Gazing behavior during problem solving tasks in domestic dogs. A critical review

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Abstract: In the last few years, several studies have assessed dogs' behavior when confronted with solvable or unsolvable tasks in the presence of human partners. In these situations, dogs tend to gaze towards people, which has been regarded as a help requesting behavior. This ability to attract the attention of a partner towards a target object is consistent with referential signaling and would have a similar function than pointing in human infants. The aim of this work is to review dogs' communicative behaviors during unsolvable or solvable but difficult tasks, particularly gazing at the human face. To be included in this review, a study had to feature a problem solving task and analyze gazing behavior towards people in the experimental situation. The relevant topics of discussion were grouped into three conceptual areas. The first one focuses on methodological aspects such as the procedures and apparatuses used, the people present during the test and the behaviors analyzed. The second one discusses some factors which could influence the display of gazing behavior, like species, training experience, living conditions and breed. Finally, a third one comprises neurobiological studies, such as research on heritability and receptor genes as well as the effects of intranasal oxytocin administration on this behavior. Overall, we conclude that gazing behavior to request for help appears to be a prevalent and robust response among dogs, although alternative explanations must be considered. To this end, ideas for further research are proposed.

Key Words: gazing behavior; unsolvable task; problem solving; domestic dogs.

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Introduction

Dogs are a particularly interesting species for the comparative study of social cognition. They have shown exceptional skills in communicating with people, displaying sensitivity to a wide array of human communicative cues like nodding and pointing (e.g., Gácsi et al., 2004; Hare & Tomasello, 2005; Reid, 2009; Topál et al., 2009) as well as to our attentional states (e.g., Virányi et al., 2004; Kaminski et al., 2009).

Besides responding to these signals, dogs are also capable of flexibly producing communicative cues to influence human behaviors. One of the most studied, is gazing towards the human face. Dogs are able to attract the attention of an observer and direct it towards an object or location both by directly looking at the partner, and by consecutively looking to a target and a person or vice versa (i.e. "gaze alternation") (e.g., Miklósi et al., 2000). This behavior is consistent with the definition of referential signaling, which describes the ability to direct the attention of an observer to a distant object (Leavens et al., 2004). In species without hands, gaze alternation is thought to have similar referential functions as pointing in humans (e.g., Leavens & Hopkins, 1998; Heberlein et al., 2016).

Most studies that focus on dogs' gazing behavior towards humans involve two different paradigms: in some tasks, a reward is located out of the animal's reach, while in others the animal faces a difficult or unsolvable problem (Prato-Previde & Marshall-Pescini, 2014).

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Regarding the first type of situation, Miklósi et al. (2000) carried a pioneer investigation. In this study, dogs witnessed a toy or piece of food being hidden in a place they could not access, while the owner was not in the room. When the owner came back, dogs looked alternatively to the baited location and the owner or vice versa, engaging in what was considered 'showing behavior'. Likewise, Gaunet & Deputte (2011), carried out a similar study and found that dogs positioned themselves close to the toy, which implies that they may also inform about the location of a desired object by using their body position as a local enhancement cue.

Thus, in these protocols, dogs' gaze alternation would function as a referential communicative behavior (Leavens et al., 2005; Gaunet & Deputte, 2011) employed to "show" a target location to a human partner. Miklósi et al. (2000) defined showing as a communicate behavior involving a directional component referring to an external target as well as an attention getting element to call the attention of the receiver.

Additionally, gazing has also been analyzed when dogs are confronted with a problem solving task. In the unsolvable task paradigm, dogs encounter a problem they cannot solve on their own, because the apparatus is locked or blocked. Dogs tend to respond by gazing toward people, along with gaze alternation between the apparatus and the human face, which have been considered as help requesting behaviors (Miklósi et al., 2003). Moreover, other studies feature solvable tasks, as dogs may request help from people when confronted with a task they perceive as difficult, even if it is not actually unsolvable.

Gaining insight on the extension and special features of dogs' communicative skills is a topic of current interest in the field of canine social cognition. Therefore, in the last few years, several studies have been published featuring solvable and unsolvable tasks in the presence of human partners, in order to assess dogs' behaviors directed to them. The aim of this work is to review dogs' communicative behaviors, particularly gazing at the human face, during unsolvable or solvable but difficult situations. The focus will be on analyzing factors that seem to influence gazing behavior, comparing the results of different works and proposing lines for further investigation. To this purpose, the analysis of the literature is divided into three areas. The first one concerns methodological aspects such as the characteristics of the tasks and apparatuses utilized, the people present during the test, and the behaviors analyzed. The second one refers to different factors which could influence the display of gazing behavior, like species, training experience, living conditions and breed. Finally, a third one comprises neurobiological studies, such as research on heritability and gene receptors as well as the effects of intranasal oxytocin administration on this behavior.

To be included in this review, a study had to feature a problem solving task and analyze gazing behavior towards people in the experimental situation. A total of 23 studies, published from years 2003 to 2017, were reviewed.

1. Methodological aspects

There is great variability concerning the type of apparatuses used during these tasks, the procedure itself, the familiarity of the people who were present during the test and their behavior. These topics will be covered in different subsections, highlighting similarities and differences among the reviewed works. Finally, this section will end with an outline of the behaviors usually analyzed, including operational definitions of gazing.

1.1. Apparatuses

Several studies featuring unsolvable tasks employed a similar device, consisting of a rectangular wooden board with a clear container placed upside down in the middle. Depending on the trial, the dog could move the container, or it was screwed to the board in order to make the food

inside inaccessible. Usually, the container was square shaped and made of plastic (Marshall-Pescini et al., 2009; Passalacqua et al., 2011; Marshall-Pescini et al., 2013; Passalacqua et al., 2013; Konno et al., 2016). In the case of Hori et al. (2013) dogs were given a lidded plastic container but it was not fixed to a board. Additionally, in Piotti et al. (2017) during the unsolvable trials the plastic container was covered with a metal basket attached to the board. Conversely, other studies have used glass containers in similar apparatuses (D'Aniello, et al., 2015; Scandurra et al., 2015; D'Aniello & Scandurra, 2016). Finally, in the study of Marshall-Pescini et al. (2017a), while dogs were confronted with a plastic container, a stainless-steel bowl was used for wolves, in order to make the task equally challenging to both species.

Other situations used in literature include rope pulling tasks in which a piece of rope has food attached in one end, but during unsolvable trials it is fixed in a way the animals cannot pull it (Miklósi et al., 2003; Smith & Litchfield, 2013). Furthermore, Miklósi et al. (2003) and Gaunet (2008) used plastic bins with a lid that could be fixed in place for the blocked trials. Moreover, Kovács et al. (2016) employed a wire mesh cage with a door that could be locked for the unsolvable trial.

Finally, some authors built novel apparatuses for their studies. For example, in Horn, et al. (2012) they made a device consisting of two wooden discs screwed on top of each other with six inner food containers that dispensed food when the upper disc was rotated. The apparatus had a mechanism that could block the rotation of the upper disk, locking it in position so no more food was dispensed. Moreover, in Persson et al. (2015, 2017) the device for the unsolvable task consisted of three plates on a base which were covered with transparent Plexiglas lids. While two of the covers could be easily moved to the side to access the food underneath, the middle lid could not be opened.

In contrast, other studies focused on solvable tasks. To this end, Marshall-Pescini et al. (2008, 2016) carried out a manipulation task using a plastic feeding box fixed to a wooden board, which could be opened by pressing a pad or nosing the lid. Furthermore, other works used plastic containers with a nylon rope inserted through the lid (i.e. 'puzzle box', in Udell, 2015; Brubaker et al., 2017). This set up allowed the dogs to open it by shaking the rope, dislodging the lid or manipulating the plastic until it broke. In Bhattacharjee et al. (2017) a similar apparatus was used in the so called unfamiliar task, while the familiar task consisted of a plastic bag containing raw chicken the dogs could readily access by ripping it open.

All in all, several types of apparatuses have been used to test dogs' help requesting behaviors when faced with a difficult or impossible task. This lack of consistency hinders the comparison between different studies. On the other hand, the presence of gazing in all those situations suggests that help requesting appears to be a prevalent and robust response among dogs, regardless of the characteristics of the apparatuses used in the task.

1.2. Procedure

The typical procedure of unsolvable task investigations, comprised a number of solvable trials in which the animal could obtain the food by manipulating the device, closely followed by one unsolvable or blocked trial in which the food was no longer accessible. Sometimes the studies started with familiarization or warm up trials in which the animals saw an experimenter retrieving the food (Miklósi et al., 2003; Gaunet, 2008; Hori et al., 2013; Smith & Litchfield, 2013), so they were aware that humans could access the food. Afterwards, they moved onto solvable trials in which they watched the apparatus being baited before being released to get the food. Some authors included a performance criterion, and only animals that succeeded in solvable trials were tested on the unsolvable ones (i.e. two out of three in Marshall-Pescini et al., 2009, 2013; Passalacqua et al., 2011; all three in Passalacqua et al., 2013; Marshall-Pescini et al., 2017a).

Moreover, the number of solvable trials varied per study, but a common design was three solv-

able trials followed by an unsolvable one (Marshall-Pescini et al., 2009; 2013, 2017a; Passalacqua et al., 2011, D'Aniello et al., 2015; Scandurra et al., 2015; D'Aniello & Scandurra, 2016). However, other authors carried out only one (Hori et al., 2013) or as many as four (Kovács et al., 2016), five (Passalacqua et al., 2013), six (Miklósi et al., 2003; Gaunet, 2008; Konno et al., 2016) or a variable number of solvable trials until reaching a criterion (Smith & Litchfield, 2013) before the unsolvable one. Finally, in Persson et al. (2015, 2017) dogs were offered three treats on a plate similar to the one from the device but without a cover, which they had to retrieve in a maximum of two minutes to qualify for the next phase.

Other studies also featured demonstration trials before the animals were confronted with the unsolvable task, in order to assess how previous interactions with the people would affect their help requesting behavior towards them. These trials included an owner behaving encouragingly or not (study 1 form Horn et al., 2012) and familiarization with experimenters playing different roles (study 2 from Horn et al., 2012; Piotti et al., 2017). For a detailed description of these works, see subsection 1.5 'Attitude of the people present during the test'.

Finally, there were studies focusing on solvable tasks. In Marshall-Pescini et al. (2008, 2016), dogs received a familiarization phase before the test, were an experimenter put food in the apparatus and encouraged them to take it. Conversely, other studies did not include training trials before the test. For example, in Udell (2015), dogs experienced two conditions in which they were allowed to solve a puzzle box (see 1.1 'Apparatus'), one being alone and one with a person present. If they failed those attempts, a third condition was added with a human encouraging them. The condition with experimenter present, but not encouraging, was replicated in Brubaker et al. (2017). Additionally, in Bhattacharjee et al. (2017) dogs underwent two tasks, a familiar one in which they had to rip open a plastic bag to obtain a piece of chicken, and an unfamiliar one with a similar apparatus than the one used in Udell (2015) and Brubaker et al. (2017).

Overall, the studies focusing on unsolvable trials always included some kind of solvable trials before the test. It is important to note that the amount of food reinforcement received in these warm up trials could influence dogs' behavior on the following unsolvable trial in which food is no longer accessible (see 'Discussion and ideas for future research', for an analysis according to frustration theory). Conversely, in solvable task studies the procedure was not uniform, as some included familiarization trials and others directly confronted the animals with the task.

1.3. Duration of the test trial

The duration of the unsolvable trials was typically of one minute (Marshall-Pescini et al., 2009, 2013; Passalacqua et al., 2011, 2013; D'Aniello et al., 2015; Scandurra et al., 2015; D'Aniello & Scandurra, 2016; Konno et al., 2016; Kovács et al., 2016; Piotti et al., 2017).

In Smith & Litchfield (2013), dingoes were given two minutes to interact with the blocked apparatus, but trials were interrupted earlier if the animal lost interest or struggled to get off the leash (averaging a trial duration of 105 seconds). Additionally, unsolvable trials lasted two minutes in Miklósi et al. (2003) and Gaunet (2008). This was also the case for the studies focusing on solvable tasks (Udell, 2015), although Bhattacharjee et al. (2017) and Brubaker et al. (2017) point out the trial was stopped sooner if the animal opened the container and obtained the food. Similarly, in the case of Marshall-Pescini et al. (2008) dogs were allowed to interact with the apparatus for a maximum of two minutes, whereas in Marshall-Pescini et al. (2016) the test phase consisted of only 1 minute (or less if the problem was solved).

Finally, a couple of studies featured a three-minute unsolvable trial period (Persson et al., 2015, 2017; Marshall-Pescini et al., 2017a). It has been proposed that more persistent animals could need more time to give up trying to solve the task by themselves and start gazing at the people present, so the extended time could allow them to display more help requesting behaviors (Marshall-Pescini et al., 2017a). However, in that study, the mean time interacting with the apparatus

ranged between 46 and 61 seconds out of the 3 minutes, which was comparable to the 30 second of interaction found in studies with 1 minute tests. Nevertheless, the authors highlight that 3 out of the 4 wolves that did not look back spent most of the time interacting with the apparatus, so they could have looked at a person had the test time been longer.

In sum, in the case of dogs a one-minute trial seems sufficient for help requesting behaviors such as gazing to appear. Nevertheless, Brubaker et al. (2017) pointed out that although dogs gazed significantly more than wolves, they spent <10% of trial time gazing at the human on average. They highlight that although help requesting behaviors and independent task persistence are negatively correlated, there may not be a causal link between them. This result is in line with Udell's (2015) study, which showed that shelter dogs gazed on average 10% of the time, and pet dogs 17%. Therefore, although gazing is a preponderant behavior which has been widely studied in these type of tasks, it is not something the animals do for the majority of test time. Additionally, both groups looked and touched the object <11% of the time, so interaction with the apparatus was also low. This poses an interesting question, as it indicates that it was not that animals were not gazing at people because they were busy interacting with the apparatus instead.

1.4. People present during test trials

In some of the revised studies only a familiar person was present during the test, be it an owner or usual caretaker (Miklósi et al., 2003, Gaunet, 2008; study one of Horn et al., 2012; Udell, 2015). Conversely, few are the works which only featured unfamiliar people (two in Piotti et al., 2017; three in study two of Horn et al., 2012), besides the understandable case of free ranging dogs (Bhattacharjee et al., 2017; Brubaker et al., 2017; Marshall-Pescini et al., 2017a), and dogs living in a research kennel (Persson et al., 2015) as they have no owner. In particular, Brubaker et al. (2017), took into account the effect of familiarity and environment as socialized wolves were tested outdoors and pet dogs were tested indoors, both by a familiar person; while free ranging dogs and another group of pet dogs were tested outdoors by a stranger.

However, in most studies both a familiar person and an unfamiliar experimenter were present for the test (Marshall-Pescini et al., 2008, 2009, 2013, 2016, 2017; Hori et al., 2013; Passalacqua et al., 2013; D'Aniello et al., 2015; Scandurra et al., 2015; D'Aniello & Scandurra, 2016; Konno et al., 2016; Persson et al., 2017). Furthermore, in one instance (Passalacqua et al., 2011) two month old puppies were tested alone with the experimenter, while older puppies and adults were tested with both an experimenter and their owner.

Nevertheless, results are mixed regarding to whom they direct more gazing behavior when two people are present. For instance, in Marshall-Pescini et al. (2009) dogs with different training experience differed in their gazing behavior, as agility dogs focused significantly more on the owner, while search & rescue dogs looked at the owner and the experimenter alike. This is in line with their working experience, as agility dogs work solely with their owners, while search & rescue dogs need to focus on finding a stranger as well as paying attention to the owner. In another study, D'Aniello et al. (2015) identified that water rescue dogs directed their first gaze significantly more towards the owner, but there were no differences in the amount of time these dogs, nor untrained pets, gazed at the owner in comparison to the unfamiliar experimenter. Conversely, Scandurra et al. (2015) and D'Aniello & Scandurra (2016), reported that none of the tested groups showed preference in gazing at the owner or the stranger in their studies. Additionally, besides familiarity, individual differences could be another factor modulating to whom animals gaze during this task. For example, in Passalacqua et al. (2013) fewer dogs with anxiety problems looked at the experimenter at least once, compared to a healthy control group, but no group differences were found in gazing toward the owner. Furthermore, Hori et al. (2013) identified that dogs that carried a shorter allele (P) of the DRD4 intron2, tended to look at the owner earlier, for longer and more frequently than at the experimenter. They suggest that dogs carrying a shorter allele could be more

dependent on their owners, as well as more discriminating against strangers.

Finally, several studies did not feature a direct comparison of the gazing behavior towards each person, but in some cases certain differences were mentioned. For instance, Marshall-Pescini et al. (2013) evaluated if the attentiveness of the experimenter influenced help requesting behavior in dogs and toddlers. They found that dogs looked more at the owner, even when the experimenter was attentive. They argue that dogs were tested in an unfamiliar environment and in presence of the owner, who is their closest attachment figure. On the contrary, toddlers were tested at their usual daycare by a caregiver instead of a parent. Finally, Marshall-Pescini et al. (2008, 2016), Passalacqua et al. (2011) and Konno et al. (2016) measured dogs' gazing responses combining gazing at the owner and the experimenter.

Overall, in most of the reviewed works there was at least one familiar person present, except those featuring dogs that have no owner, like free ranging ones. When both the owner and an unfamiliar experimenter were present, results have been mixed as in several cases dogs preferentially looked at the owner (particularly working dogs), while in others they gazed at both people equally. One possible explanation is that dogs may first communicate with their owner when facing a problem, given the relationship of dependence between them (Marshall-Pescini et al., 2013). Therefore, the nature of their bond could be a modulating factor for this behavior. The possible effects of familiarity of the people present during this task on dogs' behavior are discussed further in the next section.

1.5. Attitude of the people present during the test

In most of the studies, the people remained neutral during the test, standing still to the sides or back of the apparatus, silently ignoring the dog and avoiding eye contact by looking towards the floor or straight ahead (Miklósi et al., 2003; Gaunet, 2008; Marshall-Pescini et al., 2008, 2009, 2016, 2017a; Passalacqua et al., 2011, 2013; Smith & Litchfield, 2013; D'Aniello et al., 2015; Scandurra et al., 2015; D'Aniello & Scandurra, 2016; Bhattacharjee et al., 2017; Brubaker et al., 2017; Piotti et al., 2017). Moreover, in Horn et al. (2012) owners were asked to wear dark sunglasses and, in the second study, both experimenters had their backs turned to the dog to avoid potential unconscious cueing. On the contrary, in Konno et al. (2016) owners were told to respond to eye contact (but not to other behaviors). Similarly, Kovács et al., (2016) highlight that both the owner and the experimenter were watching the dog during the unsolvable trial in order to give them the chance to make eye contact.

One particular case is the study of Marshall-Pescini et al. (2013), as the attentiveness of the experimenter was one of the examined variables. In this study, in one condition both the caregiver and the experimenter sat or stood quietly looking at the container and ignoring the subject (dog or toddler), but would briefly smile if they made eye contact with them ("experimenter attentive" group), while in the other condition the experimenter had her back turned to the container ("experimenter back turned" group). Results indicate that both species were able to take into account the attentional state of the audience, alternating their gaze more towards an attentive person, and less if they had their back turned.

Furthermore, in Udell (2015) dogs were presented with two conditions, one alone with the apparatus and one with a person present standing neutrally (i.e. 'human-in condition'). If they were not able to solve the puzzle, a third condition was added, in which the person actively encouraged them. Only one shelter dog solved it being alone, and one pet dog solved it in the human-in condition. Moreover, when encouraged dogs spent more time in contact and looking at the apparatus, but their performance did not improve significantly. The author proposes that the improvement when encouraged is in line with the hypothesis that dogs may inhibit independent interaction with a novel object if not told otherwise, as it is a better strategy for success in human homes. Likewise, other cases in which the attitude of the experimenter varied depending on dogs' behavior

were the works by Persson et al. (2015, 2017). In these studies, the apparatus featured three plastic covers, two which could be moved to access the food and one which was fixed closed. If the dogs had not reached any treat after one of the three available minutes during the unsolvable task, the experimenter opened the mobile plastic covers halfway to encourage them. Unfortunately, the effects of this interaction on the analyzed variables were not reported.

Additionally, as more evidence accumulated of dogs looking at humans for help when confronted with problem tasks, some authors wanted to investigate if dogs could take into account prior demonstrations to select the most suitable person to help them. To this purpose, Horn et al. (2012) carried out two studies with dog-owner pairs. In the first one, dogs underwent training trials to allow them to learn how to manipulate the apparatus and were exposed to two conditions of owner behavior (encouraging owner for one group, non-encouraging owner for the other). They found that previously encouraged dogs looked back longer at their owners. However, this difference almost disappeared in the second trial, probably because dogs may have learnt that the owners were not going to help them. In the second study, they investigated whether dogs would learn about two experimenter's different abilities to solve one type of problem: one re-baited the apparatus (the filler) and the other unblocked it (the helper). The dogs approached the helper first, independently from the problem (i.e. whether the apparatus was empty or blocked). Yet, they spent more time close to the filler when the apparatus was empty, which could imply some understanding of each experimenter's specific abilities. Finally, Piotti et al. (2017) used an unsolvable task to investigate reputation formation in dogs. In the first study, dogs received three solvable trials in which they were allowed to eat food from a plastic container on a wooden board. Afterwards, they witnessed two experimenters, one skillful (who solved a puzzle and obtained food) and one unskillful (who was unsuccessful in solving the puzzle), interacting with a different apparatus. Finally, they were confronted with the first apparatus, but it was blocked with a metal basket. Dogs did not choose the skillful experimenter above chance, nor preferred her to the unskillful one, which implies they did not form a preference between them. As the authors thought the task might have been too difficult for the animals, a second study was carried out with only one experimenter present, one demonstration (which varied between skilled or unskilled, as well as nice or ignoring partner) and one unsolvable trial. Results showed that dogs did not request help more from the experimenter depending on her behavior (niceness or skillfulness). Overall, the finding of these studies could not confirm whether dogs take reputation into account when requesting human help.

In sum, the mere presence of people, even standing neutrally, seems sufficient to elicit the appearance of help requesting behaviors such as gazing when confronted with a difficult or unsolvable problem. However, in other studies people actively responded to eye contact or interacted with the animals in some way. It would be of interest to further study whether these variations modulated how gazing behavior was displayed (see 'Discussion and ideas for future research').

Regarding studies in which dogs could differentially choose who to ask for help based on prior demonstrations, results have not been conclusive as they usually picked at random. Several explanations have been proposed for these results (Horn et al., 2012; Piotti et al., 2017). For instance, elaborated demonstrations may be too complicated for dogs to follow. Additionally, dogs may partially understand how physical problems are solved, and thus not be able to follow how different people's roles relate to solving the problem. Moreover, it may be difficult for dogs to choose between two human partners, as they may have evolved a tendency to request human help regardless of the characteristics of the person. Finally, it must be noted that in these studies the experimenters were unfamiliar to the animals, which is a difference from the usual problem solving tasks in which the owner, or a familiar caregiver, is present. Remarkably, in Brubaker et al. (2017) pets in the familiar/indoor group gazed more than pets in the unfamiliar/outdoor group, which gazed even less than free ranging dogs. Results are confounded, as it cannot be disentangled whether these differences were due to having been tested by an unfamiliar person, or by the con-

ditions of the test (indoor versus outdoor, which was a potentially more distracting environment). However, in Herberlein et al. (2017) dogs were able to take into account the previous role of an unfamiliar demonstrator (cooperative or competitive) during a showing task. In particular, they led the cooperative one to a box containing a preferred food, while the competitive one was more often taken to an empty box or one containing non preferred food. Although this supports the idea that dogs could consider a previous demonstration when interacting with unfamiliar people, the task featured in this study is a different one, and they were subjected to extensive training before the test. Overall, results suggest that dogs do not appear to take into account the reputation of a partner when asking for help in problem solving situations. They may only form a reputation about a person in certain contexts or with extensive training, or could not be able to take prior demonstrations into account when asking for help.

1.6. Data Analysis

One of the main points of problem solving studies is to assess the appearance of communicative behaviors towards the people present during the test. All of the reviewed studies take into account direction, duration, frequency and/or latency of gazing behavior towards the people.

However, there is some discussion over the terminology used to define this behavior. For example, the model study of Miklósi et al. (2003) mentions both "looking" and "gazing" behavior, but ultimately focuses on "looking back", which was defined as the animals turning their head to the side with their head/nose oriented towards the caretaker/owner, who was standing one meter behind them. Additionally, Piotti et al. (2017) state their preference for the use of the term "looking" instead of "gazing", as they mention it is not always possible to determine the direction of the eyes, but only the orientation of the head/nose of the dog. It must be noted that in this work the terms are used interchangeably, as both are employed in the reviewed studies.

Particularly, Smith & Litchfield (2013), who studied gazing behavior in dingoes, stress the importance of operationally defining looking behavior. They found three types of looking behavior in their study, of which only one was referential in nature. This was the "task directed looking back", defined as the type of gaze occurring when the animal noticed the task was unsolvable and made eye contact with the nearby person, apparently asking for help. Moreover, they identified "non-referential looking back" which was related to gathering information of what the experimenter was doing. Finally, as the dingoes in this study were restrained, they also described "leash looking back" as a look back directed towards the handler in attempts of the animal to free itself. The authors point out that although looking back in this case is referential, as they needed assistance to escape, this is not the aim of the task, so it acts as a confounding variable and should be measured separately. In line with this, Leavens and Hopkins (1999) point out that visual behavior can be categorized in two ways: on the one hand, there is visual monitoring, comprising looks towards a companion. On the other hand, there is gaze alternation, which includes consecutive looks between a target object and a partner and is considered to be referential. Additionally, Smith & Litchfield (2013), indicated that fleeting glances towards the experimenter should not be considered referentially, and point out that Miklósi et al. (2003) did not provide duration of the looking back behavior in order to be considered as such. In particular, they found that dingoes appeared to look back at humans during an unsolvable task, but when applying a more precise operational definition of this behavior it became clear they were not looking back for assistance, but to track what the person was doing or try to escape restraint. For instance, Brubaker et al. (2017) stress that there may be diverse motivations and purposes for gazing behavior in different populations of dogs living different environments. Additionally, Passalacqua et al. (2013) indicate that in their study featuring dogs with anxiety problems, the interpretation of gazes towards the experimenter as expressions of fear was not supported, as these dogs sought physical contact with the experimenter, and even more so than control dogs. Therefore, other interactive behaviors, like

closeness, could be taken into account to help differentiate the nature of gazing behavior when in doubt of its referential nature.

Furthermore, besides recording gazing behavior towards the people present, several studies have analyzed gaze alternation between the apparatus and a person (Gaunet, 2008; Marshall-Pescini et al., 2009, 2013, 2017a; Passalacqua et al., 2011, 2013; Smith & Litchfield, 2013; Kovács et al., 2016; Piottti et al., 2017) as dogs often exhibit this behavior and not just direct gazing when faced with problem situations. This has been regarded as a better measure of intentional communication as it includes a referential component to the object of desire (e.g., Miklósi et al., 2000; Prato-Previde & Marshall-Pescini, 2014). For example, Marshall-Pescini et al. (2009), found that gaze alternation was significantly affected by the dogs' training experience, as search & rescue dogs were the ones that alternated their gaze more, followed by agility dogs and finally untrained pet dogs. In Passalacqua et al. (2011), adult dogs used gaze alternation more often than 4.5 month old puppies, who instead spent more time manipulating the apparatus. Additionally, Marshall-Pescini et al. (2013) reported that both toddlers and dogs exhibited gaze alternation related to the attentional state of the audience, which suggests a certain understanding that for the gesture to be effective the receiver must be paying attention. Meanwhile, Passalacqua et al. (2013) identified less gaze alternation in dogs with anxiety related problems compared to controls. Kovács et al. (2016) used the term "gaze shift" to refer to the alternating looking behavior between the cage containing the inaccessible food and the people present. They indicate that the number of gaze shifts was not affected by treatment or sex, but a breed difference was found as Border Collies shifted their gaze more than Siberian Huskies. In other studies, gaze alternation was observed but did not differ between groups (pet vs guide dogs, in Gaunet, 2008), or did not vary significantly across conditions (skillful or unskillful, and helpful or ignoring demonstrators, in Piotti et al., 2017). Finally, Smith & Litchfield (2013) mentioned that no instances of gaze alternation were observed in dingoes, which is in line with the other results of their study, as dingoes did not look back at humans during this task.

Moreover, some studies included in their analyses the interaction of the dogs with the people present, defined as the animal approaching and establishing physical contact with the person, e.g. rubbing, nosing, licking, pawing a hand or leg or jumping up (Gaunet, 2008; Marshall-Pescini et al., 2009, 2013; Passalacqua et al., 2011, 2013; Horn et al., 2012; Persson et al., 2015, 2017; Scandurra et al., 2015; D'Aniello & Scandurra, 2016; Bhattacharjee et al., 2017). Likewise, others included silent and sonorous mouth licking (Gaunet, 2008) and heading towards a person (Scandurra et al., 2015). Finally, Bhattacharjee et al. (2017) considered tail wagging, repeated gazing and sitting closely as the dogs 'showing dependence' on humans.

In addition, most studies have included behaviors towards the apparatus to ensure the animals were motivated to solve the task on their own and were interested in the food inside. Some of the analyzed behaviors included the latency to get to the apparatus, staying close, touching it, interacting with it (e.g., behaviors aimed at obtaining the food such as grasping, scratching, nosing, biting and pushing) and gazing towards it (Gaunet, 2008; Marshall-Pescini et al., 2008, 2009, 2013, 2016, 2017a; Passalacqua et al., 2011, 2012; Horn et al., 2012; D'Aniello et al., 2015; Udell, 2015; Scandurra et al., 2015; D'Aniello & Scandurra, 2016; Konno et al., 2016; Kovács et al., 2016; Bhattacharjee et al., 2017; Brubaker et al., 2017). Specifically, Marshall-Pescini et al. (2017a) labeled the time the animal spent interacting with the apparatus as "persistence", and concluded that it was the main variable affecting the results, as more persistent animals were the ones that looked less at humans, regardless of their species. Nevertheless, it must be noted that some behaviors are not mutually exclusive, as dogs could be touching the box while gazing towards it or gazing at a human.

Furthermore, the studies concerning solvable tasks featured measures about the ability of the animals to solve the problem. To this end, Marshall-Pescini et al. (2008, 2016) assessed whether the animals were successful in opening the apparatus Additionally, Udell (2015) considered the puzzle solved when the lid was fully off or when the food left the container, and registered the time

the animals took to solve it when they did so. Similarly, Brubaker et al. (2017) recorded whether the animal solved the task and the amount of time it took them. Moreover, Bhattacharjee et al. (2017) constructed a performance score ranging from 1 to 8, with 1 being the lowest performance level (i.e. dog seeing but not approaching the container/bag) and 8 being able to open it and eat the food reward inside. Other behaviors included in the score were begging, inspecting, biting and taking the object away.

Finally, other behaviors assessed in these studies include barking and vocalizations (Gaunet, 2008; Marshall-Pescini et al., 2009, Passalacqua et al., 2013), exploratory behavior (Gaunet, 2008), looking at the door or staying close to the exit (Horn et al., 2012), stress related behaviors (Passalacqua et al., 2013), body posture and position (Persson et al., 2015), and interruptions (Bhattacharjee et al., 2017).

In sum, several behaviors have been studied in problem solving tasks. Concerning gazing, authors must be careful with data interpretation as animals may look at people for different reasons not related to the problem solving task, such as fear. Therefore, it is important to have unified criteria of the type of gazes that should be considered as help requesting behaviors.

2. Origins of gazing behavior

The interaction between evolution (i.e., domestication, phylogeny), development and life experiences (i.e., ontogeny) on the display of social behaviors in different species of canids has been a topic of debate for years. For instance, some authors attribute dogs' communicative abilities to the domestication process, which led them to acquire unique skills in communicating with people (Hare & Tomasello, 2005; Hare et al., 2010). Alternatively, the "two stages hypothesis" (Wynne et al., 2008; Udell et al., 2010) highlights the importance of ontogeny in the development of the human-dog bond. Therefore, in addition to the role of domestication, the acquisition of social skills appears to depend on interactions during a sensitive developmental period, along with learning throughout the animal's life. Likewise, a synergetic model has been proposed to account for the role of both genetic and environmental effects on social behavior (Miklósi & Topál, 2011). Finally, a recent genetic study carried out by von Holdt et al. (2017) suggests that dogs' gregariousness was key during the domestication process that differentiated them from wolves. This behavior may have facilitated coexistence with people, giving hypersocial individuals an advantage during canine evolution. Nowadays it is widely accepted that both evolutionary changes and ontogenetic experiences contribute to the development of dogs' social cognition (Miklósi & Kubinyi, 2016), but debate remains still open regarding the relative weight of each factor.

To try to answer these queries, many studies have been conducted comparing species of canids, as well as groups of dogs with different levels of training and socialization. The main hypothesis underlying such works is that if domestication were what predisposed the appearance of such abilities in dogs, then wolves would perform worse. Furthermore, different dog populations should have similar performances. Conversely, if life experiences were what is primarily responsible for this behavior, then heavily socialized wolves should perform similarly than dogs. Additionally, among dogs those that have less experience with humans (such as free ranging or shelter dogs) would perform worse, and those who are heavily exposed to people (such as working dogs) should perform better.

The aim of this section will be to analyze different factors which may influence the exhibition of gazing behavior during problem solving tasks such as species, training experience, living conditions and breed. However, it is important to mention that although studies were classified into different sections, some variables are related and confounded. For example, working dogs are usually Shepherds and Retrievers, thus the breed factor may be mingled with training experience factor.

2.1. Species comparison

Some studies have focused on species as an influencing factor on problem solving abilities, to account for the role of domestication in the development of communicative abilities of domestic dogs (e.g. Hare & Tomasello, 2005, but see Udell et al., 2010).

In the pioneer study of 2003, Miklósi et al. compared the performance of socialized wolves (*Canis Lupus*) and pet dogs (*Canis Familiaris*) puppies on two unsolvable tasks. They found that dogs looked back earlier and spent more time gazing at a human than socialized wolves. The authors proposed that dogs exhibited a readiness to look at the human face that could not be accomplished in wolves despite extended socialization. Likewise, Marshall-Pescini et al. (2017a) compared the performance on an unsolvable task of similarly raised adult wolves and dogs. Additionally, they tested free ranging and pet dogs, in order to assess differences due to socialization levels. Contrary to other works on this area, they concluded that looking back behavior is highly related to when an animal gives up on the task, regardless of species or socialization levels. They included persistence, measured as the time the animal spent interacting with the apparatus, as an explanatory factor: Less persistent animals looked back earlier and for more time. Given that when not including persistence in the analyses the results replicate the differences found by Miklósi et al. (2003), the authors highlight the importance of considering persistence as a confounding effect on looking behavior during unsolvable tasks.

Likewise, Smith and Litchfield (2013) studied socialized dingo (*Canis dingo*) puppies on a rope-pulling task. As it was previously mentioned, these authors used a more restricted definition of looking back behavior. Taking this into account, they found that dingoes did not look back at humans when confronted with an unsolvable problem.

Another way to study the underlying mechanisms of different cognitive skills in dogs, is comparing them with human infants. To this end, the performance of dogs and preverbal toddlers was assessed on a similar task (Marshall-Pescini et al., 2013). Results indicate that both toddlers and dogs increased gaze alternation when the task was unsolvable. Therefore, the authors concluded that gaze alternation can be considered as an intentional and referential communicative action in both species.

A comparison between socialized wolves and dogs was also carried out in the studies of solvable tasks carried out by Udell (2015) and Brubaker et al. (2017). Udell (2015) found that wolves showed more persistence on the task while dogs spent significantly less time trying to solve the puzzle, even in a condition when no person was present. Consequently, all wolves solved the task at least once considering the two conditions (alone or with a neutral person present, see 1.5 'Attitude of the people present during the test' for a more detailed description of the procedure). Meanwhile, dogs gazed more than wolves during the task. As it was mentioned before, given that the problem was solvable in this study, the author suggests that dogs may give up faster in such tasks in general. She proposes a hypersensitivity or dependence on human social cues as a possible explanation for this behavior. In addition, Brubaker et al. (2017) found that dogs, even those living as scavengers (i.e. free ranging dogs), persisted less on the task and gazed more at the human than wolves. They remark that the species' difference was robust, despite some individual variations among dogs.

Several explanations have been proposed regarding why wolves appear to be more successful in problem solving tasks than dogs, along with their tendency to display less help requesting behaviors such as gazing. Originally, it was thought that domestication hindered dogs' ability of physical reasoning compared to wolves (e.g., Frank & Frank, 1982). Nevertheless, recently some alternative hypotheses have been proposed. For instance, studies on neophobia and exploration, found that wolves were more persistent when exploring novel objects, while dogs showed less interest in them (Moretti et al., 2015), and these differences appeared even as puppies of 5, 6 and 8 weeks (Marshall-Pescini et al., 2017b). Therefore, wolves seem to be more explorative than dogs,

which could account for motivational differences that must be considered when comparing these species' performance on cognitive tasks. Additionally, the greater degree of persistence found in wolves is likely one key factor in their greater success on these tasks. This was the case in the reviewed studies focusing on solvable problems, as wolves had a higher success rate than dogs (Udell, 2015; Brubaker et al., 2017). Moreover, Miklósi et al. (2013) proposed that wolves may be more attracted to food sources than dogs, which could explain in part why they gaze less towards people during problem solving tasks involving food.

In line with this, Marshall-Pescini et al. (2017a), propose persistency as the explanatory factor for the differences between wolves and dogs during an unsolvable task. They consider the results are better explained by the time they spent interacting with the apparatus, irrespective of socialization or species. In other words, the difference between these species appeared to be related to their persistence tendencies rather than their willingness to look at the human face. Udell (2015) raises a similar point, as she highlights that dogs' gazing behavior has been traditionally regarded as an exceptional strategy they use when faced with an unsolvable problem. What is more, this was usually interpreted as the socio-cognitive advanced way to deal with it. However, an alternative explanation could be that dogs simply persist less on problem solving tasks in general. This idea was supported by the results, as dogs failed to persist even when the problem was solvable. One point that must be remarked is that although the task could be solved, dogs may not have interpreted it as such. In line with this, Marshall-Pescini et al. (2008) suggest that pets may be unaccustomed to solving problems on their own, so they may have quickly assumed the task was impossible and looked back to the humans for help.

Additionally, Topál et al. (1997) carried out a problem solving study focusing on the bond with the owner as a factor that could influence dogs' performance. They concluded that it is not that dogs do not have the cognitive ability to solve such tasks, but that they may have been waiting for their owner's permission to get the food. In line with this, as it was stated previously, Udell (2015) proposes that conditioned inhibition could be what affected dogs' results in this task. In particular, when presented with a novel object and no human guidance, dogs may be cautious and inhibit independent interaction with it. Remarkably, in both works, dogs' performance tended to improve when they were encouraged, which further supports this hypothesis. Nevertheless, human presence during the task did not affect the results, as dogs spent similarly the same time interacting with the apparatus during the alone and neutral human condition in Udell (2015). Similarly, Marshall-Pescini et al. (2017b) indicate that dogs may have been selected during the course of domestication for a greater dependence on humans. Moreover, experiences during the lifetime of each animal may accentuate this notion, as dogs get used to receiving resources from their owner (Topál et al., 1997; Udell, 2015). Therefore, both phylogenetic and ontogenetic factors seem to be at play in the appearance of help requesting behaviors.

2.2. Life experiences and living conditions

The effects of ontogeny on the development of sociocognitive abilities have been extensively studied. For instance, Dorey et al. (2009) studied the relationship between development and the ability to understand human pointing cues. They found that puppies younger than 21 weeks had little ability to follow such gestures, but their performance improved as they got older. Problem solving tasks have also been used to assess the effects of development on help requesting behaviors. For example, Passalacqua et al. (2011) took into account dog's age as a factor, and tested puppies at 2 and 4.5 months, as well as adult dogs on an unsolvable task. At 2 months gazing behavior only appeared in approximately half of the subjects and occurred briefly. This suggests that the ability to gaze at humans to request help may develop as dogs have more experiences communicating with humans. Furthermore, Hori et al. (2013) found that latency to gaze was shorter as dogs got older in an unsolvable task. Likewise, Persson et al. (2015) reported and age

effect on eye contact during a similar task, as older dogs gazed sooner, more frequently, and for a longer duration than younger dogs. These results suggest that dogs' may have learnt to look at humans to get rewards through their daily contact with people. If that were the case, we would expect that learning history would influence their looking behavior. For instance, Barrera et al. (2011) found that shelter dogs gazed significantly less than pet dogs when food was out of their reach, and they suggested it could be due to pet dogs having more opportunities to learn to persist in their communicative responses. In line with this, D'aniello & Scandurra (2016) tested Labrador retrievers living in kennels as well as pet dogs on an unsolvable task. Their findings support the importance of ontogenetic experiences, as kennel dogs gazed less and with higher latency than pet dogs. These results are similar to those of Scandurra et al. (2015) who identified that guide dogs living in kennels gazed less towards people than dogs living with families, regardless of whether they had received specific training as guide dogs.

Additionally, Bhattacharjee et al. (2017) focused on free ranging dogs. These dogs are of particular interest, as they live in human environments and depend on human resources to scavenge food, but are less socialized and are not under direct human supervision. These dogs were tested on a familiar and an unfamiliar task, and results indicate that they were more successful and persistent on the familiar one, showing fewer behaviors directed at humans. However, during the unfamiliar task they gazed more and displayed begging behaviors towards the experimenter. Unfortunately, pet dogs were not included in this sample precluding comparisons. Likewise, Marshall-Pescini et al. (2017a) studied free ranging dogs, which were compared with pet dogs tested outdoors, as well as wolves and dogs raised similarly. The authors found no differences in looking back behavior across dog groups. This was surprising as it was expected for dogs with higher experience with humans (i.e. pets) to be more likely to exhibit such behaviors. Nevertheless, they concluded that the groups might not have been as different in terms of persistence on the task along with their acceptance of humans. In particular, free ranging dogs may often need to gain the sympathy of humans, and looking at people may be essential to obtain it. Similarly, Brubaker et al. (2017) assessed these same four groups but on a solvable task paradigm. They reported that free ranging dogs exhibited similar gaze duration than pet dogs tested indoor with their owners. Finally, in another solvable task study, Udell (2015) included shelter dogs as well as socialized wolves and pet dogs. No significant differences were identified between the different groups of dogs (i.e., free ranging, shelter or pet).

In sum, studies focusing on life experiences have shown age effects on help requesting behaviors, with dogs gazing more as they get older. Regarding living conditions, though, results have been mixed. On the one hand, in some studies dogs living in kennels gazed less than dogs living in families (Scandurra et al., 2015, D'Aniello & Scandurra, 2016), but on Udell (2015) there were no significant differences between shelter and pet dogs. Overall, the differences found between different populations of dogs were weak. Several factors could be at play to explain this. For instance, Bhattacharjee et al. (2017) point out that dogs looked towards the experimenter during the task even though the experimenter was an unfamiliar person, so a natural disposition to communicate with humans may be vital for dogs to live in human environments. However, it must be considered that free ranging dogs able to participate in these studies had to be rather comfortable with humans. This may confound the results as the evaluated subjects might have been more sociable than free ranging dogs in general. For example, Marshall-Pescini et al. (2017a) stated they approached 46 free ranging dogs but only 31 could be tested, as the others were too wary of humans or did not consume the food. Finally, it must be noted that the past history of shelter and free ranging dogs is unknown. Thus, it is impossible to know whether they ever lived as pets, particularly during the sensitive developmental period of social cognition, which could account for a higher understanding of human cues.

2.3. Training experience

Another area of study has taken into account that individual training experiences are known to affect gazing behavior (e.g., Bentosela et al., 2008). These studies focused on groups of working dogs that have gone through different training experiences. Firstly, Gaunet (2008) evaluated both pet dogs and blind guide dogs on an unsolvable task. She found no differences between groups in gazing behavior. In addition, Marshall-Pescini et al. (2009) used this task to study dogs trained for different purposes such as agility and search & rescue, as well as pets. Agility dogs were much more likely to look at a person even during solvable trials, whereas search & rescue dogs only gazed at the person in the unsolvable task, and added barking to their behavior. As it was previously mentioned, this is in line with the training they received, as agility dogs are trained to follow their guide, while search & rescue dogs are more independent workers and also need to alert the handler by barking when they find a missing person. Moreover, D'Aniello et al. (2015) focused on water rescue retrievers. Water rescue dogs spent more time gazing towards the people than untrained pet dogs. The authors suggested that this might be explained by the specific training regime they received, as it was focused on encouraging cooperation during the rescues. Lastly, Scandurra et al. (2015) tested Labrador retrievers which had different levels of training as guide dogs (i.e. dogs fully trained but not yet working, dogs that already worked as guides, and untrained dogs of the same ages). Trained guide dogs that were not yet working lived in kennels with limited interaction with humans. These dogs gazed significantly less than dogs living with families (both trained working dogs and untrained pets). Although the authors set out to investigate training effects, these results indicate that gazing towards humans is favored by living close to people and interacting with them (see 2.2 'life experiences and living conditions').

Furthermore, other studies have focused on the effect of training on problem solving abilities during solvable tasks. To this end, Marshall-Pescini et al. (2008) evaluated the performance of highly trained dogs who participated in different activities (e.g., agility, schutzhund, retriever, search and rescue), and compared it to untrained pet dogs. They found that trained dogs interacted significantly more with the apparatus and thus were more successful in opening it. Whereas, untrained pet dogs spent significantly more time looking back at people. Similarly, Marshall-Pescini et al. (2016) tested both trained and untrained dogs on a manipulation task using the same puzzle box than in the previously mentioned study. They found that dogs with training experience were more likely to be successful. Additionally, trained dogs were less likely to look at a person that non trained dogs.

The differences found on dogs that underwent different types of training suggest that it might modulate gazing responses. In the case of unsolvable tasks, trained dogs gazed more at people, although differences were found depending on the training regimen and the purposes they had been trained for. However, it must be noted that differences in gazing behavior could be explained not only by their training experiences but also by their close relationship with the owner, who is usually the one acting as a handler or guide.

Conversely, the opposite occurred in studies focusing on solvable tasks, as highly trained dogs tended to interact more with the apparatus (and thus be more likely to solve the problem). In line with this, they gazed less than non trained dogs. As an explanation for these results, Marshall-Pescini et al. (2016) suggested that dogs that participate in regular training activities may be less neophobic that non-trained dogs and therefore more likely to interact with a novel object. However, the authors point out that differences in motivation between these two groups need to be excluded as a confounding variable. Moreover, Bray et al. (2017) tested future guide dogs before they received specific training, on a battery of temperament and problem solving tasks. They found that dogs which scored high on the behavioral component they called 'independent problem solving' solved the task quicker, focused more on it and rarely looked to the experimenter. Consequently, when studying working dog populations, it must be taken into account that the animals may have

been selected for that type of work based on certain pre-existing characteristics which may influence their performance on the test, regardless of the training regimen they received.

2.4. Breed comparison

Many of the dog breeds we know today are the product of an intense process of artificial selection, focused on specific cognitive and behavioral skills necessary for performing different tasks (e.g., Serpell & Duffy, 2014). This could have impacted dogs' social behaviors, such as gazing. For instance, Jakovcevic et al. (2010) compared the acquisition and extinction of the gazing response to the human face in Retrievers, German Shepherds and Poodles when there was food out of their reach. While there were no differences in the acquisition of the response, during the extinction phase Retrievers gazed significantly more than the other groups, showing breed differences in this communicative response. Consequently, some studies have compared the performance of dogs of different breeds during an unsolvable task. Passalacqua et al. (2011), besides studying dogs of different ages (see 2.2 'life experiences and living conditions'), worked with three groups of breeds: Primitive, Hunting/Herding and Molossoid, in order to assess breed influence on gazing behavior during this task. They identified that breed differences appeared strongly in adult dogs, less pronouncedly in 4.5 month puppies, and were absent at 2 months. In particular, dogs in the Hunting/Herding group showed significantly more gazing behavior than dogs in the other two breed groups. This led the authors to conclude that selection for cooperative work with humans, such as retrieving and herding, may have had greater influence on this behavior than their genetic relatedness to wolves. Additionally, Konno et al. (2016) analyzed breed differences in visual communication during an unsolvable task. They classified dogs into five breed groups: Ancient, Herding, Hunting, Retriever-Mastiff and Working. They found that Ancient breeds made eye contact later and gazed for shorter periods of time than the other breed groups during the unsolvable situation. These dogs are genetically more closely related to wolves than those that underwent more recent intense artificial selection (i.e. pressures to create breeds dedicated to different types of work). Therefore, the authors, contrary to Passalacqua et al. (2011), propose that genetic similarity with wolves may have significantly affected gazing behavior, more so than recent selection for specific purposes. Moreover, another difference between these studies, is that Konno et al. (2016) found no significant difference between the communicative behavior of Hunting/Herding and Molossoid breeds.

Additionally, Kovács et al. (2016) found breed specific effects of oxytocin administration on the gazing behavior of Border Collies over Siberian Huskies in a problem solving task (see, 3.2 'The role of oxytocin' for a more detailed description of this study).

Finally, regarding the study of solvable tasks, the subjects in the Marshall-Pescini et al. (2016) study were divided into four breed groups (Herding, Mastiff-like, Working and Retriever). During this task, dogs from Herding and Mastif-like breeds were more likely to look at people than Retriever and Working ones. These results were partially consistent with prior studies (i.e. Herding and Mastiff-like dogs did not differ on their performance in this study, but did so in Passalacqua et al., 2011), and thus the authors suggest that breed differences appear to be task dependent.

Overall, the results of studies focusing on breed differences have been mixed. While some found evidence supporting the idea that it is genetic relatedness with wolves what mainly affects gazing behavior, others point out that the bigger differences are due to the artificial selection for different types of work. Therefore, the evidence is not conclusive enough to discard either hypothesis.

However, some limitations of studies of dog breeds must be taken into account. In particular, a recent review focusing on the topic (Mehrkam & Wynne, 2014) points out that while there are breed differences in the behavior of dogs, there are also significant within-breed variations. The authors highlight behavior is the product of complex phylogenetic and ontogenetic interactions, and thus life experiences should also be considered in the study of breed differences. In line with this, Kovacs et al. (2016) remark that dogs from different breeds are kept for diverse purposes

and receive different trainings, so life experiences may lead them to develop different social behaviors. Moreover, Mehrkam and Wynne (2014) highlight that, as breeds are usually evaluated in categories, samples of certain breeds may be underrepresented. Finally, as Marshall-Pescini et al. (2016) suggested, breed differences on performance may be task specific, which could account for variations in the results.

3. Neurobiological Aspects

While the field of canine cognition has focused for years on the study of behavior, its genetic bases and underlying neurobiological mechanisms are poorly understood (von Holdt et al., 2017). The correlation between phenotypic behavioral responses and genetic data is of remarkable interest for providing insight on how genes contribute to the expression of a given behavior.

Additionally, there is evidence that gazing behavior increases the endogenous concentration of the neurohormone oxytocin both in dogs and humans, and this led several authors to focus on the effects of nasally administered oxytocin on communicative tasks (Nagasawa et al., 2015). Moreover, polymorphisms in the regulatory region of the oxytocin receptor gene were found to be linked to social behaviors in dogs, like proximity seeking and friendliness (Kis et al., 2014).

The aim of this section will be to review studies focusing on the genetic basis of gazing behavior during problem solving tasks, as well as on the effects of oxytocin as a modulator of this behavior.

3.1. Genetic studies

Hori et al. (2013) used an unsolvable task to evaluate the dopamine receptors associated with gazing toward humans in pet dogs from various breeds as well as mongrels. These authors identified that the genotype of DRD4 intron2 was associated with dogs' gazing behavior. In particular, dogs who carried a shorter allele (P) looked at the owner sooner, longer and more frequently than those that carried a longer allele (Q).

Likewise, Persson et al. (2015) assessed laboratory Beagles which were bred and housed under highly standardized conditions, in order to study within breed variation and heritability in social behavior towards humans. The narrow-sense heritability of behaviors related to social interactions was estimated as 0.23, which indicates a significant genetic basis for this variation.

In sum, results of genetic studies in problem solving tasks indicate that social skills in dogs have a genetic basis, although individual experiences could shape and improve them.

3.2. The role of oxytocin

As it was mentioned, intranasal oxytocin administration has been shown to influence dog behavior on several studies (Thielke & Udell, 2017). Regarding problem solving situations, Kovács, et al. (2016) studied the differential effects of oxytocin administration on the social behavior of two dog breeds. To this end, they tested both Border Collies (i.e. cooperative workers) and Siberian Huskies (i.e. independent workers) in several situations, including one of unsolvable task. They found that Border Collies, but not Siberian Huskies, that received oxytocin tended to look at the experimenter sooner and for longer. Therefore, their results indicate breed specific effects of oxytocin on dogs' performance on this task.

Moreover, Persson et al. (2017) assessed the effects of oxytocin administration and polymorphisms of the oxytocin receptor gene (OXTR) on the social behavior of Golden Retrievers during an unsolvable task. Their findings indicate that dogs treated with oxytocin increased owner physical contact seeking when they had the AA-genotype at the 19131AG locus, while the opposite effect was found in those with GG-genotype. No results regarding gazing behavior were reported.

In sum, the study of the effects of intranasal administration of oxytocin on social behavior appears to be an area in development, as interactions have been found not only regarding breeds but also in relation to polymorphisms in the OXTR.

Discussion and ideas for future research

On the one hand, some methodological variations could be implemented in order to further analyze gazing behavior during problem solving tasks. For instance, it should be noted that the unsolvable trials in which food is not accessible anymore could be considered as extinction trials of a previously reinforced response (i.e. interacting with the apparatus to obtain food). This could lead to a state of frustration (Amsel & Roussel, 1958), so it would be of interest to assess stress related behaviors during the test, such as trembling, shaking, yawning, panting or lip-licking. However, only one work included stress signals in the analysis (Passalacqua et al., 2013) as they tested a group of dogs with anxiety related problems and expected them to display more of these behaviors. Results indicate that control dogs also exhibited significantly more of these signals as the task became impossible, which would be in line with the frustration theory.

On the other hand, the number of prior solvable trials may influence the perseverance of the animals during the test, as more training may produce an increase in reward seeking responses during unsolvable trials (Nevin & Shahan, 2011). Therefore, it would be of interest to conduct an experiment in which groups of dogs encountered different number of solvable trials beforehand (i.e., different number of reinforced trials). Additionally, another option would be to directly present the dogs with the unsolvable task with no previous solvable trials. This would allow to assess their response to being directly confronted with an unsolvable task, without prior interaction with the apparatus.

Regarding the behavior towards the people, in a study by Barrera et al. (2015), dogs were confronted with a commercial dog toy that was filled with food during acquisition trials and then presented empty during an extinction phase. The authors reported a significant increase in gazing behavior toward a person during extinction compared to acquisition trials. In line with this, as people do not help the dogs during the unsolvable test trial, it would be expected for help requesting behaviors to decrease until disappearing as the trial continues. Therefore, it would of interest to code the animals' behavior during different moments of the test, to assess if their responses (directed towards the people or the apparatus) are clustered at the beginning or distributed uniformly along the test time. Longer test trials may be needed to evaluate this phenomenon properly.

Furthermore, it would be relevant to assess whether different types of interaction during the test affect how gazing behavior is displayed. For instance, a comparison could be made between two conditions, one in which people remain neutrally looking ahead while in other they actively respond to eye contact throughout the test. A more explicit version of this was carried out in Marshall-Pescini et al. (2013), but in that case inattentive people also had their back turned to the dogs, which could have diminished behaviors directed to them (Virányi et al., 2004).

Another area of interest is whether dogs can flexibly display gazing behavior, particularly adjusting their behavior to prior experiences with certain experimenters. To date, the studies focusing on the topic had inconclusive results. As the demonstrations may be too complex for the animals to follow, it may be necessary to further simplify the tasks for such discrimination to appear. Additionally, increasing the number of training trials may be required for dogs to be able to differentiate between people's roles and ask for help accordingly. For instance, in a study by Carballo et al. (2015) dogs could not discriminate between a selfish and a generous experimenter in six trials, but did so in twelve. Likewise, in Herberlein et al. (2016, 2017) the subjects underwent several training trials, divided in two days and with preference tests in between to assess whether they had learned the role (cooperative or competitive) of two partners.

Another difficulty present in the demonstration studies is that the experimenters were unfamiliar to the subjects (Horn et al., 2012; Piotti et al., 2017) while in other problem solving studies usually at least one familiar person was present. Replicating the demonstration studies with familiar experimenters, and separately assessing the effects of test environment and familiarity of the people, may be helpful to gain insight on this topic.

Moreover, in Passalacqua et al. (2011) 2 month puppies were tested alone with an experimenter, while 4.5 month puppies and adults had both an owner and an experimenter present. Younger puppies did not gaze for help as older puppies and adults did, which has been interpreted developmentally, as this behavior would increase with age. However, considering that familiarity of the experimenter may play a role in the display of such behaviors, it would be important to test very young puppies on an unsolvable task with familiar people present.

Finally, features such as individual characteristics and personality may differentially affect gazing behavior and persistence in problem solving tasks. Therefore, studies focusing on particular traits and their relation to gazing behavior in such tasks are in order. For instance, Passalacqua et al. (2013) investigated the influence of pathological anxiety in the performance on an unsolvable task. They found that, when the task became unsolvable, anxious dogs had a higher tendency to stay far from the apparatus while control dogs exhibited more attention getting behaviors towards humans. Therefore, dogs with anxiety seemed less independent when confronting a novel task, and when it became impossible, they abandoned their attempts faster, choosing an ineffective coping strategy (i.e. avoidance instead of asking for human help). Moreover, Marshall-Pescini et al. (2016) pointed out that motivational differences could be behind the variations they found between trained an untrained dogs, so it should be taken into account in future research. Additionally, some studies reported sex differences, with females being more likely to exhibit social behaviors such as gazing (Hori et al., 2013; Persson et al., 2015, 2017; Kovács et al., 2016).

Conversely, in other studies sex differences were not significant (Passalacqua et al., 2011; Marshall-Pescini et al., 2013; Konno et al., 2016). However, the majority of works have not included sex in their analyzes, which would relevant for further research, given these inconsistent results. Summing it up, individual differences should be considered when analyzing dogs' communicative responses in unsolvable or difficult tasks.

Conclusion

When confronted with unsolvable or difficult situations, dogs usually tend to look at humans as toddlers do. The more accepted interpretation of this behavior is that dogs gazing behavior is a request for help. This is sometimes accompanied by gaze alternation between the human and the targeted object, which has been defined as functional referential communication. Therefore, it appears that dogs intend to call the subject's attention, direct it to a specific object and expect a modification in the receptor behavior as a response to their actions.

Nevertheless, alternative interpretations regarding the function of the gazing behavior and its underlying motivations, cannot yet be discarded. Dogs could gaze at the human to look for permission or approval to act, as well as seek human contact, or reassurance in a difficult situation. Thus, further investigations must be conducted to understand the motivations of gazing behavior in different situations. Additionally, gazing behavior when requesting for help must be properly defined in order to differentiate it from other looking backs behaviors (i.e. monitoring other individual's actions). Different methodological aspects, as discussed before, should be considered to further understand the nature and motivations of gazing behavior in unsolvable or difficult problem situations.

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Il "Gazing behavior" durante una prova di problem solving nel cane. Una review critica

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Sintesi

Negli ultimi anni, numerosi studi hanno valutato il comportamento del cane quando è messo di fronte ad un prova risolvibile o non risolvibile, in presenza del partner umano. In queste situazioni i cani tendono a guardare le persone e questo comportamento è interpretato come una richiesta di aiuto.

Questa capacità di attirare l'attenzione del partner umano verso un oggetto determinato è interpretabile come un segnale di referenza e potrebbe avere una funzione simile a quella dell'indicare col dito del bambino.

Lo scopo di questa ricerca è stato quello di effettuare una revisione critica degli studi riguardanti i comportamenti comunicativi del cane durante prove irrisolvibili o risolvibili ma comunque complicate, analizzando in particolare il comportamento di fissare il viso umano.

Per essere incluso in questa review, uno studio doveva trattare una prova di problem solving ed analizzare il comportamento di fissare la persona durante la prova sperimentale.

Gli argomenti principali di discussione sono stati raggruppati in tre aree concettuali. La prima si è concentrata sugli aspetti metodologici come le procedure e l'apparato utilizzato, le persone presenti durante il test ed i comportamenti analizzati.

La seconda area ha analizzato alcuni fattori che potrebbero influenzare l'emissione del comportamento di fissare, come la specie, l'esperienza di addestramento, le condizioni di vita e la razza.

La terza area ha preso in esame gli studi di neurobiologia, ad esempio ricerche sull'ereditabilità e sui recettori dei geni, come pure sugli effetti sul comportamento di somministrazioni intranasali di ossitocina.

In conclusione questa analisi permette di affermare che il comportamento di fissare il partner umano per richiedere aiuto appare essere il comportamento prevalente, anche se spiegazioni alternative potrebbero essere considerate. A questo scopo, sono proposte idee per future ricerche.