selection and speciation. Communication occurs when an individual, the so-called sender, transmits a signal to another, the receiver (Shannon & Weaver 1998). Following, a signal is defined as "*behavioral, physiological, or morphological characteristics fashioned or maintained by natural selection because they convey information to other organisms*" (Otte 1974). According to Otte's view, the transmission of information had to give some advantage to the sender itself in order to satisfy the definition (i.e. vocalizations, color patterns and body movements). Ambiguous traits, instead, evolved for some other function and they have been modified by selection for information transmittal. Moreover, the message conveyed should be honest (Johnstone & Grafen 1993; Kokko 1998) and reliable, even though sometimes it can also be disturbed increasing the probability of errors in the receiver. A signal is considered reliable if some characteristics of the signal are correlated with some attributes of the environment or the sender and if the receiver(s) benefitted from having information about this attribute (Searcy & Nowicki 2005).

1.1 Communication, a brief history

In a seminal paper, Richard Dawkins and John Krebs (1978) reacted to what they called the classical ethological view of animal communication. According to their opinion communication has been treated as a cooperative interaction between the signaler and receiver. If that was true then the receivers were selected to behave as if predicting the future behavior of the signalers, while the latter were selected to 'inform' reactors of their internal state, to make it easy for reactors to predict their behavior. Dawkins and Krebs proposed replacing this cooperative view of communication with another. They defined communication as an attempt on the part of a signaler to manipulate the behavior of the receiver to the signaler's advantage. Hence, the signaler communicates not in order to tell the receiver what the receiver wants to know, but to induce the receiver to do something that will benefit the signaler. This manipulative interpretation gained a growing consensus among behaviorists; it also proposed that individual selection plays the leading role in shaping the evolution of behavior. Dawkins and Krebs also offered a series of quotations from earlier papers. For example, Tinbergen (1964) was quoted as saying "one party—the actor—emits a signal, to which the other party—the reactor—responds in such a way that the welfare of the species is promoted". Quotations like these were considered as incorrect and not representative of the central ideas of ethology. To be

fair, Tinbergen's principal interest was in the evolutionary origin of displays. He studied the movements from which signals were originally derived, and in the proximate causation of display, that is the motivation of the animal to signal. Whether or not the cooperative view of animal communication represented the main trend of ethological thinking, this point of view was harshly discredited by Dawkins and Krebs' analysis that became the foundation of 'modern' ethology.

To summarize, a communicative interaction starts always with a signaling event and a certain level of experience and learning is often required in both the sender and the receiver. Often in social animals, communicative signals emerge from rudimentary actions and the signal is just a product of maturation and experience.

1.2 Intra-specific communication

Birds have always inspired human imagination. This fascination may arise from having something in common with them; both species share a strong investment in communication by vocalizations (Rogers & Kaplan 2002). Birdsong have been studied and described intensively (for further references, see Berwick & Chomsky 2013). There is less well-controlled experimental research on the communication systems of mammals than of those of birds, but mammalian systems are not simple and they show different degrees of complexity.

Among many other species in the class Mammalia, canids are highly communicative. The body posture of wolves (Zimen 1981), golden jackals (Golani & Keller 1975), and foxes (Tembrock 1962; Fox 1971) and, of course, dogs (Scott & Fuller 1974; Lorenz 2003) has been widely described. Even though domestication has clearly influenced pet dogs' repertoire (Coppinger & Coppinger 2002), we can still hear bark, growls, whines and howls of wolves daily in our apartments or backyards. Some canids produce less familiar sounds as the squeak of the bush dog (Kleiman 1972), the whistle of the dhole (Fox 1984; Durbin 1998) or the twittering of the African wild dogs (Van Lawick & Goodall 1970). Tembrock (1962) provided the first important study on canids' voices with sonographic analysis of red foxes and from there many other followed.

1.3 Dogs' communication

Dogs, as many other animals, are able to engage in visual communication, but also in tactile, auditory and olfactory communication through vocalizations and odors. The communicative importance of the different body parts during social interactions is still poorly investigated. Here, the author briefly describes the four type of communication. In both scientific and popular literature, similarity between wolves and dogs are often outlined but this might be misleading. Often the assumption is that if a dog performs a species-typical signal, such as the play bow, its motivation can

be deduced by comparison with wolf behavior (Skete 2014). Serpell and Barrett (2016) indicated at least four reasons why superficially similar dog and wolf behaviors might require different interpretation. One, dog behavior seem to be derived from the repertoire of juvenile and not adult wolves (Kretchmer & Fox 1975). Second, dogs underwent radical changes in social cognition, especially in inter-species communication (Range & Virányi 2015). Third, inter-specific socialization changes the context within which many signals function. Finally, the rewarding value of contact with humans.

1.3.1 Visual communication

Dogs communicate with other individuals modifying the position of different parts of their body. In a 1872 book, republished later, Darwin and Prodger (1998) proposed a series of illustrations to indicate different emotional states in dogs (Fig. 1).

Figure 1: examples of tail positions indicating different emotions (Darwin & Prodger 1998).

Voluntary muscles placed around the body allow them to display a wide range of postures and positions to convey different information about the signaler's inner state or intentions (Handelman 2012). Although, through artificial selection many breeds have been modified so much that their signaling capacity is reduced (Bradshaw & Rooney 2016). Brachycephalic dogs (i.e. Pugs, Pekingese) lost the ability to display different facial expressions and dogs with permanently erected ears and a short tail (i.e. Corgi) lost part of their behavioral repertoire expressed by these anatomical features. Even the fur modification can obscure visual signals like piloerection or even entire parts of dogs' body (Hecht & Horowitz 2015). Hence, visual communication is incredibly challenging for some dogs.

Generally, individuals' proximity and direct interactions are required during visual communication (Wells 2009). When dogs encounter another conspecific, body size and body posture

are the first signals perceived and they provide the first information about the other individuals' intentions (Bradshaw & Rooney 2016) (Fig. 2).

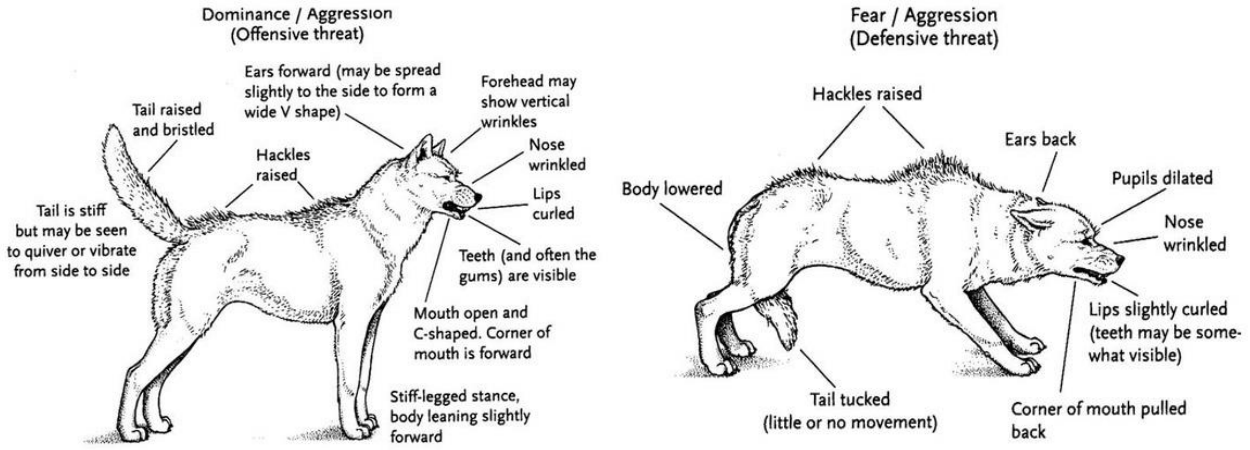

Figure 2: Two examples of body posture in dogs and wolves during an aggressive interaction (Federal Emergency Management Agency (FEMA) Community Emergency Response Team (CERT) training Module I on Animal Response).

Dogs can express confidence, alertness or threat by increasing their body size and increasing the tension of the muscles (Handelman 2012). The body size can further increase due to the piloerection of the hackles, this phenomenon occurs in several contexts and indicates an increase of the arousal (e.g. fear or surprise) or aggression and stress (Handelman 2012). Of course, dogs can also reduce size lowering their body and their tail, flattening back the ears. This behavior usually occurs to avoid conflicts or during stressful interactions (Handelman 2012; Hecht & Horowitz 2015). The tail is also crucial and its position and movements are used to convey information about the individuals' emotional state and intentions. For instance, when the tail is held high it communicates confidence, arousal or the dog's willingness to approach positively another individual for greeting or playing (Hecht & Horowitz 2015; Bradshaw & Rooney 2016). If the tail is held still expresses anxiety (Handelman 2012; Hecht & Horowitz 2015; Bradshaw & Rooney 2016) and, on the other hand, when it is held down or tucked between the back limbs it signals fear, anxiety or appeasement. Tail wagging is usually used to communicate information. A loose wag communicates friendliness or excitability, while fast movements express confidence when the tail is held high, anxiousness and nervousness if the tail is held low. There is also evidence that the direction of the wag is involved in communication; when dogs look at a positive stimulus, their tail moves more towards the right side, while if the dog looks at a negative stimulus the amplitude of the wag will be on the left side (Siniscalchi & Quaranta 2014). The movement of the tail depends on the contralateral side of the brain (Buxton & Goodman 1967) and therefore are consistent with Davidson's laterality-valence hypothesis (Davidson 2004).

In close-range social interactions, dogs can receive and manifest signals thanks to their facial expressions (Kaminski et al. 2017), the gaze, ears and mouth position. The eye region plays a decisive role in face recognition in dogs (Somppi et al. 2014; 2016), they usually stare at other individuals to threaten them and they avoid making eye-contact to appease and to decrease the tension (Handelman 2012; Bradshaw & Rooney 2016). In stressful or agonistic scenarios, dogs usually open their eyes wide to expose the sclera (Handelman 2012). Colored marking around the eyes occurring in some breeds (e.g. Dobermans and Rottweilers), could favor attention catching toward the eye region in order to facilitate the interpretation of a conspecific (Handelman 2012). This hypothesis seems to be supported by the fact that color information may be predominant with respect to brightness (Kasparson et al. 2013; Siniscalchi et al. 2017).

Together with the eyes, ears position represents an important signal. As mentioned above, it is necessary to consider breed differences in the morphology of the ears and the possibility to move them from the relaxed position (Hecht & Horowitz 2015). Typically, dogs can pull the ears back according to their arousal state: this can simply communicate appeasement or fear when flattened or pressed back. Ears kept forward, instead, are associated with interest and attention (Hecht & Horowitz 2015). Finally, a sideward position indicates a conflicting inner state.

The mouth acquires a particular importance when the dog is evaluating a potential threat. Dogs seems to look more at the mouth region in pictures representing threatening or neutral conspecific facial expressions (Somppi et al. 2016). It has been suggested that staring at a fix point could be interpreted as stalking by the receiver, who can focus its attention on the mouth to perceive more information to correctly interpret this expression (Siniscalchi et al. 2018b). Lips are also informative and the labial commissure can be drawn forward in agonistic display or pulled back to communicate stress.

Figure 3: a series of expressions presented in Bloom and Friedman (2013)

All these communicative behaviors can be described separately but, of course, they need to be considered in the context of all the others to interpret correctly the individual's emotional state.

1.3.2 Acoustic communication

Dogs are able to emit a broad vocal repertoire (Yeon 2007). Their vocalization are similar to wolves but dogs vocalize in a wider variety of social contexts. Dogs' vocal behavior clearly underwent considerable changes during the domestication process (Feddersen-Petersen 2000) and the effect of living in proximity to humans have been demonstrated in a 40-yearlong study on foxes (Gogoleva et al. 2008). As described for the foxes, dogs could have acquired the tendency to vocalize more to interact with humans. Hence, dogs developed novel forms of the pre-existing vocalizations and those acquired new acoustic and functional characteristics facilitating the communication with humans (Pongrácz et al. 2010). Humans are able to derive information from dogs' vocalizations not only about the signaler's physical characteristics but also about its emotional state (Farago et al. 2010b). Dogs vocalizations can be shaped according to the owner's response during every day interactions (Pongracz et al. 2010). It is interesting to notice how stray and feral dogs decrease significantly the production of vocalizations (Pongracz et al. 2010). Following, an overview of dogs' most common vocalizations (Fig. 4).

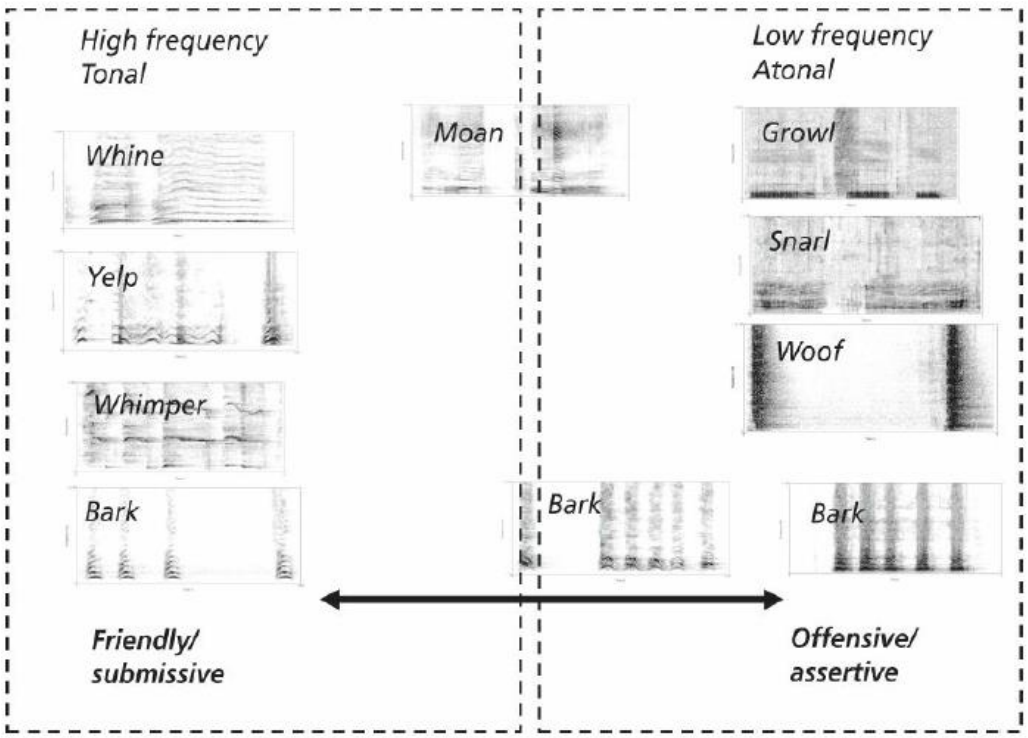

Figure 4: The vocal communication system in *Canis* (Morton 1977; Schassburger 1993; Feddersen-Petersen 2000). Sonograms supplied by Tamás Faragó and presented on Miklósi (2014).

The bark is surely the most typical vocalization in dogs. Previously thought to be a by-product of domestication, recent studies demonstrated the context-related acoustical features of barks (Feddersen-Petersen 2000; Yin & McCowan 2004; Péter et al. 2014), suggesting that they are means of communication for dogs. Barks are short, explosive and repetitive signals, with a highly variable acoustic structure. Barks are different between breeds and context (Yeon 2007). Wolf-related breeds (e.g. Shar-pei, Chow-chow) have a very low propensity to bark, whereas other breeds present a specific type of barking (e.g. hunting dogs). As mentioned above, barks carry various information about the signaler's physical characteristics, familiarity and inner state (Taylor et al. 2009; Péter et al. 2014), allowing dogs to differentiate not only between barks produced by different individuals in the same context (Molnár et al. 2009), but also between the different context in which they are produced (Péter et al. 2014). Indeed, the bark acoustic features vary according to the context; longer and low frequency barks are produced when a stranger approaches the dog, while high pitched ones are mainly emitted while in isolation (Pongracz et al. 2005b).

Similarly to barks, growls also convey information (Taylor et al. 2009; Farago et al. 2010a; Pongracz et al. 2010). Growls are low-frequency vocalizations mainly produced during agonistic interactions as a warning or a threatening signal (Handelman 2012). Curiously growls can occur also during a play session (Yeon 2007; Handelman 2012). Dogs can assess the body size of another individual by listening to its growl (Farago et al. 2010a). Moreover, they can discriminate between growls produced in different contexts (Farago et al. 2010b).

Another acoustic feature is the whine, which is an indicator of stress but it is also used to greet and for attention-seeking behaviors (Handelman 2012). Howls are for group cohesion while yelps and groans are signs of acute distress or acute pain (Faragó et al. 2014).

1.3.3 Olfactory communication

Dogs have a high olfactory sensitivity that allows them to access social and contextual information through the sense of smell (Hecht & Horowitz 2015; Wells et al. 2016; Jensen 2017). Body odors are used to send chemical signals specifically evolved to communicate with other individuals (Wyatt 2015). Glands that excrete signals are found throughout the dog's body. On the skin, we can find three types of secretory glands. First, the sebaceous glands in the hair follicles. They produce an oily, waxy substance, which when emits distinct odor. In dogs, large sebaceous glands are placed along the part of the neck, back and tail, especially in the tail gland area. Those present at the junction of the skin and mucous membranes of the lips, vulva, and eyelids are even larger. Second, the apocrine sweat glands are most numerous on the face, lips, and back and

between the toes. Apocrine glands become active at puberty. Third, the eccrine glands that function primarily for cooling. In dogs, they are located only on the footpads. Their secretion is influenced by exercise or heat stress, but can be also stimulated by the nervous system (Evans & De Lahunta 2013).

Olfactory communication is very efficient due to the persistency of some odors in the environment. The olfactory signals are released below the threshold of consciousness (Pause 2012) and they can occur without intentionality (Penn et al. 2006; Siniscalchi et al. 2016). On the other hand, dogs can mark the environment depositing urine, faeces or glandular secretions. Together with the deposition, dogs can produce other signals by the act of scratching. This enriches the chemical signal with additional secretions coming from the interdigital glands (Handelman 2012; Hecht & Horowitz 2015). Dogs also release their odor rolling on the ground, marking with the face and their entire body.

Dogs are able to discriminate conspecifics on the basis of their odor (Bekoff 2001) and they are able to distinguish between their own smell from that of others (Bekoff 2001; Horowitz 2017). During social interactions dogs show interest into exploring the face, the neck, the inguinal and the perianal areas (Handelman 2012; Bradshaw & Rooney 2016), all areas in which different type of glands are located. Dogs also investigate urine and faeces placed in the environment (Handelman 2012), both male and female dogs manifest a strong interest in unfamiliar urine, and they investigate it thoroughly (Lisberg & Snowdon 2009). Olfaction plays also an important role in mating. The female dogs communicate their reproductive status through urine marks and vaginal secretions (Pal 2003) and these odors are extremely attractive for other dogs (Siniscalchi et al. 2011).

Finally, it has been demonstrated that dogs are able to perceive the emotional state of a conspecific through odors (Siniscalchi et al. 2016; D'Aniello et al. 2018).

1.3.4 Tactile communication

This last form of communication is probably equally important for dogs but rarely studied. Tactile communication is used during agonistic interactions or to maintain social bonds (Overall 1997; Handelman 2012; Kuhne et al. 2012). Resting in close contact, placing the head over the shoulders of another dog and social grooming are all ways to maintain social cohesion. Although, these interactions are used rarely and for short period.

1.4 Dog-Human relationship

Dogs (*Canis familiaris*) shared a common environment with humans for presumably a longer time period than any other species (Bergström et al. 2020; Smith & Van Valkenburgh 2020). Dogs

are omnipresent in human lives and they are able to establish unique relationships with us. In the last 20 years, they became subjects of research and exciting studies. This interest toward dogs has transformed them into a fascinating model to which we can refer to when studying the mental abilities in animals. The research on their socio-cognitive abilities indicates that they are particularly skillful in communicating with humans in a variety of contexts and tasks (Bensky et al. 2013; Kaminski & Nitzschner 2013). In an incredibly resourceful review, Bensky et al. (2013) identified all the areas in which there has been empirical research on this species. In addition, the authors grouped the studies on dogs' cognitive abilities in two broad categories: physical and social cognition. This classification focused on different topics i.e. discrimination learning, object permanence, object learning, categorization and inferential reasoning, object manipulation, problem-solving, quantitative understanding, and spatial cognition. Hence, there is growing evidence that dogs' social skills are rather unique and probably contributed to turning them into "man's best friend". However, the way these abilities evolved and develop are all matters of lively debate in the field of comparative cognition.

1.4.1 Interspecific communication

Although communication is usually defined for intra-specific interactions, the concept can be generalized for individuals belonging to different species and it falls under the name of inter-specific communication.

Humans and dogs are mutually sensitive to different (visual, acoustic, or tactile) behavioral cues used to initiate a communicative interaction. Many experiments showed that the effectiveness of signaling is increased if the sender (the dog or the human) was able to direct the attention of the receiver to himself by the utilization of adequate attention-getting signals (ostensive signals). Due to the co-habitation (Kaminski & Nitzschner 2013) and the human-dog attachment (Topal et al. 2005; Siniscalchi et al. 2013; Previde & Valsecchi 2014) occurring in both species, dogs are able to perceive and understand cross-species signals and correctly respond to them.

For visual communication is the core of this study, it will be analyzed and described in a different section (see below).

Dogs and humans use vocal signals with communicative interactions that are able to produce changes in other species behaviors (Andics & Miklósi 2018). Humans often use a modified type of speech for verbal communication with their dog, the 'doggerel' (Hirsh-Pasek & Treiman 1982; Prato-Previde et al. 2006). This form of speech seems to be related to the 'baby talk' or 'motherese' used by mothers when talking to infants. When talking to children humans speak at higher frequencies, they talk slowly, use simple sentences, express affection and talk from the infant perspective. Mitchell

(2001) provided a detailed comparison between ‘motherese’ and ‘doggerel’. Dogs are able to perceive the emotional content of human vocalizations, especially when it comes to novel or ambiguous situations (Gaunet 2010; Colbert-White et al. 2018). It has been demonstrated that dogs can correctly match happy or angry faces with a vocalization expressing the same emotional valence (Albuquerque et al. 2016). Human vocalizations are being processed in an asymmetrical way in the dog brain, the right hemisphere is engaged in the analysis of vocalizations with a negative valence and the left hemisphere in the analysis of positive ones (Siniscalchi et al. 2018a). Dogs also actively use vocal signals to solicit care from the owner and solicit his or her attention. They mostly use barks, growls or whines while they reserve long distance calls to conspecifics (Feddersen-Petersen 2000). Humans are able to receive information through dogs' vocalizations; for instance, people can assess the signalers’ body size by listening to its growls (Taylor et al. 2008) and they can perceive the emotional state of the dog (Pongracz et al. 2005b; Faragó et al. 2017). Interestingly, the human's ability to categorize dogs' vocal signal is independent from previous experiences and the same performances have been collected from adults, children and blind people (Pongracz et al. 2005b; Molnár et al. 2010; Pongrácz et al. 2011).

Dogs are able to recognize people by their odor and associate humans' odors with previous experiences. When presented with veterinary sweat odor they show an increase of their arousal state (Siniscalchi et al. 2011). When investigating the human body, dogs prefer the face and the upper limbs (Siniscalchi et al. 2016).

Trained dogs can been used to track people and numerous studies (i.e. Kalmus 1955; Szinak 1985) have their ability to differentiate humans by their scent. Some authors have suggested that dogs might be able to detect the presence of a human even in absence of a track (Syrotuck 2000), while still being able to trace human-laid trails (Wells & Hepper 2003). Following the literature, Vyplelová et al. (2014) hypothesized the existence of odor fallout, the release of a human’s odor onto an untouched object, in human subjects. They suggested that holding a hand above an absorbent surface would produce enough scent to be matched in a detection test by service dogs. Fascinatingly, their results seem to confirm this theory.

Dogs can discriminate between the body odors of two identical twins living in the same environment (Pinc et al. 2011) and even respond to metabolic changes of their owner (Chen et al. 2000). Recent studies demonstrated that dogs are even able to perceive humans' emotion through the scent and they react accordingly (Siniscalchi et al. 2016; D’Aniello et al. 2018).

Finally, tactile communication is a typical feature of human-dog communication. Contrary to common knowledge, some dogs can hardly tolerate physical contact and display withdrawing behaviors, other show discomfort only if a specific part of the body is touched (De Keuster et al.

2006; Luescher & Reisner 2008). The familiarity with the human is surely influencing the dogs' response to tactile interaction (Kuhne et al. 2012).

1.5 Individual behavior

Schleidt (1976) noted that some individuals belonging to different species presented a variation in the expression of some behaviors. It was assumed that an individual variation normally exists within the species, just as it happens for phenotypic traits. Individual behaviors were therefore considered an interaction between genes and environment, and some individuals are more similar than the others are. Thirty years later, Jones and Gosling (2005) defined for the first time the 'personality traits'. Those traits are characteristics of adult individuals that describe and account for consistent patterns of feeling, thinking and behaving across contexts and time.

In the last 30 years, it became clear that personality exists in many species, from primates to cephalopods (Gosling 2001). Personality can have a large fitness consequence (Réale et al. 2007). It can have a clear genetic basis, and can be heritable (Spady & Ostrander 2008). Often it is related with physiology or neuroendocrine system (Careau et al. 2008) or to other characteristics of individuals (e.g. age) and their environment (e.g. predator risk) (Gosling 2001).

1.5.1 Personality in dogs

The concept of animal personality has been revitalized by wide interest and the findings of individual behavioral differences in animals, consistent over time or across situations, have proven to be useful in the understanding of the evolution of behavior (Benus et al. 1991; Wilson et al. 1994) as well as in applied animal behavior (Le Scolan et al. 1997; Slabbert & Odendaal 1999; Grignard et al. 2001).

The results of personality studies in animals have revealed suggestions of human personality traits in different species of animals. The shyness–boldness axis, a fundamental dimension in humans that can be defined as an individual's general tendency to approach novel objects and willingness to take risks (Kagan et al. 1988), has been studied and detected in a range of species of different taxa, e.g. octopus (Mather & Anderson 1993), fish (Wilson et al. 1993), cat (Feaver et al. 1986), and primate (Stevenson-Hinde et al. 1980). For humans, there is today a consensus for the existence of five major human personality dimensions; the ''Big Five'' (Digman 1990; Goldberg & psychology 1990; Costa Jr & McCrae 1992). The Big Five includes the traits Extraversion (associated with sociability and activity), Neuroticism (anxiety and moodiness), Conscientiousness (competence and self-discipline), Agreeableness (trust and compliance), and Openness (fantasy and ideas). There have been attempts to apply this model to nonhuman animals, with some success. Gosling and John (1999)

found support for the Big Five in a review including data, mostly from exploratory analyses, from 12 different species.

One species that is interesting in the study of animal personality is the domestic dog and numerous evaluation methods have been used to help understand dog behavior (e.g. Humphrey 1934; Herron et al. 2009; Turcsán et al. 2011). These methods are usually used to predict adult behavior in puppies (Robinson et al. 2016), to test aggressiveness and other problematic behaviors (van der Borg et al. 1991), or to test working dogs (Foyer et al. 2016).

Importantly, however, as Jones and Gosling (2005) pointed out, the vast majority of dogs tested were in working contexts, and pet dogs, with a fuller representation of dog breeds, were relatively neglected. Also, they mention that few studies investigated dogs over the age of 4 years, so we know little about how aging affects personality traits. The situation is similar with neutering, although previous studies suggest that there are several personality differences between intact and neutered dogs (Podberscek & Serpell 1996). Other studies have started to compensate for this imperfection and investigated the associations between dog behavior and independent variables. For example, Bennett and Rohlf (2007) studied the relationship between demographic variables (several were unusual, like the amount of experience the owner reported having with dogs, owners' age, family size, etc.) and dog behavior with a questionnaire survey in 413 adult individuals. They found that problematic behaviors were associated with numerous owner and dog characteristics, although most differences were small. For example, the number of people in the household positively correlated with aggression and disobedience. Dogs acquired from a pet shop had more problematic behaviors. However, involvement in professional training courses and other shared activities decreased the occurrence of problematic behaviors (Jagoe & Serpell 1996; Kobelt et al. 2003).

Two types of questionnaire are employed for these studies: situational (e.g. Hsu & Serpell 2003) or adjective based questionnaire (e.g. Ley et al. 2008). Usually, the owner or a familiar person are asked to characterize the behavior of their pet.

Another method to assess the personality is the behavior test battery. Which allows the experimenter to observe the focal animal through a series of different scenarios (e.g. Svartberg 2002).

2. Study I

A Wolfdog Point of View on the Impossible Task Paradigm

Andrea Sommese [a,b] , Kamila Nováková[b], Naděžda Fiala Šebková [b], Luděk Bartoš[a,b]

[a] Department of Ethology, Institute of Animal Science, Přátelství 815, 104 00 Praha-Uhříněves, Czech Republic

[b] Department of Ethology and Companion Animal Science, Czech University of Life Sciences Prague, Kamýcká 129, 135 11 Praha 6 - Suchdol, Czech Republic

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Abstract

In order to elucidate the role of domestication, we used the impossible task paradigm to test Czechoslovakian Wolfdogs with a known proportion of 'wolfblood' in their DNA and, as a control group for our subjects, we used German shepherd dogs. We hypothesized that the difference between wolves and domestic dogs is based on genetics and modified by obedience; if so, the looking back performance of the subject should be linked to its proportion of wolf-genes. To prove that, we observed 73 Czechoslovakian Wolfdogs, and 27 German shepherd dogs, and analyzed their human-directed gazing behavior during our test. Our apparatus consisted of a glass container placed upside-down over a small amount of food. The test proceeded with three solvable trials, in which the subject could obtain the food by manipulating the container, followed by an unsolvable one in which the container was fixed onto the board. Our results suggest that there is no significant correlation between the probability of looking back in Czechoslovakian Wolfdogs and their proportion of 'wolf blood'. However, the probability of looking back was higher in German Shepherd dogs than in Czechoslovakian Wolfdogs (odds ratio = 9.1). German Shepherd dogs showed not only a higher frequency of looking back, but also the duration of their looks was longer.

Introduction

Dogs (*Canis familiaris*) shared a common environment with humans for presumably a longer time period than any other species (Frantz et al. 2016; Freedman & Wayne 2017) and a flourishing research on socio-cognitive abilities indicates that they are particularly skillful in communicating with humans in a variety of contexts and tasks (Bensky et al. 2013; Kaminski & Nitzschner 2013). This evidence has triggered an on-going debate regarding how dogs' socio-cognitive and communicative abilities originated and evolved.

The "domestication hypothesis" proposes that the processes of artificial selection on the wild ancestor of dogs is the key that have led to genetic changes that allowed dogs to develop socio-cognitive skills and, therefore, to effectively communicate with humans (Hare et al. 2002; Miklosi et al. 2003; Hare & Tomasello 2005; Hare et al. 2010). This theory is based on experiments showing that 6 weeks old pups can already understand human communicative cues to locate hidden food (Agnetta et al. 2000; Hare et al. 2002; Riedel et al. 2008; Dorey et al. 2010) and studies where dogs outperformed wolves raised by humans in certain cue-following tasks (Hare et al. 2002). Further insight on the evolution of dogs' communication with humans comes from research on the New Guinea singing dog (*Canis hallstromi*) (Wobber et al. 2009), Australian dingoes (*Canis dingo*) (Smith & Litchfield 2010a; Smith & Litchfield 2010b) and foxes (*Vulpes vulpes*) (Hare et al. 2005). Altogether, these studies seem to point to the importance of domestication in dogs' ability to engage in inter-specific communication with humans. Finally, to tackle the 'domestication effect' other domestic species have been observed with mixed results. Firstly, cats (*Felis catus*) (Miklosi et al. 2005); secondly horses (*Equus caballus*) (Malavasi & Huber 2016; Alterisio et al. 2018) and finally goats (Nawroth et al. 2016).

On the other hand, the 'Two-Stages Hypothesis' advocates that domestication is not enough to account for dogs' communicative skills. Udell et al. (2010) proposed that human interactions in a sensitive period leads the dog to accept the human companion but also the learning process and the living conditions are crucial. Undergoing specific training programs can affect a dog's cognitive performance when interacting with both humans and the environment (Topal et al. 1997; Bentosela et al. 2008; Marshall-Pescini et al. 2008; Gacsi et al. 2009a; Gacsi et al. 2009b; Marshall-Pescini et al. 2009; Reid 2009; Udell et al. 2010; Barrera et al. 2011; Horn et al. 2013; Marshall-Pescini et al. 2013; Merola et al. 2013). Among others effects, researchers evaluated how intensive training affects communicative skills and problem-solving abilities. Highly trained dogs are more proficient in using human cues than untrained dogs (McKinley & Sambrook 2000; Range et al. 2009); however, Cunningham and Ramos (2014) obtained no evidence that intensive training improved performance

on a cue-following task. Nevertheless, when compared to untrained dogs, trained ones appeared to be less inclined to follow their owners' misleading indications in a food choice task (Prato-Previde et al. 2008), suggesting that training experiences could reduce dependency and favor independent decision making. Ontogeny seems to play an important role and could represent a key piece in the puzzle. Lazarowski (2015) compared pet and research dogs' performance on object-choice tasks when guided by humans. Their results showed that pet dogs were successful above chance level, while research dogs were not. In yet another study using the same paradigm, D'Aniello et al. (2017) compared kennel dogs with limited human interaction to pet dogs (living with human families since puppyhood). They demonstrated that pet dogs outperform kennel dogs, suggesting that the ontogenetic development represents a turning point. In addition to that, when wolves were raised with intensive socialization with humans, they outperformed dogs in following human social cues (Udell et al. 2008).

In the studies mentioned above dogs and wolves can obtain a reward by following human signals. The activity of the experimenter inevitably catches the dog's attention. It is possible to change these conditions and create an experimental setting in which the human researcher is inactive in order to observe whether the dogs will choose to refer to humans or not. This condition has been broadly observed with the impossible task paradigm. Miklosi et al. (2003) observed 9 pet dogs and 9 human-socialized wolves coping with an "unsolvable task," where trapped food could not be obtained through individual effort. The dogs quickly gave up and gazed at a nearby human both sooner and more frequently, while the wolves persisted with the task.

The so-called 'looking back behavior' is a singular behavior observed in both dogs and wolves and it has been widely discussed. The expression of this behavior in dogs seems to be related to several problem-solving tasks, such as: the detour task (Pongracz et al. 2005a), object choice paradigm (Viranyi et al. 2008), in situations where dogs witness an object of desire being hidden (Polgárdi et al. 2000; Gaunet & Deputte 2011) or placed out of reach (Barrera et al. 2011; Jakovcevic et al. 2012), or when they are confronted with an unknown and potentially scary object (Merola et al. 2012a). Indeed, wolves were found capable of following both human and conspecific gaze from behind a barrier, as well as human gazing into distant space (Range et al. 2011; Range & Viranyi 2011). A recent study also suggests that dogs and wolves seem to gaze towards humans in a similar way (Heberlein et al. 2016). Ultimately, dogs' and wolves' close relatives, coyotes and dingoes, have been found to engage in human-directed gazing under some conditions (Udell et al. 2008; Udell & Wynne 2008; Udell et al. 2011; Udell et al. 2012; Smith & Litchfield 2013). Altogether, these studies provide evidence that dogs use gaze and gaze alternation to communicate with their human partners when confronted with a distant or inaccessible object or food source. The occurrence of the gaze

alternation should suggest that this behavior it is both intentional and referential (Prato-Previde & Marshall-Pescini 2014).

Bentosela et al. (2008) showed that learning and reinforcement contingencies play an important role in shaping looking behavior in dogs enhancing this behavior significantly. Marshall-Pescini et al. (2009) compared untrained dogs and dogs trained in two substantially different activities (i.e., agility and search and rescue training) using an 'impossible task paradigm'. It emerged from their results that the untrained and trained dogs were comparable in interacting with the apparatus, but they differed in their human-directed gazing behavior. Agility-trained dogs gazed longer at humans than the search-and-rescue and untrained dogs. Varieties of studies using the same paradigm have confirmed that dogs' experience with humans might affect their looking back behavior. For instance, dogs kept in a kennel with reduced exposure to humans from birth display a higher latency and a shorter duration of the looking back behavior in an unsolvable task paradigm when compared to pet dogs (D'Aniello & Scandurra 2016). In another 'impossible task' study, guide dogs for visually impaired people did not differ in gazing behavior from the untrained group (Gaunet 2008). However, it is worth to mention that Scandurra et al. (2015) showed that trained guide dogs gaze toward humans for less time and with a higher latency when compared to working dogs and untrained dogs.

Age seems to also have a relevant effect in this paradigm; in fact, older dogs expressed the tendency to gaze at humans more than younger dogs did (Passalacqua et al. 2011b; Persson et al. 2015).

How genetics affect the development of the behavior is also a matter of interest. Persson et al. (2015) conducted a study on a large population of beagles. Within their framework, the 'impossible task' demonstrated that social interactions (i.e. frequency and duration of both looking and physical contact with the test leader) were significantly heritable tracts, suggesting that there are genetic components of such behaviors. Moreover, an association between owner-directed gazing behavior in the unsolvable task and polymorphisms in the dopamine receptor D4 gene was demonstrated; dogs carrying a shorter allele looked at their owner more frequently, for longer periods of time, and earlier than dogs carrying a longer allele (Hori et al. 2013). Thus, in addition to the ontogenetic component, gazing behavior appears to have a clear genetic basis. Within the setup used for the 'impossible task' human-directed gazing is not the only interesting behavior observed, another effect to take into account seems to be persistency.

More than 30 years ago, Frank and Frank (1985) already noted that after presenting dogs and wolves with a puzzle-box task, the wolves (*Canis lupus*) approached the problem until they either managed to solve it or the trial ended. Conversely, dogs investigated the puzzle box and, after experiencing that the food was not easily accessible, displayed solicitation and begging behaviors

toward the nearby experimenter. As reviewed in a recent study (Rao 2018, in press) dogs and, wolves differ strongly in their problem-solving success in various paradigms (Frank & Frank 1982; Frank et al. 1989; Miklosi et al. 2003; Udell et al. 2008; Hiestand 2011; Marshall-Pescini et al. 2015; Range & Viranyi 2015; Udell 2015; Heberlein et al. 2016; Marshall-Pescini et al. 2017; Rao et al. 2018). Generally, wolves are more focused on the problem, more persistent and also faster and more successful at obtaining food from puzzle boxes (Frank & Frank 1982; Udell 2015; Rao et al. 2018). These differences have partly been attributed to the different ecological niches they live in (Viranyi et al. 2008; Range & Viranyi 2013; Marshall-Pescini et al. 2015; Werhahn et al. 2016; Marshall-Pescini et al. 2017). In a recent study, Marshall-Pescini et al. (Marshall-Pescini et al. 2017) tested similarly raised adult wolves and mixed breed dogs, pet dogs and free-ranging dogs. In their study, wolves were more persistent than all the dog groups. Regardless of socialization or species, less persistent animals looked back sooner and longer. Free-ranging dogs, despite little exposure to dog-human communication, behaved similarly to other dogs. Together, these results might suggest that basic differences between wolves and dogs in motivation and exploration may override differences in human-directed behavior when animals are equally socialized, and that once the human is considered a social partner, the looking behavior occurs easily.

Taken together, these results show that human directed gazing and looking back appear to be the result of a complex combination of genetic and environmental factors. The predisposition for an increased likelihood of gazing was probably unconsciously selected during the domestication since eye-to-eye contact forms the basis of any communicative act between humans and dogs. Breed selection additionally shaped this behavior, resulting in noticeable differences between breeds. It is important to keep in mind that Passalacqua et al. (2011b) already compared breed groups using the impossible task paradigm. In their study adult dogs in the hunting and herding groups gazed at humans for a longer time than those dogs belonging to the molossoid and primitive groups. The same result was then confirmed in puppies already at 4.5 months.

To further investigate the issue, we used a modified version of the classic ‘impossible task paradigm’ to observe Czechoslovakian Wolfdogs’ behavioral response. These dogs represent a unique opportunity to investigate the effect of domestication and ontogeny on the development of dogs’ communication with humans. Czechoslovakian Wolfdogs are the result of a military experiment conducted in Czechoslovakia in 1958. The aim of the experiment was to create a new breed of dogs showing the good sides of the German shepherd dogs (temperament and controllability) but also the strength of a wolf. The first cross-breeding involved a female Carpathian Wolf named Brita and a male German shepherd dog called Cézar. Only four additional crossings with wolves happened since then, specifically in: 1960, 1968, 1974 and 1983. In the year 1999 the breed was

officially recognized with its own standard by the FCI (Fédération Cynologique Internationale). After the official recognition (standard FCI n° 322/3.09.1999) any crossing with Wolves has been strictly forbidden (Smetanova et al. 2015; Caniglia et al. 2018).

Given previous results, we predicted that more wolf-like Wolfdogs, in other words dogs with a higher percentage of 'wolfblood', would be less prone to use human-directed gazing (Konno et al. 2016) and would show a higher persistence than others. Moreover, according to previous findings showing the effect of life experiences on the looking back behavior, we expected older and more obedient dogs to show this behavior more than younger and untrained dogs. The degree of obedience was assessed subjectively with a questionnaire submitted to the owner prior to testing (see below).

In addition, we decided to compare the Czechoslovakian Wolfdog to its sister breed: the German shepherd.

German shepherds dogs generated from a herding dog broadly distributed in Europe prior 1859 (Talenti et al. 2018). Around 1890, three lines were selected which brought to us the German shepherd, the Belgian shepherd and the Dutch shepherd. In 1899 a dog named Hektor Linksrhein (subsequently changed into Horand von Grafrath) was declared to be the first German shepherd dog. Horand was then bred with other dogs and his progeny was selected and inbred to cement the traits being sought in the breed. Additionally, 4 wolves were crossed with the population.

The two breeds appear to share some commonalities, with the Czechoslovakian Wolfdogs presenting the most recent product of the Dog x Wolf crossing. Based on this and previous studies, we then hypothesized an effect of the breed with German shepherds engaging more and for a longer time in human-directed gazing and, therefore, being less persistent.

Material and Methods

Subjects

A total of 121 Czechoslovakian Wolfdogs and 36 German shepherd dogs were recruited for the study through personal contacts and dog shows held in Czech Republic. Forty-eight Czechoslovakian Wolfdogs and 8 German shepherd dogs were excluded for they did not reach the set criteria or they were not interested in the food provided (small pieces of chicken meat). The Wolfdog group included 40 males and 33 females, while the German shepherd group included 19 males and 9 females. All the dogs were kept as pets and their living conditions were evaluated through the questionnaire (see below).

Apparatus and testing area

The apparatus consisted of a glass food container (21x15x7 cm), placed on a rectangular wooden platform (80 × 50 cm), previously used on dogs (D'Aniello et al. 2015) and comparable to the apparatus used in previous studies (Marshall-Pescini et al. 2009; Passalacqua et al. 2011b). The lid was screwed onto the platform, whereas the container was placed upside down on the tracks of the lid during the solvable trials and was locked during the unsolvable one. We ascertained the food palatability of the dogs by administering small quantities of food to them before the test.

The two breeds were always kept on a long lead during the whole testing time due to the aggressiveness of some subjects and the outdoor conditions. However, the dogs were free to move in the testing area and the lead did not representing a constraint for them. The lead was only kept as a preventive measure for the experimenter and it was not hold tight at any point during the experiment.

We collected our data during dog-shows or similar events. The dogs were tested in an unfamiliar outdoor location. Due to the nature of the testing area there were some situations we were not able to prevent or predict (e.g. horses passing by), therefore we discarded those subjects and their tests in which a strong disturbance occurred.

Questionnaire

For this study, we submitted a questionnaire to the owners prior to testing, in order to gather useful information about the subject's age, sex, living conditions, perceived obedience and even the gender of the owner.

Here we will list the entries of Table 1. Number of dogs/wolfdogs owned is the mean number of individuals owned by the same person/group of people. Time spent with the owner, meaning the average time (expressed in hours) that the owner spends with his/her dog companion through the whole day and during the night. Perceived obedience, we asked the owners to quantify (scoring from 1 to 5) subjectively the obedience of their pets asking whether the dog always responds to the commands (1), if it does it only at home, almost never or if it does not listen (5). Thanks to the unique, and recent, history of the Czechoslovakian Wolfdog breed, we were also able to collect an important piece of information. All the Wolfdogs tested are included in the Wolfdogs database (http://www.wolfdog-database.com) from which is possible to retrieve precious data about the individuals. For our study, we considered the theoretical 'wolfblood' percentage which indicates the shortest distance of generations to Carpathian Wolf x German shepherd and total deposits in pedigree. Nowadays, Czechoslovakian Wolfdogs have a wolf blood percentage that goes from 25-30%. As we mentioned before, no fresher wolf blood is included, as these dogs are not legally allowed to be bred

with wild wolves. All the dogs we tested had a pedigree and they belonged to lines of which we have the full track of their ancestors with initial genetic analysis of part of them (Cilova et al. 2011).

Variable	**C. Wolfdogs (total)**		**G. shepherd dogs (total)**	
	Mean	**STD Error**	**Mean**	**STD Error**
Age of the dog (months)	28.59	2.54	49.38	5.75
Number of dogs owned	1.73	0.15	4.86	1.41
Number of wolfdogs (if more than 1)	0.40	0.06	/	/
Perceived obedience	2.61	0.08	1.93	0.23
Proportion of 'wolfblood'	24.37	0.87	0	0
Eats x day (number of meals)	1.74	0.09	1.50	0.13
Time spent with the owner (hours x day)	10.83	0.60	8.50	1.81
Number of puppies in the litter	6.15	0.29	5.93	0.78
Weaning (counted in days)	46.33	2.95	37.50	7.42
Class fixed factors				
Variables	**Levels**			
Sex of the owner	Male, Female			
Living conditions	Apartment, garden, kennel, other			

Table 1: Variables used in the analysis according to breed for the dogs analyzed.

Procedure

The test consisted of three "solvable" trials in which the animals could obtain the food by manipulating the container, followed by an unsolvable one in which the container was fixed onto the wooden board. The subjects were tested with an unfamiliar experimenter and the owner present in the area. A third person was filming the tests with a video camera Canon XL-H1 3CCD HD Camcorder.

Figure 5: testing area with the Owner on the left and Experimenter on the right. The dog was held very loosely on a long lead for every trial.

The owner brought the subject close to the apparatus. For security and practical reasons, the animal was held by its lead for the duration of the entire test. Then the owner and experimenter stood approximately 50 cm away on both sides of the board (Fig. 5). In all the trials, the owner and an unfamiliar experimenter were maintaining an identical position standing at both sides of and one step back (30 cm) from the wooden board on which the container was placed. During the entire test period, the two people looked straight ahead and ignored the dog. Prior to the beginning of each trial, the experimenter held food in his hand, presenting it to the animal and drawing its attention by calling its name. Once the subject was responsive to the call, the experimenter baited the apparatus by placing the food on the wooden board and covering it with the container. The dog was finally allowed to move, while still on the leash, around the apparatus and within the testing area.

The solvable trials were terminated as soon as the individual obtained the food or, if not successful, after 60 seconds. At the end of each solvable trial, the owner called the subject back while the experimenter re-baited the apparatus. Trials were presented one after the other with no interruption. Only the dogs that were able to reach the food in at least two solvable trials were considered motivated enough and were tested for the last unsolvable one. The unsolvable trial lasted 60 seconds and consisted of the same apparatus but with the container fastened to the wooden board.

Behavior analysis

We analyzed several mutually exclusive behaviors. Each behavior was measured using Noldus Observer XT10. Our ethogram drafted following previous studies (i.e. Scandurra et al. 2015), and it is presented in Table 2. In other studies using the same paradigm, another type of behavior was coded: the gaze alternation (Miklosi et al. 2003; Marshall-Pescini et al. 2009); intended as the looking toward the apparatus immediately followed by looking at the person (or vice versa). However, this behavior was never observed in our study, hence, we did not code it.

Behavior	**Description**
Start (latency)	The time elapsed between the moment the owner releases the dog (i.e. the moment the owner's hand leaves the dog's collar) and the first time the dog touches the food container (with a paw or the muzzle).
Looking back (frequency)	The dog's head is oriented towards one of the humans' upper body but the dog is not in contact or walking towards the human. All looks (referential and non-referential) have been recorded.
Looking back (latency)	The time from the beginning of the test until the first look.
Looking back (duration)	How long the look back event lasted.
Interaction with the apparatus	The time spent interacting with the apparatus during the solvable trials (i.e. from the 1st to 3rd) (i.e. any part of the body of the dog is in contact with apparatus or within 10 cm from it) when the dog's head was oriented towards the food container.
Away from the apparatus	The time spent away from the apparatus (i.e. the dog's head and/or paws are at least 10 cm away from the food container).
Physical contact	The body of the dog is in contact with the caretaker or the experimenter (i.e. rubbing, nosing, licking, pawing a hand or leg or jumping up).
Persistency	Recorded only during the last and unsolvable trial. The time the dog spent trying to obtain the food inside the container (i.e. grasping, scratching, nosing, biting and pushing the experimental apparatus).
Others	Marking, barking, growling, etc.

Table 2: Behaviors coded during the test

Each owner provided supplementary demographic information about themselves and the dog. The participants completed the questionnaires before or after the test.

Statistical analyses

The statistical analyses were conducted for all data collected and were implemented in SAS System version 9.4 (SAS Institute Inc.). We used a multivariate General Linear Mixed Model approach (GLMM, PROC GLIMMIX or PROC MIXED, with Kenward-Roger degrees of freedom method). To account for the use of repeated measures on the same individuals, appropriate analyses were performed using a mixed model with individual dogs nested within breed as a random effect. We constructed the GLMMs by entering first those factors expected to have an effect on the dependent variables: categorical variable breed (Czechoslovakian Wolfdogs and German shepherd dogs), countable variable obedience (ranging from 1 to 5) and then checking all models with addition of the factors which could also affect the result (Table 1). The significance of each fixed effect in the GLMMs was assessed by the F-test. Any factors which did not add to significance ($P > 0.05$) were dropped from the model and will not be mentioned any further.

The analysis was made in two basic steps. First, with binary dependent variable "looking back" (Yes / No), we used PROC GLIMMIX for binary distribution modelling the probability that the canine looked back ("Yes"). Link function was logit and error terms were binomial in the GLMMs. Since the models did not converge, we replaced the default method and chose METHOD=LAPLACE instead, as suggested by Kiernan et al. (2012), with containment degrees of freedom method. Initially, we checked the probability of looking back across all Trials (Trial 1, Trial 2, Trial 3, and experimental trial 4) in the form of an interaction between breed and trial. Then we estimated the probability of looking back in the experimental trial 4 only. Because in the experimental trial each dog entered the model only once, only in this case we applied GLMM as a fixed-effects model. Second, to verify that there were differences between the breeds either in the number of looking back events, their duration, and the latency with which the dog looked back, we applied PROC MIXED on the data when the individual did look back in any of the trials. In three separate GLMMs, the number of looking back events, their duration, and the latency with which the dog looked back, entered the model as a dependent variable.

To compare whether the chance of a certain event occurring differed in the two breeds, we computed the odds ratio (Stokes et al. 2012). An odds ratio greater than 1 implies that the event is more likely to occur in the German shepherd dogs compared to Czechoslovakian Wolfdogs.

Results

The interaction between breed and trial has shown a variation in the probability of looking back between the breeds and the trials (PROC GLIMMIX for the interaction breed*trial, $F_{(7, 301)}$=15.08, P<0.0001, Fig. 3).

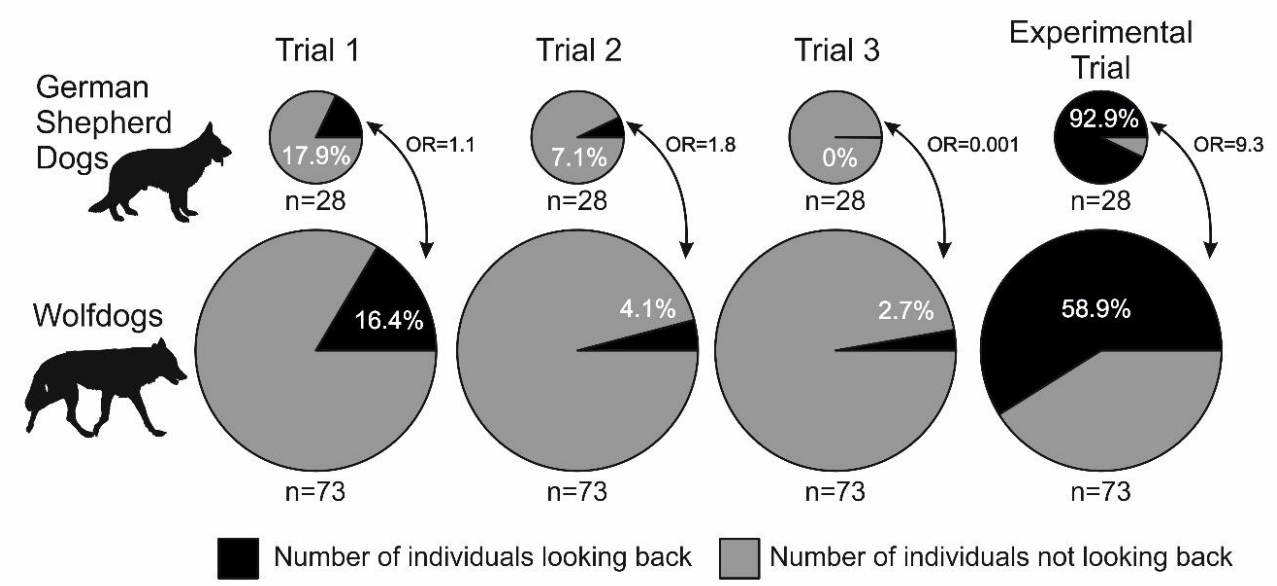

Figure 6: proportion of individuals looking back (%) according to Breed and Trial. (n = number of individuals involved, OR = odds ratio). A value greater than one implies that the looking back is more likely in the German shepherd dogs than in Wolfdogs.

In three trials (Trial 1, Trial 2, and Trial 3), there was a minimal but not significant difference between German shepherd dogs and Czechoslovakian Wolfdogs in the probability of looking back. There was no effect of proportion of Wolfblood on the probability of looking back among Wolfdogs (calculated with PROC GLIMMIX for Wolfdogs only, $F_{(1, 3)}$=0.96, P=0.400). We expected an effect of the breed, which appeared the case (PROC GLIMMIX, $F_{(1, 4)}$=8.17, P=0.046). On the other hand, in contrast to the second prediction advanced, we investigated other possible effects on the occurrence of the 'looking back' behaviors, as suggested from previous studies (D'Aniello & Scandurra 2016). None of them (i.e. living conditions, sex of the dog or of the owner, etc.) yielded significant results. We found no effect of perceived obedience nor of any other factor listed in Table 1 in all GLMMs. Thus, in the crucial experimental trial (the fourth one), the probability of looking back was significantly higher in German shepherd dogs than in Wolfdogs (t=2.82, P=0.005, odds ratio = 9.312). When looking back across all trials and focusing mainly on the experimental one, German shepherd dogs had a higher frequency of looking back events (PROC MIXED, $F_{(1, 404)}$=7.88, P=0.005, Fig. 7a) and the events lasted longer with them (PROC MIXED, $F_{(1, 404)}$=7.10, P=0.008, Fig. 7b). On the other

hand, the two breeds did not differ in the latency to look back (PROC MIXED, $F_{(1, 67.1)}$=0.00, P=0.998, Fig. 7c) in time spend interacting with the apparatus (PROC MIXED, $F_{(1, 404)}$=0.19, P=0.663, Fig. 7d).

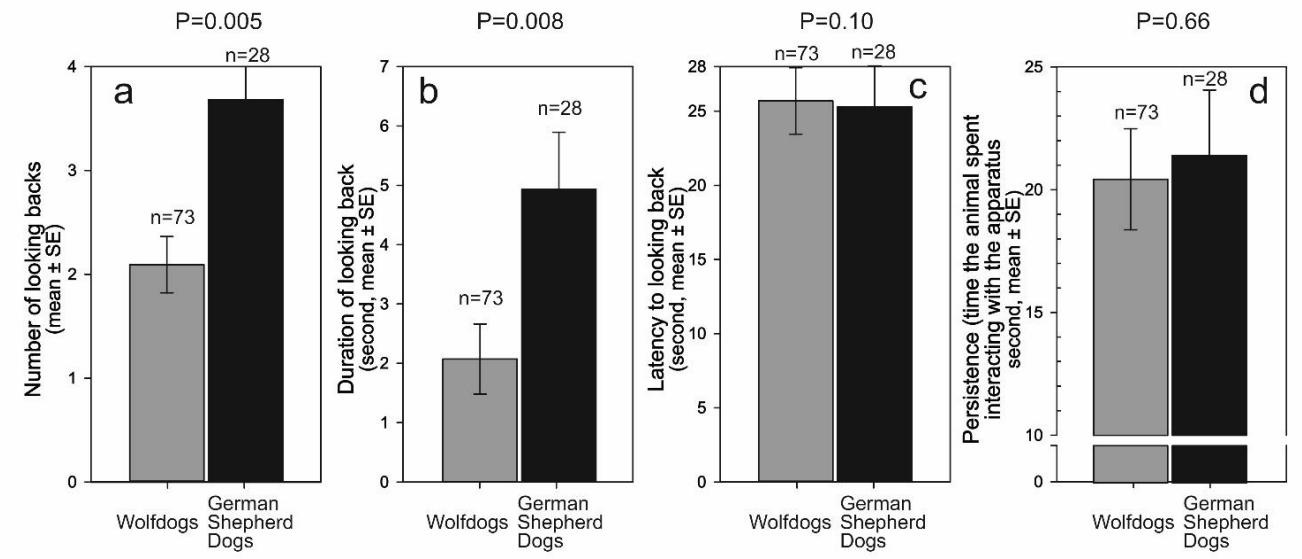

Figure 7: comparison between German shepherd dogs and Wolfdogs during the experimental trial. Comparison according to the number of looks back (a), duration of looks back (expressed in seconds, b), latency to look back (expressed in seconds, c), and persistence (expressed in seconds, d).

Discussion

The aim of the current study was to explore the potential effects of breed and development on dogs' human-directed communicative behavior in an unsolvable task. Czechoslovakian Wolfdogs did not show any difference during the trials.

While the concept of wolf-blood is still purely theoretical, our first hypothesis took it into account: however, no effects or any intragroup differences were found as either the percentage was too low, or there is no wolf-blood effect at all. Most of our Wolfdogs belong to the Czech population, therefore we would generally expect a low genetic variability. Further genetic tests would be needed to confirm the latter assumption and the reliability of the 'wolf-blood' variable. We did not find any real support for the presumption that looking back in Wolfdogs would be modified by the level of obedience and time the owner had spent training and living with the subject as shown for domestic dogs (Marshall-Pescini et al. 2008; Marshall-Pescini et al. 2009; Scandurra et al. 2016). We also did not find any age effect suggested in previous studies (Passalacqua et al. 2011b; Persson et al. 2015). However, this inconsistency could be caused by the fact that all the dogs used in our study were

relatively young. Finally, in contrast to our prediction and based on previous findings (D'Aniello & Scandurra 2016), the Wolfdogs with limited exposure to humans, such as those living outside the home environment, interacted using gazing behavior towards humans equally to those living as members of human families. As it stands so far, we did not find any strong ontogenetic effect in our sample. One possible interpretation could be that the training method used by the owners was not consistent in our sample. During our tests, we have noticed a strong difference in the approach and manners used to deal with Wolfdogs, but we collected and took into account only subjective observations (i.e. using the questionnaire).

As expected, when compared to the Czechoslovakian Wolfdogs, the probability for German shepherd dogs to look back during the fourth impossible trial was higher and also the duration of this behavior was longer. Not only that, but German shepherds were 9.3 times more likely to gaze toward the nearby human than the Wolfdogs. Nevertheless, the latency of expressing this behavior was not significantly different.

In both the FCI and AKC (American Kennel Club), but also the genetic clustering proposed by Parker (2004) categorization, German shepherd dogs are included in the herding group. As expected from literature (Passalacqua et al. 2011a), these dogs are more likely to gaze at humans for longer periods of time when compared to other breed groups (i.e. molossoid and primitive). Interestingly, according to the FCI categorization, Czechoslovakian Wolfdogs belong to the same group as German shepherd dogs. Instead, Wolfdogs belong to the foundation stock service group within the AKC framework. We did not find any genetic clustering indications on our focal breed in previous studies.

In both groups, we did not observe any significant preference between the experimenter and the owner in the experimental trial as found in another study (D'Aniello & Scandurra 2016). Such result does not necessarily mean that such preference does not exist; in the 'impossible task paradigm', preferences for the owner have emerged due to specific training (Marshall-Pescini et al. 2009; D'Aniello et al. 2015).

Looking at others and alternating gaze between an observer and a specific target are considered ways to initiate communication by attracting and directing the audience's attention towards a specific object or location (Gómez 1996). The triadic communicative interactions is a behavior initiated by looking at a human partner and alternating gaze between the human and an object of interest (Horn et al. 2012). Studies suggest that pet dogs recur to this behavior when they want to direct attention to a hidden reward out of their reach (Gaunet 2008) or when they are facing an extremely difficult or even unsolvable problem (Miklosi et al. 2003; Udell 2015; Marshall-Pescini et al. 2017). It has been proposed that this strong tendency to look toward humans in communicative

contexts is a behavioral feature that distinguishes dogs from wolves (Kubinyi et al. 2007). However, the latter never occurred in our study. We believe that this behavior was not observed due to the characteristics of our location which was only relatively quiet (as described in the material and method section), which did not allow the dogs to fully focus on the task in all cases.

According to Topal et al. (1997), dogs' decreased problem-solving performance depends less on their cognitive abilities and more on a strong relationship with the owner, which prevents them from completing the task successfully. We did not find any significant correlation between the time spent with the owner and the inability of the dog to deal with our task. We are aware that the time invested by the owner in its dog might not be a sufficient measure to ascertain the bond the two share and we suggest furthering assessing the strength of the attachment beforehand.

In our first study, we measured the performance of the dogs within a time limit of 60 seconds. It has been proposed (Marshall-Pescini et al. 2017) that longer testing time could allow the individuals to better express their behaviors, but we did not have the chance to test our dogs for a longer time span. Generally, German shepherd dogs showed a trend of spending more time interacting with the apparatus (persistency), but this did not reach the formal level of significance as all the tested dogs left the apparatus or were not interested in it before the 60'' limit passed.

Conclusions

Miklosi et al. (2003) seminal work surely ignited an ongoing interest in dogs' communicative abilities. Whether exhibited by conspecifics or humans, dogs seem to have an extraordinary understanding of gazing and this behavior can carry different meanings depending on the context. Dogs appear to be able to use gazing as a referential cue and as a cue to understand human attention states. Dogs might also be able to use gazing as an ostensive cue. Considering all the studies and the different paradigms, the emerging pattern is the flexibility that dogs exhibit when it comes to communicate with humans, but further research is necessary. Studies suggest that dogs are able to use cues to communicate with their human partners intentionally and referentially. A continuously growing body of research converges on the point that dogs show gaze alternation when in a requesting context and when they try to achieve a desired goal. Moreover, dogs also look toward a human partner before approaching a new and potentially scary object, and they are able to take into consideration their partner's emotional state. This suggests that looking toward humans might serve as a way to synchronize their behavior with the partner in order to respond to environmental stimuli. Studies comparing hand-raised wolves and dogs, different breeds, using genetic methods and different paradigms, all suggest that this behavior is a combination of ontogeny and phylogeny. Clearly, now,

the investigation of this aspect is relatively limited and future studies are needed to achieve a better understanding of the phenomenon.

With our study, we support the idea that dogs' capability and predisposition to communicate with humans has been changed for the most part through domestication but further research is hence needed to clarify the issue.

We suggest investigating more in depth the effect and the style of the training to which the dogs are exposed. It could be crucial to test the dogs without the lead. Moreover, it would be interesting to compare a peculiar breed such as the Czechoslovakian Wolfdog to other well-studied breeds with a longer domestication history (e.g. Labrador retrievers) in order to get a fuller picture and elucidate the differences between the groups.

Ethical statement

All procedures involving animals were approved with the recommendations in the Guide for the Care and Use of Animals of the Czech University of Life Sciences Prague. The protocol was approved by the Czech Central Committee for Protection of Animals (Permit number: MŠMT 26663/2010-30, 7/2010).

The legal requirements of the Czech Republic must be approved by the Central Commission for Animal Welfare (Ministry of Agriculture of the Czech Republic) and by the Commission for Animal Welfare of the Czech University of Life Sciences Prague. The experiment did not require any specific arrangement, because it was based on a contactless observation of the dogs carried by their owners.

3. Study II

Comparing behavioral characteristics of Czechoslovakian Wolfdogs, German shepherds and Labrador retrievers in Italy and the Czech Republic

Andrea Sommese [a], Paola Valsecchi [b], Annalisa Pelosi[c], Emanuela Prato-Previde[d]

a Department of Ethology and Companion Animal Science, Czech University of Life Sciences Prague, Kamýcká 129, 135 11 Praha 6 - Suchdol, Czech Republic

b Dipartimento di Scienze Chimiche, della Vita e della Sostenibilità Ambientale Università degli Studi di Parma, Italy

c Dipartimento di Medicina e Chirurgia Università degli Studi di Parma, Italy

d Dipartimento di Fisiopatologia Medico-Chirurgica e dei Trapianti, Sezione di NeuroscienzeUniversità degli Studi di Milano, Italy

Abstract

The human dog-relationship is considered the oldest domestic animal partnership and trough domestication and subsequent selection dogs' behavioral traits have been selected for functional purpose that are progressively losing their importance. Since worldwide dogs are kept most often as pet, gathering information on the behavioral characteristics on breeds assumed to be potentially dangerous or obtained through hybridization is growing. In the current study we used the Canine Behavioral Assessment and Research Questionnaire (C-BARQ) to evaluate the behavior of the Czechoslovakian wolfdog, a recent breed obtained through hybridization of the Czechoslovakian wolf and the German shepherd dog. The diffusion of this breed as a pet is rapidly growing, but very little is known on its behavioral characteristics. An Italian and a Czech version of the C-BARQ questionnaire were shared online to collect data on Czechoslovakian wolfdogs (CWDs), their parental breed, i.e. German shepherd dogs (GSs) and Labrador retrievers (LRs), a breed that is generally considered particularly suitable as a pet.

Overall, we found a limited number of behavioral differences across breeds together with a great level of variability, and some differences in the evaluations given by the owners of the two different counties.

Introduction

The human dog-relationship is considered the oldest domestic animal partnership (Bergström et al. 2020; Bethke & Burtt 2020). This relationship is complex and can be sometimes problematic both for dogs and humans (Boyd et al. 2018; Gobbo & Zupan 2020; Lord et al. 2020). Hence, gathering information on dog breeds and their behavioral characteristics is relevant at both scientific and practical level. It provides evidence on how domestication, artificial selection and environmental factors shaped dog's behavior; it also has clear applications for the management of both working dogs and pets (Svartberg & Forkman 2002; Strandberg et al. 2005; Turcsan et al. 2012), enhancing dogs' welfare and allowing future owners to make appropriate choices that reflects their needs and the familiar environment they live in.

This second aspect appears particularly relevant in the case of dogs kept as pets and assumed to be potentially dangerous (Ott et al. 2008; Grant 2011), when hand reared wild canids as dingoes (*Canis dingo*) start to be kept for companionship and live in the human environment (Oakman, 2001; Smith, 2014; Smith, 2015, Smith et al., 2017) or when new breeds obtained through hybridization grow in popularity as a companion animals (e.g. Czechoslovakian Wolfdog, Saarloos Wolfdog, Lupo Italiano, and Kunming Wolfdog) (Hope 1994). Wolfdog breeds were deliberately created crossing wolf-like dogs or ancient breeds, such as the Siberian Husky, the Alaskan Malamute, and more recently the German Shepherd, with wild wolves. Among these breeds, the Czechoslovakian Wolfdog (CWD) is the most popular of all.

The CWD is a recent breed created about 60 years ago through the hybridization between the wild Carpatian Wolf and the German shepherd dog (GS). The breed is the outcome of a military hybridization attempt conducted in former Czechoslovakia in 1958 with the goal to create a new line of dogs showing the positive traits of the GSs (e.g. temperament and trainability) but also some characteristics of the wolf including health, strength and night vision. The first breeding involved a female Carpathian wolf and a male GS dog; then, only four additional crossings with wolves occurred, with the last crossed breeding in 1983. In 1999, the breed obtained its own standard by the FCI (Fédération Cynologique Internationale). After the official approval (standard FCI n° 322/3.09.1999), any crossing of this breed with wolves has been strictly forbidden (Smetanova et al. 2015; Caniglia et al. 2018), although the occurrence of new crossings cannot be completely ruled out.

In recent years, the CWDs have grown in popularity since part of the public is attracted by dogs with ancient traits that resemble their ancestors in both appearance and behavior. Currently there are 36317 registered individuals worldwide (CLC-Italia data-base, http://clc-italia.it). The fast-growing number of registered CWDs worldwide demonstrates the elevated economical value of this breed, the growing interest in keeping this type of dogs and the need of a deeper comprehension of its behavioral/temperamental traits.

To our knowledge only two studies have considered CWDs' behavior, focusing on their human directed behavior, namely gazing behavior (Sommese et al., 2019; Maglieri et al., (2019) and providing initial scientific evidence on this breed behavior in comparison with other common breeds.

Sommese et al. (2019) tested a large sample of CWDs in the Czech Republic using an "unsolvable task" comparing gazing behavior of CWDs and GSs. The aim of this study was to investigate the effects of genetics and ontogeny on dogs' human-directed communicative behavior. The authors reported that GSs looked back at humans more frequently and for longer than CWDs. The gazing behavior in wolfdogs was not affected by the level of obedience and time the owner had spent training and living with the subject as shown for domestic dogs (Marshall-Pescini et al. 2008, 2009; Scandurra et al. 2016). Also, there was no age effect as suggested in other studies (Passalacqua et al. 2011; Persson et al. 2015), and the wolfdogs with limited exposure to humans (e.g. living outside and/or in a kennel) gazed towards humans as much as those living indoor.

Using the same task, Maglieri et al. (2019) evaluated human-directed gazing behavior in an unsolvable task in an Italian sample of CWDs. Authors selected CWDs kept exclusively as pets and living in the human household etc. and compared their behavior with GSs and LRs raised in the same way. Even though all dogs were kept only for companionship, lived in the household with their owner and had no specific training, CWDs did not show the tendency to gaze towards humans, while the other two breeds showed a tendency to look back at humans in this task with LR being the most human oriented. Furthermore, Maglieri et al. (2019) found that comparing gazing behavior of their CWDs, GSs and LRs with that of dingoes tested in a comparable situation (Smith & Litchfield 2013) there was a substantial similarity between the CWDs and dingoes in gazing behavior.

Taken together these results suggested that CWDs differ from both GS and LR in gazing behavior being also more similar to dingoes. Therefore, it seemed that CWDs went through an artificial selection that produced a breed with traits more similar to those possessed by ancient, more wolf-like breeds or hand reared dingoes. However, as noted by the authors, there is a possibility that, depending on the breed, the owners behave differently in everyday situations. Thus, influencing their dog's behavior cannot be ruled out.

GSs and LRs are two common modern pure breeds resulting from the domestication process and the subsequent process of artificial selection common to all modern breeds. The LR is a waterdog, usually employed as a duck retriever. According to the AKC (American Kennel Club), the breed originated in Canada (Newfoundland) in the early 1800s and it is not clear how the name 'Labrador' became associated with it. During the second half of the 19th century, British breeders refined the standard of the breed; the Kennel Club (England) recognized the breed in 1903, and the AKC registered its first dog of the breed in 1917. Since then, millions of people around the globe own these dogs, which are considered one of the most -if not the most- popular, breeds (https://www.akc.org/).

As far as we know, GSs dogs has been selected from a herding dog commonly distributed in Europe prior to 1859 (Talenti et al. 2018). Then, three different lines were selected leading to the GS, the Belgian shepherd and the Dutch shepherd. By the end of the 19th century. In 1899, a dog named Hektor Linksrhein was declared the first GS and was therefore added to the newly founded Society for the German Shepherd Dog (Verein für Deutsche Schäferhunde). This dog was then inbred to select and to consolidate the traits being sought in the breed. In the process, four wolves were crossed with the population (Caniglia et al. 2018).

Unlike CWDs, GSs and LRs have been studied to a greater extent using both tests and questionnaires (e.g. Wilsson & Sundgren 1997; Van der Waaij et al. 2008). Wilsson and Sundgren (1997) compared a large sample of GSs and LRs reporting that retrievers were more cooperative and sociable than shepherds when tested. There is also evidence that retrievers spontaneously gaze at the human face significantly longer then GSs in the presence of out-of-reach food (Jakovcevic et al. 2010). Recently, Sundman et al. (2018) reported that during a problem-solving task LRs display more human directed social behaviors and eye contact compared to GSs. Differences in the behavior of these breeds have been reported by (Serpell & Duffy 2014) in a survey based on the C-BARQ. In particular, they compared a large sample of GSs (N=781) and LRs (N=1120) reporting that GSs had higher scores in stranger and dog directed aggression compared to LRs.

Although the direct observation of the individual could be the best tool for behavioral assessments and researchers have developed several behavioral tests to evaluate dogs temperament (e.g., Netto & Planta 1997; Jones & Gosling 2005; Svartberg et al. 2005; Sforzini et al. 2009) behavioral tests are often not easy to conduct and time consuming and the possibility that the emergence of a novel behavior may be dependent on the experimental setting itself cannot be excluded. Thus, in order to assess dog behavior and to tackle possible behavior problems, it could be effective to obtain information about individual dogs from their owners, who might know best the typical behaviors of their dogs.

In the current study, we used the C-BARQ questionnaire (Hsu & Serpell 2003) to gather information from dog owners on the behavioral characteristics of the CWDs comparing them with those of the GSs and LRS, two modern pure breeds widely diffused as pet dogs. Serpell and Hsu (2001) developed a tool (Canine Behavioral Assessment and Research Questionnaire: C-BARQ) for measuring behavioral traits in pet dogs. The C-BARQ has been available for completion via a publicly accessible online website since 2005. Its database at the University of Pennsylvania contains detailed behavioral evaluations for approximately 50,000 pet dogs comprising more than 300 different breeds and crossbreeds.

The C-BARQ is an useful resource for investigating dogs' behavior and several studies have used it to investigate breed differences in behavioral traits making comparisons with previous findings possible (Serpell & Hsu 2005; Duffy et al. 2008; van den Berg et al. 2010; Duffy et al. 2014). This questionnaire is available to a wide variety of dog-related organizations, working groups and projects. In addition, even dog owners are allowed to use it to compare their pets to other dogs in the database. Therefore, it has been validated for use in several languages and these translations make the C-BARQ a consistent tool for assessing dog behavior in a wide variety of cultures (Mandarin (Hsu & Sun 2010), Japanese (Nagasawa et al. 2011), Dutch (van den Berg et al. 2006), Swedish (Svartberg 2005), Italian (Marshall-Pescini et al. 2008), Farsi (Tamimi et al. 2015), Latin American Spanish (González-Ramírez et al. 2017), Brazilian Portuguese (Rosa et al. 2017) and European Portuguese (Canejo-Teixeira et al. 2018).

The aim of our research, was firstly to obtain a deeper comprehension of the CWD behavioral/temperamental traits and potentially problematic behaviors through the C-BARQ, and secondly to compare the behavioral profile of this recent breed with those of its sister breed, the GS, and of a common breed, the LR, considered highly suitable to live with humans and in general not problematic. In addition, the latter two breeds are commonly kept as pet dogs and were used in the two previous studies involving CWD (Sommese et al.2019; Maglieri et al., 2019).

The study was carried out in two different countries: Italy and the Czech Republic. The rationale for this choice was that CWDs originated in the Czech Republic (formerly part of Czechoslovakia) and almost half the population of wolfdogs resides in Italy (43.66% of the total).

An issue that emerges from the literature based on questionnaire is that apparent breed differences in behavior, besides reflecting underlying biological/behavioral reality, might reflect systematic biases in how owners of different breeds evaluate them in surveys. Thus, the assessment of how a large number of owners from two different countries, i.e. Italian and Czech, evaluate the same dog breeds could help to clarify this aspect.

Material and Methods

Subjects

One thousand four hundred twenty owners participated to the survey: 1119 from Italy (79.1% females) and 301 (83.7% females) from Czech Republic. The Italian sample of dogs consisted of 291 CWDs (26.0%), 301 GSs (26.9%), 527 LRs (47.1%); the Czech sample consisted of: 75 CWDs (24.9%), 155 (GSs (51.5%), 71 LR (23.6%). However, since we decided to exclude dogs with age < 12 months, the final sample consisted of 1024 Italian and 274 Czech dogs.

C-BARQ

The questionnaire used for this study was the complete and validated C-BARQ and thus included all the items of the questionnaire (Hsu & Serpell 2003; Duffy & Serpell 2012). This questionnaire is a standardized procedure designed to assess the prevalence and severity of behavioral problems in dogs, but it has been used widely also from regular owners who want to know more about their pets or decide upon taking a dog in their households (i.e. Duffy et al. 2014). Moreover, various studies have used this questionnaire to investigate differences in behavioral traits across dog breeds (Serpell & Duffy 2014).

The validation and reliability of C-BARQ have been widely described elsewhere (Hsu & Serpell 2003; Serpell & Hsu 2005; Duffy & Serpell 2012). The questionnaire contains items regarding different aspects of behavior such as trainability, aggression, fear and anxiety, separation-related behavior, excitability, attachment and attention-seeking, and a list of miscellaneous behavior problems ranging from chasing to coprophagia and stereotypic spinning/tail-chasing. Respondents are asked to grade their dogs' typical responses (in term of severity or frequency) to different everyday situations during the recent past on five-point scales.

The following fourteen different categories of dog behavior were considered in the study:

- Trainability: Willingness to attend to the owner, obey simple commands, learn quickly, fetch objects, respond positively to correction, and ignore distracting stimuli.
- Stranger-directed aggression: Threatening or hostile responses to strangers approaching or invading the dog's or owner's personal space, territory, or home range.
- Owner-directed aggression: Threatening or hostile responses to the owner or other members of the household when challenged, manhandled, stared at, stepped over, or when approached while in possession of food or objects.

- Dog-directed aggression: Threatening or hostile responses when approached by unfamiliar dogs.
- Dog rivalry: Threatening or hostile responses to other familiar dogs in the same household.
- Stranger-directed fear: Fearful or wary responses when approached by strangers.
- Non-social fear: Fearful or wary responses to sudden or loud noises, traffic, and unfamiliar objects and situations.
- Dog-directed fear: Fearful or wary responses when approached by unfamiliar dogs.
- Separation-related behavior: Vocalizing and/or destructiveness when separated from the owner, often accompanied or preceded by behavioral and autonomic signs of anxiety including restlessness, loss of appetite, trembling, and excessive salivation
- Excitability: Displaying strong reactions to potentially exciting or arousing events, such as going for walks or car trips, doorbells, arrival of visitors, and the owner arriving home; has difficulty settling down after such events.
- Attachment and attention seeking: Maintaining close proximity to the owner or other members of the household, soliciting affection or attention, and displaying agitation when the owner gives attention to third parties.
- Chasing: Chasing cats, birds, and/or other small animals, given the opportunity.
- Touch sensitivity: Fearful or wary responses to potentially painful procedures, including bathing, grooming, nail-clipping, and veterinary examinations.
- Energy level: Energetic, "always on the go", and/or playful.

Two professionals and native speakers translated the original material into Italian and in Czech. The survey was shared online through the Facebook pages (e.g. *Canis sapiens* Lab - University of Milan) and via word of mouth, inviting CWDs, GSs and LRs owners to participate. A cover page to the C-BARQ contained questions concerning the dog (breed, age, sex, neuter status, living condition, training experience) and the owner (country, age, gender).

Statistical analysis

Due to the great difference in sample size of the Italian and Czech respondents and the significantly different distribution of breeds (χ^2_2=22=73.39, p<.001), the statistical analysis explored the two samples separately.

Contingency tables were analyzed using chi squared test. For each country, behavioral differences were analyzed using subscale scores as dependent variable and dogs' breed, sex, neuter

status and training experiences as fixed factors in univariate ANCOVAs, in which dogs' age was included as covariates (we did not consider the owners' gender as covariate, due to the strong sample imbalance). Pairwise post-hoc t-test were carried out using Bonferroni correction. To avoid type I error, we considered R squared values along with p-values to detect both statistical and practical significance. The larger the sample size, the more likely a hypothesis test will detect a small difference. Thus, it is important to consider practical significance when sample size is large.

Results

In both samples the majority of respondents were women (Italy F= 79.1%; Czech Republic: F= 83.7%). The information about country, breed and sex distribution of the dogs is depicted in Table 1. Most of the dogs of the Italian sample (79.9%) lived indoors (CWDs= 74.2%; GSs=78.4%; LRs=83.9%). In the Czech sample 51.5% of the dogs lived indoor (CWDs= 54.7%; GSs=51.6%; LRs=47.9%).

Country	Sex	Breed			Total
		CWD	GS	LR	
Italy	M	134 (27.3)	122 (24.9)	234 (47.8)	490
	F	132 (24.7)	150 (28.1)	252 (47.2)	534
Czech Rep.	M	32 (22.5)	73 (51.4)	37 (26.1)	142
	F	34 (25.8)	70 (53.0)	28 (21.2)	132

CWD: Czechoslovakian Wolf Dog; GS: German Shepherd; LR: Labrador Retriever; M: Male; F; Female

Table 3. Country, breed and sex distribution frequency (%).

Italian sample

Italian owners reported very low level (scores < 1) for people-directed aggression, dog rivalry, fear, touch sensitivity and separation – related behavior for all breeds (table 4). Scores reported for dog directed aggression, excitability and energy level indicated fairly low levels of expression of these behaviors (scores < 2), while the expression of the remaining behaviors (attachment/attention seeking, chasing, trainability) were judged moderate across breeds (scores > 2 but < 3). Differences related to the breed and/or to the sex were scarce, both from an interpretative and a statistical point of view: indeed, although p-values concerning some behaviors were under the significant cut off (alpha: .05), their effect size coefficients (R^2) were negligible (< .10, see table 5).

	CWD		GS		LR	
	M	**F**	**M**	**F**	**M**	**F**
Stranger-directed aggression	.69 (.07)	.68 (.07)	.90 (.08)	.79 (.07)	.73 (.05)	.68 (.05)
Owner-directed aggression	.19 (.03)	.09 (.02)	.16 (.03)	.10 (.02)	.19 (.02)	.13 (.02)
Dog directed aggression	**1.59** (.09)	**1.44** (.1)	**1.83** (.09)	**1.40** (.09)	**1.59** (.07)	**1.32** (.07)
Dog rivalry	.29 (.05)	.36 (.06)	.26 (.05)	.51 (.06)	.32 (.04)	.38 (.04)
Dog fear	.37 (.05)	.45 (.05)	.41 (.05)	.47 (.05)	.43 (.04)	.43 (.04)
Stranger fear	.28 (.05)	.30 (.05)	.39 (.06)	.58 (.07)	.42 (.05)	.42 (.05)
Non-social fear	.78 (.05)	.82 (.05)	.96 (.05)	.92 (.05)	.88 (.04)	.83(.04)
Touch sensitivity	.54 (.05)	.56 (.05)	.50 (.05)	.54 (.04)	.53 (.04)	.50 (.03)
Excitability	**1.80** (.07)	**1.94** (.07)	**1.90** (.07)	**1.77** (.06)	**1.81** (.05)	**1.75** (.05)
Energy level	**1.54** (.08)	**1.32** (.07)	**1.52** (.09)	**1.34** (.08)	**1.53** (.06)	**1.38** (.06)
Separation – related behavior	.64 (.05)	.61 (.04)	.68 (.06)	.58 (.05)	.56 (.03)	.56 (.03)
Attachment/attention seeking	**2.41** (.07)	**2.47** (.06)	**2.46** (.07)	**2.28** (.07)	**2.42** (.05)	**2.27** (.05)
Chasing	**2.05** (.09)	**2.34** (.09)	**2.16** (.1)	**2.18** (.08)	**2.02** (.07)	**2.19** (.06)
Trainability	**2.40** (.05)	**2.46** (.04)	**2.44** (.05)	**2.59** (.04)	**2.42** (.03)	**2.54** (.03)

CWD: Czechoslovakian Wolf Dog; GS: German Shepherd; LR: Labrador Retriever; M: Male; F; Female

Table 4. Italian sample: mean (standard error of mean) score for each subscale. Scores greater than 1 are in bold.

	Breed [df: 2;1006]	**Sex** [df: 1;1006]	**Trainer-ship** [df: 1;1006]	**Neuter status** [df: 1;1006]	**Breed * Sex** [df: 2;1006]	**Breed * trainer-ship** [df: 2;1006]	**Breed* Sex*trainer-ship** [df: 2;1006]
Stranger dir. aggression (R^2= .024)	*F=1.2, ns,* η^2_p= *.002*	*F=1.9, ns;* η^2_p= *.002*	*F=.09, ns;* η^2_p= *.000*	*F=.98, ns,* η^2_p= *.000*	*F=.22, ns,* η^2_p= *.000*	*F=.84, ns,* η^2_p= *.000*	**F=2.4*,** η^2_p**= .012**
Owner dir. aggression (R^2= .038)	*F=1.2, ns,* η^2_p= *.002*	**F=10.2**,** η^2_p**= .01**	*F=1.7, ns,* η^2_p= *.002*	*F=.03, ns,* η^2_p= *.000*	*F=.42, ns,* η^2_p= *.001*	*F=.83, ns,* η^2_p= *.002*	*F=1.4, ns,* η^2_p= *.007*
Dog dir. aggression (R^2= .046)	*F=.86, ns,* η^2_p= *.002*	**F=12.6**,** η^2_p**= .012**	*F=.19, ns,* η^2_p= *.000*	*F=.89, ns,* η^2_p= *.001*	*F=1.1, ns,* η^2_p= *.002*	*F=1.9, ns,* η^2_p= *.004*	*F=.34, ns,* η^2_p= *.002*
Dog rivalry (R^2= .040)	*F=.61, ns,* η^2_p= *.001*	**F=13.4**,** η^2_p**= .002**	*F=1.4, ns,* η^2_p= *.001*	*F=.01, ns,* η^2_p= *.000*	*F=2.4, ns,* η^2_p= *.005*	*F=1.4, ns,* η^2_p= *.003*	*F=2.2, ns,* η^2_p= *.011*
Dog fear (R^2= .010)	*F=.30, ns,* η^2_p= *.001*	*F=.67, ns,* η^2_p= *.001*	**F=3.9*,** η^2_p**= .004**	*F=.04, ns,* η^2_p= *.000*	*F=.39, ns,* η^2_p= *.001*	*F=.11, ns,* η^2_p= *.001*	*F=.66, ns,* η^2_p= *.003*

Stranger fear (R^2= .033)	**F=4.2*, η^2_p= .008**	*F=.64, ns, η^2_p= .001*	*F=.01, ns, η^2_p= .000*	*F=.00, ns, η^2_p= .000*	*F=1.6, ns, η^2_p= .003*	*F=.04, ns, η^2_p= .000*	**F=2.6*, η^2_p= .013**
Non-social fear (R^2= .028)	**F=3.9*, η^2_p= .008**	*F=.72, ns, η^2_p= .001*	**F=9.2**, η^2_p= .009**	*F=.07, ns, η^2_p= .000*	*F=.63, ns, η^2_p= .001*	*F=.42, ns, η^2_p= .001*	*F=1.6, ns, η^2_p= .008*
Touch sensitivity (R^2=.009)	*F=.21, ns, η^2_p= .000*	*F=.21, ns, η^2_p= .000*	*F=1.4, ns, η^2_p= .001*	*F=.11, ns, η^2_p= .000*	*F=.63, ns, η^2_p= .001*	*F=.19, ns, η^2_p= .001*	*F=.89, ns, η^2_p= .004*
Excitability (R^2=.020)	*F=.50, ns, η^2_p= .001*	*F=.28, ns, η^2_p= .000*	**F=9.6**, η^2_p= .009**	*F=2.8, ns, η^2_p= .003*	**F=2.9*, η^2_p= .006**	*F=.46, ns, η^2_p= .001*	*F=.44, ns, η^2_p= .002*
Energy level (R^2=.099)	*F=1.1, ns, η^2_p= .002*	**F=8.9**, η^2_p= .009**	**F=7.1**, η^2_p= .007**	*F=.89, ns, η^2_p= .001*	*F=.13, ns, η^2_p= .000*	*F=1.1, ns, η^2_p= .002*	*F=2.1, ns, η^2_p= .001*
Separation rel. behavior (R^2= .040)	*F=1.2, ns, η^2_p= .002*	*F=1.5, ns, η^2_p= .002*	**F=8.4**, η^2_p= .008**	*F=.01, ns, η^2_p= .000*	*F=.35, ns, η^2_p= .001*	*F=.86, ns, η^2_p= .002*	*F=1.9, ns, η^2_p= .010*
Attachment / atten. seeking (R^2= .046)	*F=1.1, ns, η^2_p= .002*	*F=2.1, ns, η^2_p= .002*	**F=5.1*, η^2_p= .005**	*F=2.8, ns, η^2_p= .003*	**F=3.7*, η^2_p= .007**	*F=.36, ns, η^2_p= .001*	*F=.98, ns, η^2_p= .005*
Chasing (R^2= .047)	*F=.62, ns, η^2_p= .001*	**F=5.6*, η^2_p= .005**	**F=3.7*, η^2_p= .004**	*F=2.3, ns, η^2_p= .002*	*F=2.2, ns, η^2_p= .004*	*F=.34, ns, η^2_p= .001*	*F=.58, ns, η^2_p= .003*
Trainability (R^2= .076)	*F=1.2, ns, η^2_p= .002*	**F=10.8**, η^2_p= .011**	**F=48.9**, η^2_p= .046**	*F=.86, ns, η^2_p= .001*	*F=.64, ns, η^2_p= .001*	*F=.31, ns, η^2_p= .001*	*F=1. 6, ns, η^2_p= .008*

df= degrees of freedom; * p<.05; ** p<.01; n.s. p> .05

Table 5. Italian sample: ANCOVAs on the different C-BARQ categories

Overall results indicate that owners rated their male dogs, regardless of breed and training, as more aggressive towards conspecifics (Dog-directed aggression), more excitable and active (Excitability, Energy level) and more prone to show attention seeking behavior (Attachment/attention seeking) than females. In addition, males were reported to be less trainable and less prone to chase cats, birds, and/or other small animals (when given the opportunity) than females (fig. 8). It also emerged that, independently from sex or breed, dogs that had not received any training were considered as more excitable, active, seeking for attention, more prone to chase and less trainable (fig. 9).

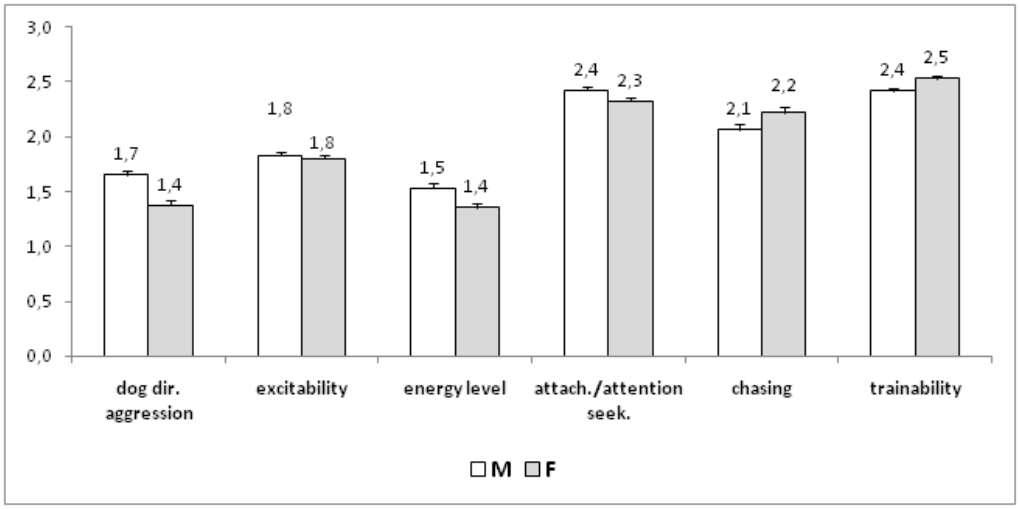

Figure 8: Gender differences in behaviors with scores of frequency/intensity greater than 1.

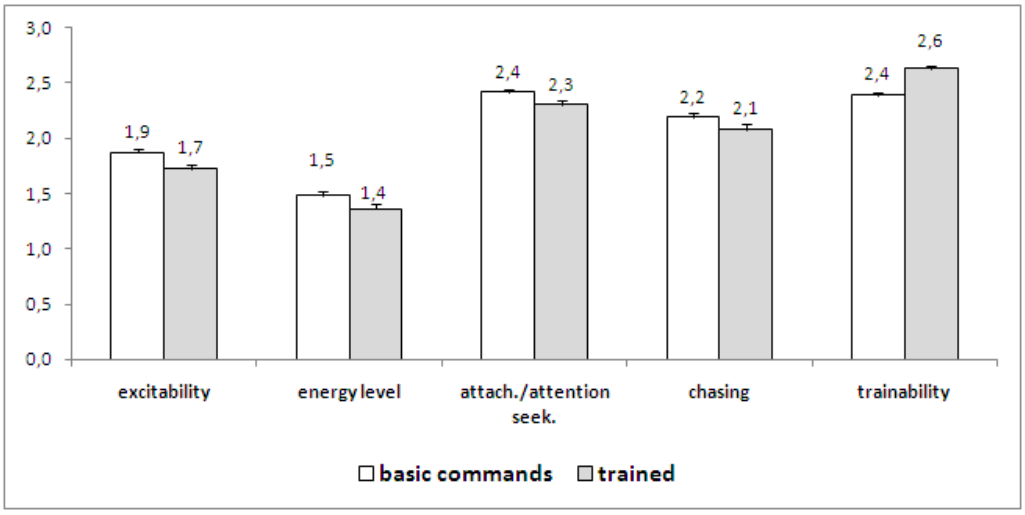

Figure 9. Differences in behavior between trained and untrained dogs

When looking at breed differences it emerged that CWDs are considered to be less fearful towards strangers compared to GSs and LRs and to be less fearful of non-social stimuli than GS.

In GSs and LRs males are considered more excitable than females while in CWDs a greater excitability is reported for females. The same trend emerges when considering attachment and attention-seeking behaviors (fig. 10). However, it is worth noting that in general there was a great individual variability not depending, if not marginally, from the factors we considered for our analysis.

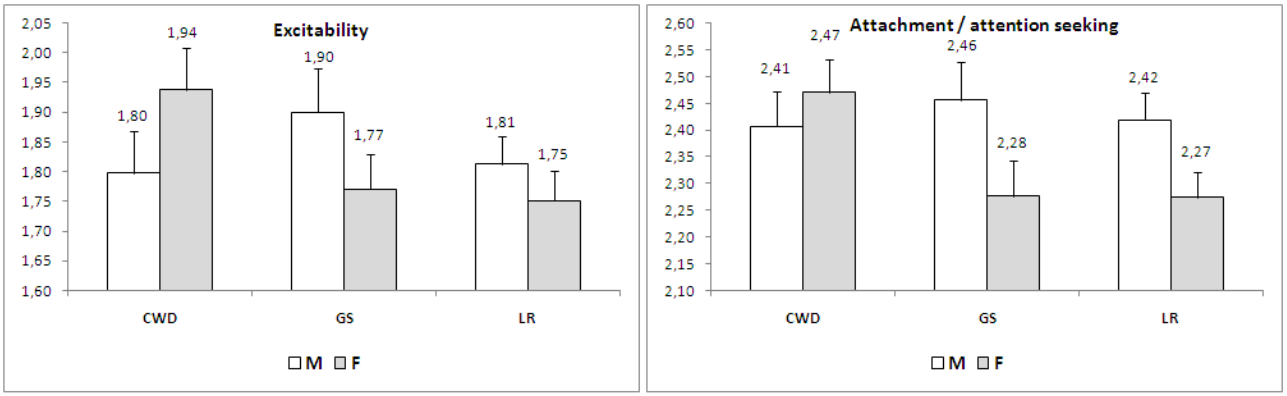

Figure 10. Breed and sex differences in excitability and attachment.

Finally, when dogs are trained, males and females are comparable in their aggressiveness towards strangers. On the other hand, in untrained dogs, GSs and LRs males are more aggressive than females (fig. 11).

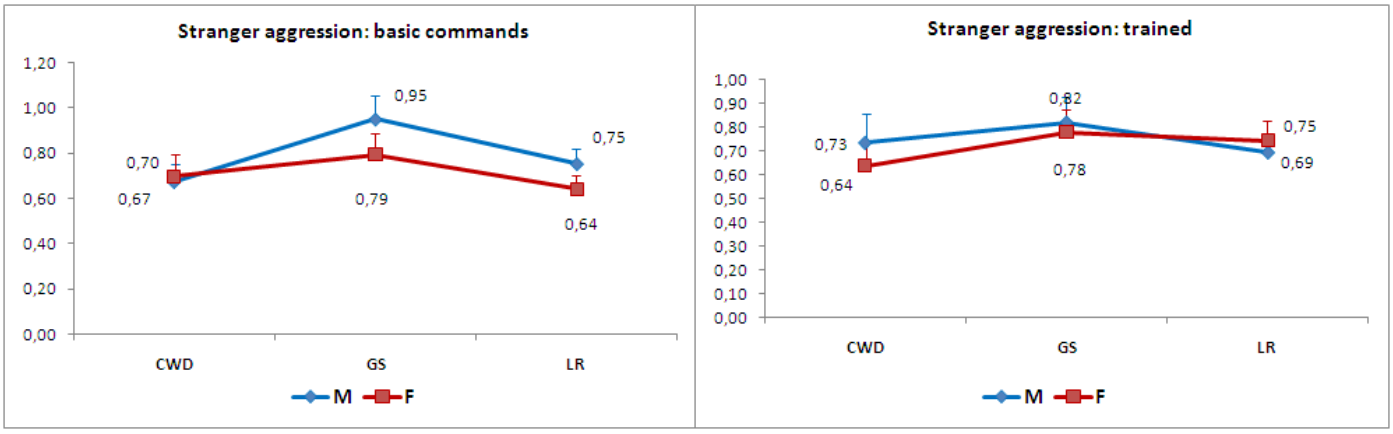

Figure 11. Training (basic commands and intensive training) and gender differences across breeds.

Czech sample

As reported in Table 6 the behaviors that overall had an average score > 1 were practically the same emerged in the Italian sample, namely dog directed aggression, excitability, energy level, attachment/attention seeking, chasing, trainability) (table 6).

	CWD		GS		LR	
	M	**F**	**M**	**F**	**M**	**F**
Stranger-directed aggression	1.02 (.14)	.78 (.11)	1.10 (.1)	.95 (.09)	.40 (.07)	.33 (.08)
Owner-directed aggression	.32 (.07)	.12 (.03)	.13 (.04)	.08 (.03)	.07 (.02)	.04 (.14)

Dog directed aggression	**2.23** (.17)	**1.66** (.14)	**2.05** (.13)	**1.59** (.13)	**1.23** (.13)	**.65** (.14)
Dog rivalry	.47 (.12)	.46 (.12)	.62 (.11)	.62 (.09)	.33 (.07)	.32 (.11)
Dog fear	.13 (.04)	.20 (.07)	.36 (.08)	.25 (.05)	.38 (.09)	.22 (.07)
Stranger fear	.45 (.16)	.49 (.13)	.28 (.06)	.26 (.07)	.18 (.07)	.22 (.1)
Non-social fear	.75 (.13)	.61 (.09)	.50 (.07)	.55 (.08)	.67 (.10)	.50 (.09)
Touch sensitivity	.48 (.08)	.54 (.10)	.47 (.08)	.41 (.05)	.45 (.08)	.47 (.08)
Excitability	**2.15** (.14)	**2.16** (.12)	**2.25** (.08)	**2.03** (.09)	**1.98** (.14)	**2.21** (.16)
Energy level	**1.63** (.19)	**1.47** (.14)	**1.77** (.12)	**1.44** (.11)	**1.34** (.17)	**1.45** (.13)
Separation – related behavior	.90 (.11)	.93 (.13)	.63 (.07)	.46 (.06)	.42 (.06)	.38 (.06)
Attachment/attention seeking	**2.44** (.13)	**2.18** (.13)	**2.22** (.11)	**2.12** (.10)	**2.27** (.13)	**2.31** (.15)
Chasing	**2.09** (.19)	**2.15** (.13)	**1.99** (.13)	**1.89** (.12)	**1.39** (.15)	**1.64** (.21)
Trainability	**2.40** (.10)	**2.37** (.10)	**2.96** (.06)	**3.08** (.06)	**2.85** (.08)	**3.03** (.10)

CWD: Czechoslovakian Wolf Dog; GS: German Shepherd; LR: Labrador Retriever; M: Male; F; Female

Table 6. Czech sample: mean (standard error of mean) score for each C-BARQ subscale. Scores greater than 1 are in bold.

Similarly to the Italian sample, it emerged that p-values concerning some behaviors were under the significant cut off (alpha: .05) but their effect size coefficients (R2) were negligible (< .10, see table 7).

	Breed [df: 2;256]	**Sex** [df: 1;256]	**Trainer-ship** [df: 1;256]	**Breed * Sex** [df: 2;256]	**Breed * trainer-ship** [df: 1;256]	**Neuter status** [df: 1;256]	**Breed* Sex*trainer-ship** [df: 5;256]
Stranger dir. aggression (R^2= .119)	***F=12.7**, η^2_p= .009***	*F=2.9, ns; η^2_p= .011*	*F=1.1, ns; η^2_p= .004*	*F=.09, ns, η^2_p= .001*	*F=1.7, ns, η^2_p= .013*	*F=3.2, ns, η^2_p= .012*	*F=.63, ns, η^2_p= .012*
Owner dir. aggression (R^2= .085)	**F=3.4*, η^2_p= .026**	**F=5.5*, η^2_p= .021**	*F=1.6, ns, η^2_p= .006*	*F=2.7, ns, η^2_p= .021*	*F=.69, ns, η^2_p= .005*	*F=.29, ns, η^2_p= .001*	*F=.49, ns, η^2_p= .009*
Dog dir. aggression (R^2= .247)	**F=14. 6**, η^2_p= .11**	**F=20.9**, η^2_p= .075**	*F=.07, ns, η^2_p= .000*	*F=.81, ns, η^2_p= .006*	*F=1.3, ns, η^2_p= .010*	*F=.01, ns, η^2_p= .000*	*F=1.6, ns, η^2_p= .030*
Dog rivalry (R^2= .057)	**F=3.2*, η^2_p= .025**	*F=.28, ns, η^2_p= .001*	*F=.61, ns, η^2_p= .002*	*F=.29, ns, η^2_p= .002*	*F=.21, ns, η^2_p= .002*	*F=.29, ns, η^2_p= .001*	*F=.73, ns, η^2_p= .014*
Dog fear (R^2= .093)	*F=2.7, ns, η^2_p= .021*	*F=.82, ns, η^2_p= .003*	*F=.66, ns, η^2_p= .003*	*F=.19, ns, η^2_p= .001*	*F=2.6, ns, η^2_p= .020*	*F=.18, ns, η^2_p= .001*	*F=1.1, ns, η^2_p= .021*
Stranger fear (R^2= .147)	***F=10.8**, η^2_p= .078***	*F=1.1, ns, η^2_p= .004*	***F=9.9**, η^2_p= .037***	*F=1.1, ns, η^2_p= .008*	***F=4.5*, η^2_p= .034***	F=2.2, ns, η^2_p= .008	***F=3.6**, η^2_p= .066***
Non social fear (R^2= .135)	*F=.43, ns, η^2_p= .003*	*F=.21, ns, η^2_p= .001*	***F=26.1**, η^2_p= .091***	*F=.84, ns, η^2_p= .006*	*F=.42, ns, η^2_p= .003*	*F=.01, ns, η^2_p= .000*	*F=.35, ns, η^2_p= .007*
Touch sensitivity (R^2=.087)	*F=.54, ns, η^2_p= .004*	*F=.01, ns, η^2_p= .000*	**F=7.6**, η^2_p= .029**	*F=.47, ns, η^2_p= .004*	*F=.69, ns, η^2_p= .005*	*F=.89, ns, η^2_p= .003*	*F=.19, ns, η^2_p= .004*

Excitability (R^2=.058)	*F=.16, ns, η^2_p= .001*	*F=.24, ns, η^2_p= .001*	*F=1.3, ns, η^2_p= .004*	*F=2.1, ns, η^2_p= .017*	*F=1.1, ns, η^2_p= .009*	*F=1,5, ns, η^2_p= .006*	*F=.61, ns, η^2_p= .012*
Energy level (R^2=.150)	*F=.36, ns, η^2_p= .003*	*F=.27, ns, η^2_p= .001*	*F=2.2, ns, η^2_p= .009*	*F=.18, ns, η^2_p= .001*	*F=.83, ns, η^2_p= .006*	*F=.99, ns, η^2_p= .004*	*F=.78, ns, η^2_p= .015*
Separation rel. behavior (R^2= .177)	**F=10.3**, η^2_p= .074**	*F=1.1, ns, η^2_p= .004*	*F=.21, ns, η^2_p= .001*	*F=.31, ns, η^2_p= .002*	*F=.84, ns, η^2_p= .006*	*F=1.1, ns, η^2_p= .004*	*F=1.1, ns, η^2_p= .020*
Attachment / atten. seeking (R^2= .057)	*F=.54, ns, η^2_p= .004*	*F=1.4, ns, η^2_p= .005*	**F=4.7*, η^2_p= .018**	*F=.27, ns η^2_p= .002*	*F=.04, ns, η^2_p= .000*	*F=.38, ns, η^2_p= .001*	*F=.86, ns, η^2_p= .017*
Chasing (R^2= .101)	**F=3.2*, η^2_p= .024**	*F=.46, ns, η^2_p= .002*	*F=1.6, ns, η^2_p= .006*	*F=.32, ns, η^2_p= .003*	*F=.15, ns, η^2_p= .001*	*F=3.1, ns, η^2_p= .012*	*F=.14, ns, η^2_p= .003*
Trainability (R^2= .319)	**F=12.5**, η^2_p= .089**	*F=1.3, ns, η^2_p= .005*	**F=23.6**, η^2_p= .084**	*F=.08, ns, η^2_p= .001*	*F=.96, ns, η^2_p= .007*	*F=.61, ns, η^2_p= .002*	*F=1.5, ns, η^2_p= .028*

df= degrees of freedom; * p<.05; ** p<.01; n.s. p> .05

Table 7. Czech sample: ANCOVAs on the different C-BARQ subscales.

CWDs and GSs were rated as significantly more aggressive towards strangers and other dogs than LRs ($p < 0{,}01$). In addition, CWDs resulted to be significantly more afraid of strangers ($p < 0.01$), more prone to separation related behaviors ($p < 0.05$) and less trainable ($p < 0.05$) than both GSs and LRs. The only difference related to sex emerged in dog aggression, with males being rated as significantly more aggressive than females ($p < 0.01$).

Trained dogs were reported as less fearful, less prone to seek attention and to engage in chasing behavior and, of course more trainable than untrained dogs (fig 12).

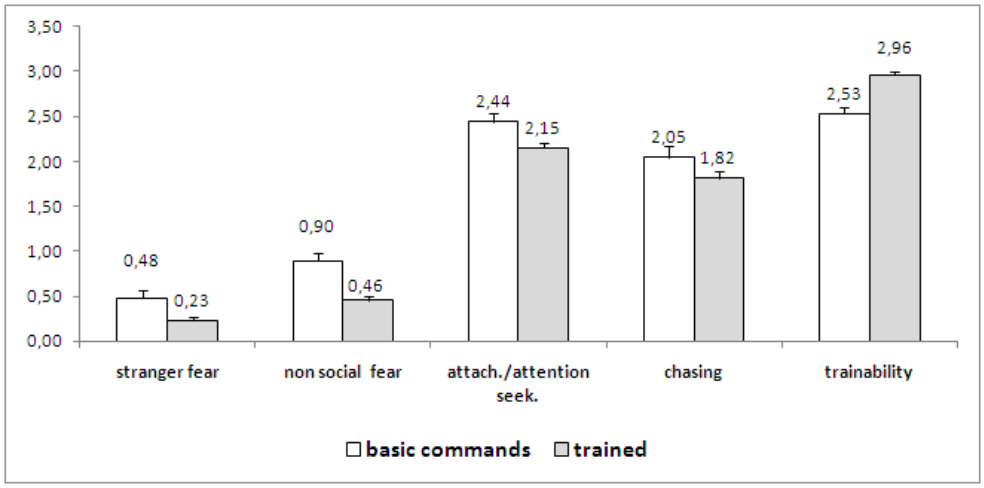

Figure 12. Differences in behavior between trained and untrained dogs

Conversely, untrained dogs, and particularly CWDs, were rated as more fearful of strangers (fig. 13).

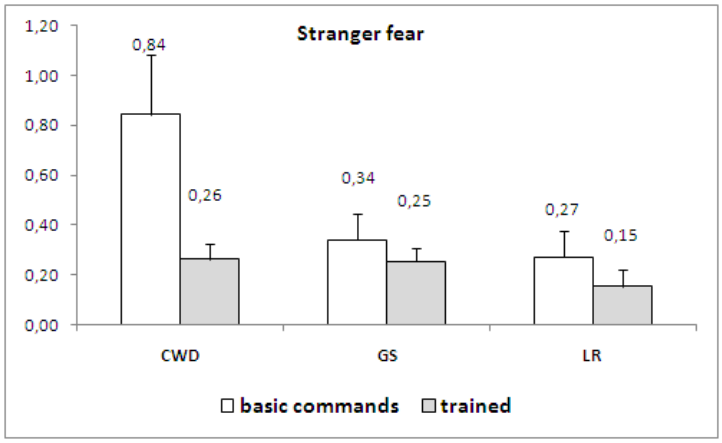

Figure 13. Training (basic commands and intensive training) differences across breeds.

Considering stranger fear untrained LRs and trained CWD females are rated more fearful than males (figure 14).

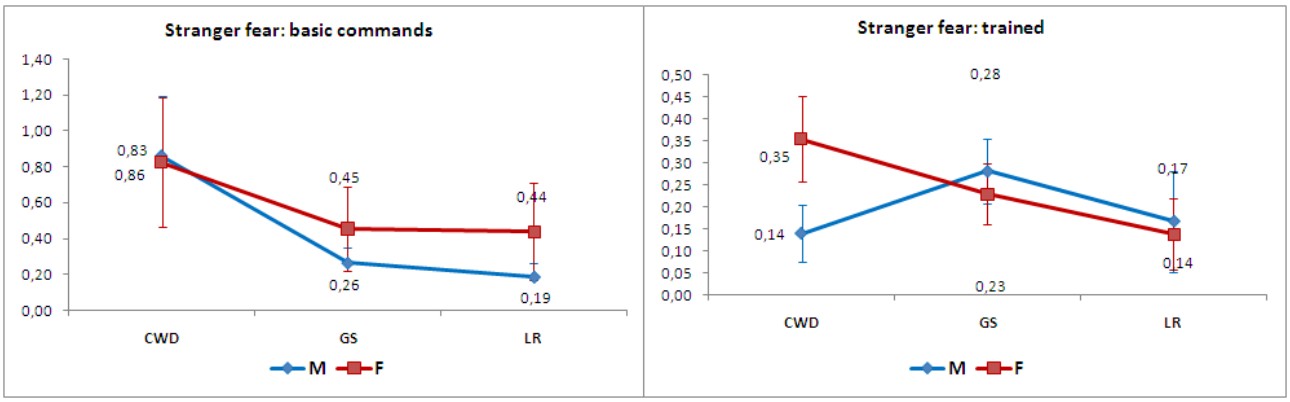

Figure 14. Gender differences across breeds.

Discussion

Data showing differences between the breeds and their behavioral characteristics are resourceful at both scientific and practical level. They provide evidence of how domestication, artificial selection and environmental factors shaped dogs' behavior. Nonetheless, thorough knowledge of all the traits of pure-bred dog's future owners could make a more accurate choice that reflects their needs and the familiar environment they live in. Therefore, studies like ours can enhance the welfare of dogs as more breeds can be better understood.

To our knowledge no study has investigated in detail the behavioral characteristics of the CWD, a breed created about 60 years ago through the hybridization between the GS dog and the wild Carpatian Wolf. Hence, behavioral comparisons between this breed and other breeds are very limited. CWDs are growing in popularity as a portion of the public is looking for individuals with ancient traits that will look more like their ancestors. Currently there are 35787 registered individuals worldwide (CLC-Italia data-base, http://clc-italia.it).

Maglieri et al. (2019) tested an Italian sample of CWDs, GSs and LRs for human-directed communicative behavior (i.e. gazing behavior) in an 'unsolvable task' and found that even though all dogs were kept for companionship, lived in the same household with their owner and had no specific training, CWDs did not show the tendency to gaze towards humans, while the other two other breeds often looked back at humans in this task. A similar result was obtained in the Czech Republic by Sommese et al. (2019) comparing CWDs and GSs for human-directed gazing behavior in an equivalent task. Here the authors reported that GSs looked back at humans more frequently and for longer than CWDs.

In the current study, we used the C-BARQ questionnaire (Hsu & Serpell 2003) to gather information from dog owners on the behavioral profile of the CWDs and to compare this profile with that of the GSs and LRS, two modern pure breeds widely diffused as pet dogs. We administered the questionnaire to an Italian and a Czech sample of owners to evaluate possible cultural differences in the way the behavior of these three breeds was rated. The C-BARQ represents an useful tool for investigating dogs' behavior and several studies have used it to investigate breed differences in behavioral traits making comparisons with previous findings possible (Serpell & Hsu 2005; Duffy et al. 2008; van den Berg et al. 2010; Duffy et al. 2014).

Our results show that the scores given by both Italian and the Czech owners to their dogs' behavior were quite low (below 1) for some traits, higher than 1 or ranging between 2 and 3 in the remaining ones, with a certain degree of uniformity across the breeds. Except for a few differences, a comparable pattern of results emerged between the Italian and the Czech sample. These C-BARQ scores are in agreement with those reported by (Serpell & Duffy 2014) in a study on the behavioral traits of the most popular breeds registered by the American Kennel Club. In this study the average scores on the aggression factors (i.e. stranger, dog and owner directed aggression and dog rivalry) tended to be low: in particular, LRs scores were very low for all the aggression factors, whereas GSs scores were somewhat higher on stranger and dog directed aggression. Similarly, the scores for the fear factors across breeds (i.e. stranger-directed fear, dog-directed fear, nonsocial fear separation-related behavior and touch sensitivity) tended to be skewed toward zero. The authors suggested that these results on aggression and fear could depend on relatively intense selection against excessive

levels of aggression in dogs, particularly when directed toward human members of the same household, and in favor of less neophobic individuals. Serpell and Duffy (2014) also found a high degree of uniformity among breeds in scores on attachment/attention seeking and excitability (i.e. showing strong reactions to potentially exciting/arousing events) with average scores of 2, and breed differences in trainability with some working breeds (including golden and Labrador retrievers) obtaining high average scores (higher than 2).

Overall, in both the Italian and the Czech sample some differences between CWDs, GSs and LRs emerged despite a great deal of variability in individual dog behavior. In according with others (Duffy et al. 2008; Serpell & Duffy 2014) we found a great within-breed variability in C-BARQ scores: this suggests that in our study a dog's propensity for a given behavior (e.g. aggression or attention-seeking) does not depend simply on the breed, but also on individual differences and factors including the way the owner handles their dogs or the training received. In addition, all questionnaire reports inevitably involve a degree of subjectivity, and it is possible that Italian and Czech owners' answers were to some extent influenced by both popular breed stereotypes, their own beliefs and/or perceptions on their dog behavior or the tendency to not choose extreme values when it comes to describe their own pet.

As regard the Italian sample**,** breed and/or sex related differences were limited, both from an interpretative and a statistical point of view. Males GSs and LRs were considered more excitable and more prone to react to potentially exciting/arousing events than females; conversely, males CWDs were considered less excitable than females. A similar trend emerged for attachment and attention-seeking behavior: GSs and LRs males were rated as more prone to keep close proximity to the owner/other members of the household and to seek affection or attention, displaying agitation when the owner attended to third parties (i.e. attachment); CWDs females were depicted as more attached than males. Tonoike et al. (2015) showed that dogs in the ancient and spitz breeds present lower attachment and attention-seeking behavior when compared with modern dogs. When comparing dingoes with modern and ancient dog breeds, Smith et al. (2017) also found a difference between the latter two but, surprisingly, dingoes showed no difference with either groups.

Generally, male dogs belonging to all three breeds were rated as more aggressive towards conspecifics, more excitable and active, and more prone to show attention-seeking behavior than females. This finding confirms previous evidence suggesting gender differences in the two sexes with males being aggressive or express more traits related to boldness (e.g. lower frequency of fearful behaviors) (Hsu & Sun 2010; Starling et al. 2013; Dinwoodie et al. 2019). In addition, males were viewed as less trainable and less prone to engage in chasing behavior than females. Interestingly,

there was no difference in behavior between neutered and non-neutered dogs. Whether sterilization has an effect on the behavior of pet dogs or not is still a matter of discussion (e.g. Kaufmann et al. 2017; Gfrerer et al. 2019) and our result seem to support the second hypothesis.

CWDs, regardless of sex and training, were reported to be less fearful towards strangers compared to GSs and to LRs which in turn were comparable. This breed was also reported to be less fearful of non-social stimuli, and the difference was significant with respect to GSs, which in turn were similar to LRs. This could be probably explained by reference to the original function of the breed, CWDs were bred trying to keep the best traits of a GS and the strength and resiliency of a wild animal.

Finally, there was an effect of training, with dogs without any training being rated by their owners as less trainable and more excitable, active, seeking for attention and prone to chasing. Aggressiveness towards strangers was comparable in trained males and females dogs; however, while in CWDs untrained male and female were alike for this behavior, GSs differed remarkably and untrained males scored higher than females; the same trend, but with a smaller difference, was found also in LRs. This last finding is in line with various studies showing that that life experiences, including training, affect dog' behavior and socio-cognitive abilities (Marshall-Pescini et al. 2009; Carballo et al. 2020).

In the Czech sample results were as follows: in all our breeds, excitability and energy level were not influenced by any of the factors considered (e.g. sex, breed, trainability). On the other hand, chasing, aggressiveness and trainability appear to be strongly influenced by the breed with LRs showing the lowest scores for these items. Irrespective of sex and training, LRs are also significantly less aggressive, towards strangers and other dogs, and less likely to show chasing than the CWDs and GSs.

GSs in our sample are comparable to CWDs for aggressiveness, both towards strangers and other dogs, and in chasing propensity; GSs were also considered more aggressive than LRs in another study, corroborating our results (Notari & Goodwin 2007). Although, this breed is similar to LRs when it comes to trainability, fear of strangers and separation-related behavior. Once again, these results can be explained referencing to the working roles of the breeds. A selection for stranger-directed aggression makes sense in the context of their widespread use as guard dogs, while high scores obtained for chasing might reflect a selection for hunting dogs.

In contrast with the Italian sample, CWDs appear to be significantly more afraid of strangers, show more separation anxiety behaviors and are less trainable than both GSs and LRs. This difference

in the scoring might be affected by a cultural difference between the two countries and it is clear that trainers in the two countries use a different approach with their dogs, especially when it comes to more '*wild'* breeds. Hence, this difference could be a product of a difference in attitude about the 'ideal dog' behavior.

Regardless of breed and training, our breeds present a difference between the two sexes. Males are significantly more aggressive than females. The same trend is not surprising and emerged also in the Italian sample, confirming once again a general tendency found in other studies too (Hsu & Sun 2010; Starling et al. 2013; Dinwoodie et al. 2019).

Finally, training seems to have an influence on stranger and non-social fear, with trained dogs being less fearful than untrained ones. Trained dogs are often exposed to different stimuli and/or socialization which might help them to learn, together with the owner, how to react to a situation in a less instinctive way (Hakanen et al. 2020). Furthermore, trained dogs are also less attention-seeking, less prone to chasing and, of course more trainable.

Although a broader sample size (i.e. more individuals but also more breeds) and further research in both Italy and the Czech Republic are necessary, use of the C-BARQ confirms to be advantageous to understand the genetic influences on behavioral traits.

Conclusion

In the current study, owners of LRs, GSs and CWDs in Italy and the Czech Republic reported on their dogs and rated their behavior. We found many similarities between reports from the two countries but also some interesting divergencies. Overall, the data we collected on the three breeds in Italy and the Czech Republic are expression of cross-cultural differences. It appears clear that dogs and the way they are kept, but also the owners' perception of their pet, vary considerably around the world. This should be considered when interpreting the results of a study on dog cognition and behavior as, normally, dogs are recruited within a single country, region, or even city, while the following scientific findings are often applied to dogs in general.

4. Study III

Dogs providing emotional comfort for the owner look more at a familiar rather than an unfamiliar person in an ambiguous situation

Enikő Kubinyi[1], Andrea Sommese[1], Márta Gácsi[2], Ádám Miklósi[1,2]

[1]Department of Ethology, Eötvös Loránd University, Budapest, Hungary

[2]MTA-ELTE Comparative Ethology Research Group, Budapest, Hungary

Abstract

Looking at humans plays a key role in dog-human communication. The present study was designed to characterize dogs based on their referential looking behavior and investigate the link between personality and dog-owner relationship. We observed the behavior of 163 dogs in an ambiguous situation when they encountered a novel object for 1 minute. Before testing, we also collected data on the personality of the dogs and the emotional comfort they provide via a questionnaire filled in by their owners. Cluster analysis suggested four groups based on the looking at the owner and looking at the experimenter behavioral variables. In Cluster 1, dogs looked at the familiar and the unfamiliar human partners 2-3, in Cluster 2 6-7, in Cluster 4 9-12 times. However, in Cluster 3, dogs looked 10 times at the owner and only 4 times at the experimenter when they encountered the novel stimulus. According to the owners, these dogs provided more emotional comfort to them than dogs looking infrequently at both humans (Cluster 1). The latter group was also reported to be more aggressive with both humans and dogs. Dogs looking frequently at both humans (Cluster 4), were reported as lively and aggressive. The results suggest that the relationship between referential looking at partners is not necessarily linked and it is associated with dog personality and the relationship with the owner.

Introduction

Looking at others during social interaction is one of the main nonverbal communication signals in humans (e.g. Cook 1977). For example, looking at each other's faces helps humans to recognize others' emotions, this ability is crucial in human infants where language has not yet been acquired (Repacholi 1998) but later in life (i.e. around 10 months of age) can also be used to guide one's behavior (Mumme et al. 1996). Looking at social partners in ambiguous situations enables inexperienced individuals to rely on the displays of the partner for evaluating the situation. Social referencing allows avoiding mistakes and it may be advantageous especially to young and inexperienced individuals (e.g. Itakura 1995; Tomonaga et al. 2004; Roberts et al. 2008). Many studies showed the existence of social referencing in humans, already at a young age (Vaish & Striano 2004; Hoehl et al. 2008). Toddlers and infants look at the informant (generally the caregiver) and adjust their behavior according to the emotional message they receive (Walden & Ogan 1988).

In non-human species, the evidence for social referencing is mixed, and it varies according to the species, the familiarity of the partner, and even the age of the tested subject. Itakura (1995) used the social referencing paradigm to investigate the responses to novel objects of mother-infant dyads of captive chimpanzees. He found that the infants looked at and returned to the mother more often in the presence of a novel object than in its absence. Russell et al. (1997) described the behavior of young nursery-reared chimpanzees facing the same paradigm but although the individuals were not with the mother but with a familiar caregiver. Each chimpanzee looked at their caregiver and adjusted their behavior toward the novel objects to the emotional information that they received. In contrast, Tomonaga et al. (2004) found no evidence of such a phenomenon in captive chimpanzees. Roberts et al. (2008) used a similar paradigm to investigate the gazing behavior of barbary macaque (*Macaca sylvanus*) infants and their mothers. Only a few gazed at their mother when the novel object was present but the older infants did that more than the younger ones. Even though in this study the mother was not able to see the object which makes the evaluation of this experiment difficult.

Dogs gaze back at humans if they are not able to obtain a desired object (Miklosi et al. 2003) and many studies show that they are sensitive to the direction of the human body and gaze (e.g. Gacsi et al. 2004; Viranyi et al. 2004; Kaminski et al. 2009; Savalli et al. 2016). Hence, dogs can communicate with humans both intentionally and referentially in a variety of situations (e.g. Polgárdi et al. 2000; Marshall-Pescini et al. 2009; Merola et al. 2012a). Merola et al. (2012a) estimated the occurrence of gazing behaviors in dogs in an ambiguous situation that did not involve requesting an object or food. For this scope, they observed the behavior of several dogs in presence of a novel, and potentially scary, object. Most of their subjects looked at the owner when the object was in the room

but there was almost no difference in their behavior when the owner was approaching the object in a positive or negative manner. In a following study (Merola et al. 2012b), they tested dogs using the same paradigm but this time either the owner or a stranger was acting as the informant. Their results showed that most dogs gazed back at either informant. When the owners were giving a positive emotional message (i.e. talking to the dog with a happy voice and happy facial expressions), dogs looked at them more often and spent more time near the object. However, if the owners were giving a negative message (i.e. using a fearful voice and facial expressions) the dogs approached and interacted less with the object. Overall, similar results were obtained when the stranger acted as the informant.

More recently, Fugazza et al. (2018) tested 8-week-old pet dog puppies by exposing them to a novel stimulus while a human or a conspecific was present. The puppies alternated their gaze between the novel stimulus and the social partner in every condition. When tested with humans showing positive vocal and facial signals, the dogs were more likely to interact and moved closer to the novel object. Even after a one-hour delay, the puppies regulated their behavior based on what they experienced previously. Nevertheless, very little is currently known about the potential effects of age, personality, and life experiences on gazing behavior in ambiguous situations.

Dogs also display gazing behavior in the so-called 'unsolvable/impossible task' paradigm. In this setup, after several opportunities to obtain the target object, the dog is faced with a situation when the object is not available anymore. Dogs' tendency to look towards people (i.e. the owner and/or the experimenter) is usually considered as the initiation of a communicative interaction (Miklosi et al. 2003; Cavalli et al. 2019). Looking at humans during an unsolvable task seems to be affected by several factors such as genetic factors (Hare et al. 2002; Persson et al. 2015; Sommese et al. 2019), life experiences (Barrera et al. 2011; D'Aniello & Scandurra 2016), age (Passalacqua et al. 2011a) and training (Marshall-Pescini et al. 2009; Lazarowski et al. 2020).

Personality traits might also play a role in modulating gazing behavior. Personality is generally defined as the consistency of inter-individual behavioral traits through time and across contexts (Gosling 2008; Fratkin et al. 2013). Jakovcevic et al. (2012) investigated the effect of personality traits on gazing behavior in dogs. They showed that dogs with highly sociable personality trait looked at humans and persevered in their communication attempts significantly longer than less sociable ones. Passalacqua et al. (2013) investigated the influence of anxiety during an unsolvable task. Dogs with high levels of anxiety looked at and sought for physical contact with the experimenter for longer.

For this study, we investigated whether dogs can be categorized based on their gazing behavior in ambiguous situations and whether there is an association between gazing behavior and personality

traits measured by the means of questionnaires. We deployed the Budapest Canine Personality Survey (Wan et al. 2009) that provides scores for four main scales: liveliness, confidence, aggressiveness, and attachment to humans.

We used a remote-controlled toy care to elicit fear in dogs (King et al. (2003), and observed their looking pattern in the presence of an owner and a stranger. When facing an ambiguous situation, dogs showed also the tendency to stay close to their owner even in the absence of any relevant emotional signal (Gácsi et al. 2013; Cimarelli et al. 2016). Moreover, staying in the proximity of their owner or handler is usually explained by dogs' displaying a 'freezing strategy' Walker et al. (1997) or by the 'safe-haven effect' (Gácsi et al. 2013; Cimarelli et al. 2016). Salamon et al. (2020) showed that when dogs are facing a 'threatening human' they tend to look more and stay close to the owner when this is reassuring them (i.e. talking with a relatively high-pitched voice and leaning towards the stranger). Hence, we expect that dogs scoring lower in confidence/higher in fearfulness rely more on their social partners and look at them more frequently.

Consequently, we also expect that dogs with a stronger emotional relationship with their owner stay close and look more frequently at them but not necessarily at the experimenter and, based on previous observations in the unsolvable task, we assume that dogs gaze more frequently when confronted with an ambiguous situation.

Previous working experiences and training might have an effect on dogs' attention that is related to the scope of the activities the dogs are trained for. In a selective attention test, where the owner and an unfamiliar experimenter performed a series of transit across a room, untrained dogs showed a higher frequency of gazes towards the owner compared to assistance and agility dogs (Mongillo et al. 2017). In light of this, we also assume that untrained family dogs would look more at their owners.

Materials and methods

Ethics statement

A written statement (PE/EA/3742-4/2016) was obtained from the Food Chain Safety and Animal Health Directorate Government Office based on the decision of the Scientific Ethics Council of Animal Experiments. According to this statement and the corresponding definition by law, the current non-invasive observational study is not an animal experiment, therefore it is currently allowed without the need for permission from the University Institutional Animal Care and Use Committee (UIACUC, Eötvös Loránd University, Hungary).

Subjects

163 dogs (mean age=4.36, SD=2.94, min=0.6, max=14 years; 57% males, 40% neutered, 24% untrained) were recruited from volunteers of the Family Dog Project database in Budapest, Hungary. Mixed breeds, Labrador retrievers, Golden retrievers, German shepherd dogs, and Border collies were represented by more than 10 individuals. Trained dogs participated in one or more of the following courses: obedience, agility, assistance, therapy, herding, guarding, detection, dog dancing, search and rescue.

Behavior test: Encountering a novel stimulus

All dogs were tested in an unfamiliar room (3x6 m2) at the Department of Ethology. In the room, there was a chair for the owner (O), a large bag with books on it, an empty bin, a small table, a file folder, a paper box, a bag, and a chest of drawers where some relevant objects were kept. Four cameras in each corner of the room videotaped all testing sessions. During the testing, dogs (D) were off-leash and free to move through the room. The test was part of a larger test battery labelled as Social Interaction Test (Kubinyi et al., in. prep). Before the test the dogs were encouraged to fetch objects, meet an unfamiliar, friendly woman, and were briefly (~1 minute) separated from people, therefore they became acquainted with the testing room and the experimenter (E).

In the encountering a novel stimulus test, E entered the room and took out a remote-controlled car from the drawer, posited it on the floor, and started to follow D with the car for 20 seconds (active phase). Then E stopped the car under O's chair and we recorded D behavior during the next 40 seconds (passive phase).

Based on video recordings, we counted the number of looking at the owner and the experimenter in both phases. As looking was a short event, the occurrence provided more precise information than duration. We also coded when the dog approached the car: in the active phase, in the passive phase, or never. To assess the inter-observer reliability of the scoring N = 10 videos were coded by two observers.

Questionnaires

Before testing, each owner filled in a personality questionnaire about their dog, the Budapest Canine Personality Survey (BCPS, Wan et al. 2009), Table S1). This survey asks owners to rate their dogs on a five-point scale on 17 items. The ratings provide scores for four main scales: liveliness, confidence, aggressiveness, and attachment to humans. In addition, we asked three questions about the emotional comfort the dog provides to the owner: 1) My dog enables me to love somebody; 2)

My dog makes me feel loved; 3) My dog provides me more companionship than anyone else. The BCPS survey was missing for 17 dogs and the emotional comfort survey for 36 dogs.

Statistical analysis

The inter-rater reliability of the variables was analyzed using a two-way random intraclass correlation, looking for absolute agreement between average measures. The reliabilities were satisfactory (ICC>0.7, N=10). The internal consistency of the 3 emotional comfort questions was checked with Cronbach's alpha and it was good (0.746), therefore we calculated a mean from the 3 questions and labelled the score as "emotional comfort". Two-step cluster analysis with Akaike's Information Criterion was used for grouping the dogs based on the looking at the owner and looking at the experimenter variables. We investigated the relationship between the clusters, the looking at O/E, age, the four-personality trait, and emotional comfort scale scores with Kruskal-Wallis tests with pairwise comparisons. The relationship between training status (trained vs untrained), approaching the car and the clusters were investigated with Chi-square test. We used SPSS v25 for the statistical analysis.

Results

The cluster analysis revealed four clusters (fig. 15). Kruskal-Wallis test confirmed that the clusters differed in the numbers of looking at the owner ($KW = 112.9$, $p < 0.001$) and looking at the experimenter ($KW = 118.65$, $p < 0.001$). According to pairwise comparisons, in Cluster 1 ($N = 55$) the number of both looking at the owner and the experimenter was low (median = 2 vs 3, lowO-lowE). In Cluster 2 ($N = 56$) the number of both looking at the owner and the experimenter was middle (median = 6 vs 7, midO-midE). In cluster 3 ($N = 41$) the number of looking at the owner was high, looking at the experimenter was low (median = 10 vs 4, highO-lowE). In cluster 4 ($N = 15$), the number of looking at the owner was middle-high, looking at the experimenter was high (median = 9 vs 12, midhighO-highE).

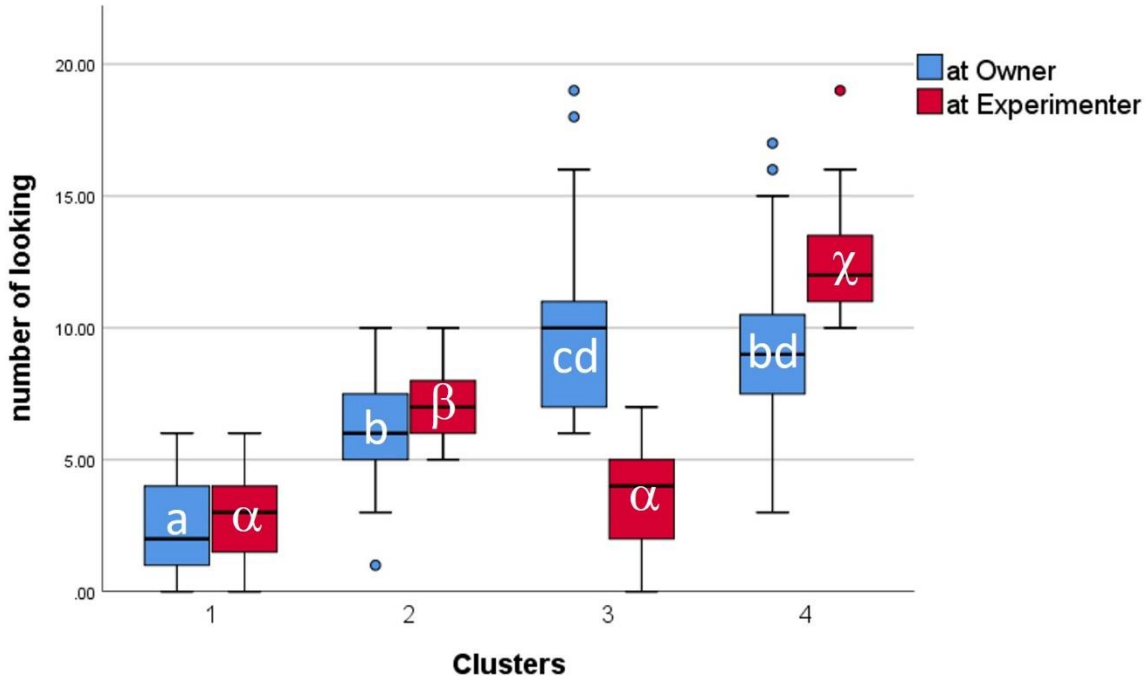

Figure 15. The mean number of looking at the owner and the experimenter. According to pairwise comparisons: cluster 1 (N = 55, median = 2 vs 3, lowO-lowE), cluster 2 (N = 56, median = 6 vs 7, midO-midE), cluster 3 (N = 41, median = 10 vs 4, highO-lowE), and cluster 4 (N = 15, median = 9 vs 12, midhighO-highE). Within a category, different letters mean significant differences.

The liveliness personality trait score was higher in cluster 4 (midhighO-highE) than in cluster 2 (midO-midE) (KW = 10.633, p = 0.014, median = 4.09 and 3.50, 95% C L= 3.50-4.50 and 3.33-3.67 respectively).

Aggression was reported to be higher in cluster 1 (lowO-lowE) and cluster 4 (midhighO-highE) than in cluster 2 (midO-midE) (KW = 13.325, p=0.004, median = 2.67, 3.00 and 2.33, CL = 2.67-3.00, 3.00-4.00 and 2.33-2.67 respectively).

The emotional comfort score was higher in cluster 3 (highO-lowE) than in cluster 1 (lowO-lowE) (KW = 9.918, p = 0.019, median = 4.00 and 3.33, CL = 3.67-4.67 and 3.33-4.00 respectively). Confidence, attachment, and age did not differ between the clusters, nor did the proportions of trained vs untrained status; males vs females; neutered vs intact status. 67% of dogs approached the car in the active phase, 14% in the passive phase, 19% never. Clusters did not differ in the proportion of dogs approaching at different times.

Discussion

The novel object test is used to quantify fear and exploration of novelty and it was deployed in many studies on numerous species (e.g. Bremner-Harrison et al. 2004; Boogert et al. 2006; Krueger et al. 2014; Brown & Jones 2016). The present study was carried out to characterize dogs based on their gazing behavior towards humans in an ambiguous situation. We assumed that looking at the owner and looking at other humans in ambiguous situations do not necessarily correlate. We also hypothesized that gazing behavior toward humans is linked to personality traits.

Dogs in cluster 1 were looking less at both the owner and the experimenter. These dogs probably behave independently in everyday situations. Dogs in cluster 2 looked at both human partners more often than dogs in cluster 1. Dogs in cluster 3 seemed to have a strong preference for the owner: they looked more frequently at the owner than at the experimenter. This may indicate that these dogs have a closer social relationship with the owner (Topal et al. 1997). Finally, dogs in cluster 4 displayed the most cases of looking behavior overall but they looked at both the human and the experimenter at a similar frequency. This may indicate a higher level of social fear, and these dogs may score high on the acceptance of stranger trait, measured in the Strange Situation Test (Topál et al 1998).

Dogs in cluster 1 (lowO-lowE) were reported to be more aggressive with both humans and dogs by our personality questionnaire. Svartberg (2005) suggested that aggressiveness is negatively related to the social interest which could explain why the dogs in our sample gazed less at both the owner and the experimenter in the room. Dogs in cluster 2 (midO-midE) were the least lively and least aggressive according to the owners. Dogs in cluster 3 (highO-lowE) scored high for emotional comfort. These dogs probably rely preferentially on their owner and they have a strong relationship with them (Gácsi et al. 2013; Cimarelli et al. 2016; Salamon et al. 2020). Interestingly, the dogs that looked more frequently at both humans, in cluster 4 (midhighO-highE), were reported as livelier and but also more aggressive. Aggressiveness is also positively related to fear of strangers (Svartberg 2005), these dogs might have been extremely careful towards the experimenter and looked in that direction more often.

We assumed that dogs with lower scores in confidence/higher scores in fearfulness look at any of the social partners more frequently while facing an ambiguous situation. The present observation did not support this idea. We also expected that dogs with a stronger emotional relationship with their owner spend more time looking at them and not necessarily at the experimenter. Our results supported that some dogs (25% in the present sample, cluster 3 in fig. 15) looked more frequently at the owner than at the experimenter when they encountered a novel stimulus (a moving remote-controlled car). This group provided more emotional comfort to the owners than dogs looking infrequently at both human partners (cluster 1).

Finally, in contrast to our expectations training experience did not affect the looking behavior in our test. According to Carballo et al. (2020) training experience is a too broad category. There could be some overlap between working and companion dogs in terms of training while the latter dogs are trained only "informally". Several different forms of dog training courses may affect the human-dog relationship in opposite ways. Dogs trained the blind may develop a different connection with their owner than dogs pulling sleds.

It has often been reported that dogs' behavior can be predicted to some extent by the breed or the breed group (Passalacqua et al. 2011a; Konno et al. 2016). One of the possible limitations of this study is that our companion dogs' sample did not include a large variety of breeds which could explain the lack of a stronger association between gazing pattern and personality traits. A related strength of this study is that our sample was fairly represented by mixed-breed dogs (N = 39 and N = 3 mixed Labradors). These dogs represent the majority of the entire dogs' population and studies about their behavior are scarce. Interestingly, Turcsán et al. (2017) demonstrated that purebred and mixed-breed differ in some of their personality traits, and the frequency of behavior problems reported by the owner.

In summary, we corroborate the idea that personality and type of training may influence the way dogs to look at their owners. Hence, dogs apply different gazing strategies in ambiguous situations depending on specific personality traits.

In further studies, researchers should investigate more the effect of the training to which the dogs are exposed as different studies led to different conclusions. Moreover, a broader diversity of breed groups should be included when possible. Finally, new studies are needed to investigate the association between gazing patterns in an ambiguous situation or problem-solving tasks and specific personality traits (Jakovcevic et al. 2012; Passalacqua et al. 2013; Gobbo & Zupan 2020).

5. General discussion

Communication is a necessary process for every social interaction. Canids are highly communicative and, in this regard, domestication has also clearly influenced pet dogs. Dogs showed exceptional skills in communicating with people, being able to respond to a variety of human communicative cues like nodding and pointing (e.g. Gacsi et al. 2004; Hare & Tomasello 2005; Reid 2009; Topál et al. 2009) but they are also able of producing communicative signals to interact with and influence the behavior of their human partner. Dogs can attract the attention of an observer and direct it towards a wanted object or location, i.e. "gaze alternation" (Polgárdi et al. 2000).

Most studies that focus on dogs' gazing behavior towards humans usually involve a difficult or unsolvable problem (Cavalli et al. 2019). When dogs encounter this kind of situation, they tend to respond by looking at people, showing gaze alternation between the apparatus and the human face (Miklosi et al. 2003). The occurrence of this behavior has been interpreted as a request for help. Interestingly, some dogs manifest it even when confronted with a task that they perceive as difficult but not actually unsolvable.

In our first study, we wanted to explore the potential effects of breed and development on dogs' human-directed communicative behavior in an unsolvable task. For this goal, we selected a relatively recent breed with a very well documented history the Czechoslovakian Wolfdog and we compared our results to their parental-breed the German shepherd.

We did not find any real support for the presumption that looking back in Wolfdogs would be modified by the level of obedience and time the owner had spent training and living with the subject as shown for other domestic dogs (Marshall-Pescini et al. 2008; Marshall-Pescini et al. 2009; Scandurra et al. 2016). We also did not find any age effect as suggested in previous studies (Passalacqua et al. 2011b; Persson et al. 2015). In contrast to our prediction and based on previous findings (D'Aniello & Scandurra 2016), the Wolfdogs with limited exposure to humans, such as those living outside the home environment, interacted using gazing behavior towards humans equally to those living as members of human families. As it stands so far, we did not find any strong ontogenetic effect in our sample.

When compared to the Czechoslovakian Wolfdogs, the probability for German shepherd dogs to look back during the experimental impossible trial was higher and also the duration of this behavior was longer. German shepherds were 9.3 times more likely to gaze at a nearby human than the Wolfdogs. Nevertheless, the latency of expressing this behavior was not significantly different.

The occurrence of personality in animals has been studied for decades using many different approaches (Weiss & Gartner 2017). Several studies have been carried out to describe the

characteristics and the personality traits of numerous dog breeds but none have yet focused on modern breeds like the Czechoslovakian wolfdog. In this framework, the C-BARQ (Hsu & Serpell 2003) represents a good measurement tool to study dog behavior. This questionnaire offers results from studies carried out in different countries and the way to perceive the dog-owner interaction seems to be different from one culture to another. In our second study, we wanted to offer a behavioral profile for our breeds. We chose German shepherds and Labrador retrievers as they are commonly kept as pet dogs, whilst the Czechoslovakian wolfdog has become more and more popular only recently (Caniglia et al. 2018). The second aim of our study was to provide a cross-country evaluation for dogs from Italy and the Czech Republic. We wanted to assess whether cultural differences between the two countries influence the ownership and behavioral characteristics of the dogs.

In both the Italian and the Czech samples the same differences between the breed emerged but not as much as we expected. Overall, the Czechoslovakian Wolfdogs in the Italian sample were considered to be more aggressive. This difference in the scoring might be affected by a cultural difference between the two countries and it is clear that trainers in the two countries use a different approach with their dogs, especially when it comes to more '*wild'* breeds. The use of the C-BARQ is advantageous to understanding the genetic influences on behavioral traits and to possibly assist in identifying the genes responsible for behavioral disorders.

Personality traits might also modulate gazing behavior in variety of tasks. Hence, the third study was carried out to characterize dogs based on their gazing behavior towards humans in an ambiguous situation. In parallel, owners were asked to fill in a questionnaire about the personality of their dog. We assumed that looking at the owner and looking at other humans in ambiguous situations do not necessarily correlate. We also hypothesized that gazing behavior toward humans is linked to personality traits.

Dogs in cluster 1 were looking less at both the owner and the experimenter. These dogs probably behave independently in everyday situations. Dogs in cluster 2 looked at both human partners more often than dogs in cluster 1. Dogs in cluster 3 seemed to have a strong preference for the owner: they looked more frequently at the owner than at the experimenter. This may indicate that these dogs have a closer social relationship with the owner (Topal et al. 1997). Finally, dogs in cluster 4 displayed the most cases of looking behavior overall but they looked at both the human and the experimenter at a similar frequency. This may indicate a higher level of social fear, and these dogs may score high on the acceptance of stranger trait, measured in the Strange Situation Test (Topál et al 1998).

While several studies have investigated problem-solving behavior in dogs, only a few have analyzed the relationship between these abilities and personality traits (Jakovcevic et al. 2012;

Passalacqua et al. 2013; Gobbo & Zupan 2020). Our results corroborate the idea that personality and type of training may influence the way dogs gaze at their owners. Hence, dogs apply different gazing strategies in ambiguous situations depending on specific personality traits.

5.1 Conclusions

Miklosi et al. (2003) seminal work surely ignited an ongoing interest in dogs' communicative abilities. Whether exhibited by conspecifics or humans, dogs seem to have an extraordinary understanding of gazing and this behavior can carry different meanings depending on the context. Dogs appear to be able to use gazing as a referential cue and as a cue to understand human attention states. Dogs might also be able to use gazing as an ostensive cue. Considering all the studies and the different paradigms, the emerging pattern is the flexibility that dogs exhibit when it comes to communicating with humans, but further research is necessary. Studies suggest that dogs are able to use cues to communicate with their human partners intentionally and referentially. A continuously growing body of research converges on the point that dogs show gaze alternation when in a requesting context and when they try to achieve the desired goal. Moreover, dogs also look toward a human partner before approaching a new and potentially scary object, and they are able to take into consideration their partner's emotional state. This suggests that looking toward humans might serve as a way to synchronize their behavior with the partner in order to respond to environmental stimuli. Studies comparing hand-raised wolves and dogs, different breeds, using genetic methods and different paradigms, all suggest that this behavior is a combination of ontogeny and phylogeny. Clearly, now, the investigation of this aspect is relatively limited and future studies are needed to achieve a better understanding of the phenomenon.

With our studies, we support the idea that dogs' capability and predisposition to communicate with humans have been changed for the most part through domestication but further research is hence needed to clarify the issue. Personality and individual behavior also influence the way dogs communicate with their owners and handlers. We suggest investigating more in-depth the effect and the style of the training to which the dogs are exposed. Moreover, it would be interesting to compare a peculiar breed such as the Czechoslovakian Wolfdog to other well-studied breeds with a longer domestication history in order to get a fuller picture and elucidate the differences between the groups.

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Supplement

List of scientific contributions

Scientific papers:

- Kubinyi E., **Sommese A.**, Gácsi M., Miklósi Á.: ‘Affectionate assistance and therapy dogs gaze more at humans’ (under review)
- **Sommese A.**, Prato-Previde E., Pelosi A., Valsecchi P.: ‘Comparing behavioral characteristics of Czechoslovakian Wolfdogs, German shepherds and Labrador retrievers’ (under review)

- Czeibert, K., **Sommese, A.**, Petneházy, Ö., Csörgő, T., & Kubinyi, E. (2020). Digital endocasting in comparative canine brain morphology. Frontiers in Veterinary Science.
- Fugazza, C., **Sommese, A.**, Pogány, Á., & Miklósi, Á. (2020). Did we find a copycat? Do as I Do in a domestic cat (Felis catus). Animal Cognition, 1-11.
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- Saggiomo L., Picone F., Esattore B., **Sommese A.**: ‘An overview of understudied interaction types amongst large carnivores’. Food Webs, 12, 35-39.
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Publications in book of abstracts and conferences:

- Dror S., **Sommese A.**, Pogány Á., Temesi A., Miklósi Á., Fugazza C. (2020), oral presentation: "Where is my ball? I cannot see it!" - Multimodal Mental Representation of Objects in a Family Dog. ABS virtual conference.
- Dror S., **Sommese A.**, Temesi A., Fugazza C. (2019), poster: Can dogs learn words? Magyar Etológiai Társaság XXI konferenciája.

- **Sommese A.**, K. Nováková, N. Šebková Fiala, L. Bartoš (2018), oral presentation: A Wolfdog Point of View on the 'Impossible Task Paradigm'. Sixth Canine Science Forum.
- **Sommese A.**, K. Nováková, N. Šebková Fiala, L. Bartoš (2017), oral presentation: The degree of communication between humans and dogs, wolfdogs and wolves in association with the genetic background. Fourth European Student Conference on Behavior and Cognition.
- **Sommese A.** (2016), oral presentation: Sulle orme del lupo. In collaboration with ARDEA Onlus, Associazione Cibele, Sci Club Fondo Matese, Az. Agroturistica "Falode" and the Regional Park of the Matese.

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