Animal Cognition
https://doi.org/10.1007/s10071-021-01501-8

REVIEW

A review of the unsolvable task in dog communication and cognition: comparing different methodologies

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Received: 1 August 2020 / Revised: 23 February 2021 / Accepted: 2 March 2021

Abstract

Communication between dogs and humans is a topic of growing interest, and the "unsolvable task" is a common method used to measure human-directed communication. In this task, dogs learn how to solve a problem to obtain a reward. After a fixed number of trials, the reward becomes impossible to access, arguably leading to communicative attempts from the dog. Although useful to observe dogs' communicative behaviors in a fairly naturalistic situation, the methodology varies among studies regarding apparatus, number of trials, and other factors. The proxies used, for instance, gaze duration or frequency of gaze alternation, also vary, and there are discrepancies and a debate regarding what the task actually measures. Therefore, in this study, we reviewed the usage of the unsolvable task in canids of the genus Canis, searching Web of Science and Scopus for the terms "dog*", "Canis", "dingo*", "wolf" or "wolves" in the title and "unsolvable task" or "impossible task" in the topic. We included thirty-five studies in this review and discussed their different methodologies and proxies, such as different apparatuses, number of solvable trials, and different interpretations of "looking back", pointing out how they can affect results and hinder comparisons. Lastly, we used current data to propose strategies to homogenize the use of this important paradigm, with an ethogram of possible behaviors and their interpretation and a predefined set of methodological aspects for future research.

Keywords *Canis familiaris* · Impossible task · Cognition · Communication · Wolf · Dingo

Introduction

Communication between domestic dogs and humans has been a topic of interest in the past 2 decades. Dogs appear to be particularly skillful in understanding human communicative gestures such as pointing and gazing (Agnetta et al. 2000; Miklósi and Soproni 2006; Reid 2009), with some studies suggesting they outperform wolves and chimpanzees in the use of such cues (Hare 2002). Furthermore, dogs seem to actively emit communicative signals to engage with humans (Miklósi et al. 2003; Gaunet 2008; Savalli et al. 2014; Albuquerque et al. 2018). These particular skills have led to an extensive debate on the effect of domestication and ontogeny on dogs' socio-cognition (Udell et al. 2008; Wynne et al. 2008; Hare et al. 2010), highlighting the importance of effectively assessing dogs' communicative behavior.

Gazing behavior is particularly relevant for dogs to establish effective communication with humans. Dogs tend to look back at a person when there is a hidden reward (Miklósi et al. 2000), when they lose access to desired food (Miklósi et al. 2003), and to increase visual communicative behaviors once they establish eye contact with their owners (Savalli et al. 2016). Human-directed gazing is affected by the level of training (Marshall-Pescini et al. 2009), age (Passalacqua et al. 2011), breed group (Konno et al. 2016), audience attention status (Marshall-Pescini et al. 2013; Savalli et al. 2014), and associative learning (Barrera et al. 2011). These various characteristics and interactions may contribute to when, how, and how much a dog communicates with humans.

In an attempt to further understand how these factors influence dogs' human-directed communication, one of the

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Published online: 23 March 2021

experimental protocols widely used is the "unsolvable task paradigm". In this experiment, a dog is presented with a desirable piece of food, which is immediately placed upon an apparatus. The dog then needs to solve a simple task—for example, open a container—to obtain the food. After a fixed number of trials, the apparatus becomes "locked" and the task impossible to solve. There are generally humans available for the dog to communicate with, and the dog's behavior is then observed, with a focus on gazing behaviors. Some of these commonly assessed behaviors include the duration of gazing (the dog's head and nose are oriented towards the human's face), frequency of looking back (the dog turns its head and nose towards the human face), frequency of gaze alternation (gaze at the human's face followed by gaze at the container or vice-versa within a short time; also called referential gazing), and latency to gaze (time elapsed until the first gaze). It is often considered that this set of behaviors indicates communicative attempts from the dog, possibly a form of seeking help (Gaunet 2008; Passalacqua et al. 2013). Moreover, some authors analyze dogs' persistence, using the duration of touching the apparatus as a proxy (Rao et al. 2018; Lazzaroni et al. 2019).

This setup allows for observing of dogs' gazing behavior in a fairly naturalistic situation—when they are trying to obtain food. The presentation of previous solvable trials allows the dog to be familiarized with the possibility of obtaining food in that situation and may increase the reward-seeking response due to training (Cavalli et al. 2018). Therefore, the task can contribute to evoke communicative behavior. With careful manipulation of groups and conditions, researchers can focus on different factors surrounding dogs' characteristics and try to understand their effects on communication and other behaviors. For instance, Passalacqua et al. (2011) found that adult dogs and 4.5 months-old pups are more likely to communicate with humans than 2 months-old pups, and Marshall-Pescini et al. (2009) showed that agility and search-and-rescue dogs are more likely to communicate with humans than untrained dogs.

Each year more experiments use the unsolvable task paradigm as a tool; yet researchers struggle to find a well-structured and consensual methodology to follow. Studies vary in the apparatus used, number of trials, the familiarity of the person who is available for visual contact, and other important characteristics. Additionally, it is challenging to find a clear explanation as to what exactly dog's behaviors facing the unsolvable task proposes to measure, since different interpretations could be obtained from it. It was first used to assess attraction to the human face, and it has been extensively interpreted as a way of evaluating communicative behavior, with some authors explicitly addressing it as help-seeking (Gaunet 2008; Hori et al. 2013; Passalacqua et al. 2013; please refer to Table 1 for more examples). It has eventually been used to assess a dog's bond with their owner with authors considering that dogs that gaze more at their owners have a closer bond with them (Sanford et al. 2018). More recently, it has been used to measure dogs' persistence in the task, with dogs that spend more time in contact with the apparatus considered to be more persistent (Rao et al. 2018; Lazzaroni et al. 2019, 2020). A recent study has even suggested that perhaps the task does not measure communication at all and rather that it measures persistence (Lazzaroni et al. 2020). The different measures obtained from the test (such as latency to gaze, frequency of gaze alternation, gaze duration, and duration of touching the apparatus) have been used as a proxy for different variables somewhat loosely. For instance, gaze at the human face has been considered as a communicative attempt, attraction to the human face, or gathering of information. Moreover, similar discrepancies can be seen in the use of the unsolvable task with other species, for instance, horses, goats, and kangaroos (Ringhofer and Yamamoto 2017; Alterisio et al. 2018; Langbein et al. 2018; McElligott et al. 2020; Yoshida and Koda 2020).

Given the controversial interpretations for what this task actually measures in dogs, it is fundamental to look into these past decades' research concerning the unsolvable task and discuss how it has been used and how we could work in the direction of a more unified methodology. Cavalli et al. (2018) have presented a comprehensive review of dogs' gazing behaviors during problem-solving situations, including both solvable and unsolvable tests. We contribute to this subject with a focus on studies that use only the unsolvable task, by discussing the variation in procedures and its impact on the results and interpretations. Our review includes new publications, discusses points raised by Cavalli et al. (2018), and further argues which theoretical variables and proxies are appropriate for the use of unsolvable task.

Therefore, this work aims at (1) reviewing the use of the unsolvable task with canids of the genus *Canis*, pointing out differences in methodologies and operationalizations, (2) discussing the effect of these variations in methodologies on results, and (3) proposing a framework to unify the use of the task.

Methods

In order to comprehend the range of studies that have used the unsolvable task paradigm, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (Moher 2009) was used. Given that comparative studies with other species of the genus *Canis* are of interest in understanding dog communication, we included all species of this genus in the search. The steps are described below and depicted in the flow chart (Fig. 1):

Table 1 References of all studies included in this review and its main characteristics

References	Number of solvable trials	Achievement of training criterion	People available for communication	Apparatus	Duration of unsolvable trial	Humans' attitude (posture, distance, gazing)	Variables (proxies)	Theoretical variables
Miklósi et al. (2003)	6	100%	Caregiver	Rope in a cage and bin (A, B)	2 min	Standing up, 1 m, not stated	Gaze duration, latency to gaze, frequency of looking back	Attraction to the human face
Gaunet (2008)	6	100%	Caregiver	Bin (B)	2 min	Standing up, not stated, looking ahead	Gaze duration, frequency of gaze alternation	Communicative behavior, help-seeking behavior
Marshall-Pescini et al. (2009)	3	100%	Caregiver + experimenter	Wooden board (D)	1 min	Standing up, 20 cm, looking ahead	Frequency of gaze alternation, gaze duration, latency to gaze	Communicative behavior
Miller et al. (2010)	Other	Other	None	Commercial feeder	Other	No humans present	Duration of touching the apparatus	Persistence
Passalacqua et al. (2011)	3	66%	Caregiver + experimenter	Wooden board (D)	1 min	Standing up/kneeling, 50 cm, looking ahead	Latency to gaze, gaze duration, frequency of gaze alternation	Communicative behavior, requesting behavior
Horn et al. (2012)	Other	Other	Caregiver (exp 1)/ caregiver + two experimenters (exp 2)	Wooden disc (I)	5 min	Sitting, not stated, wearing sunglasses	Duration of touching the apparatus, gaze duration, latency to gaze, human proximity	Expectation of humans' actions
Hori et al. (2013)	1	Other	Caregiver + experimenter	Container with lid	Not provided	Standing up or sitting, not provided, not provided	Gaze duration, latency to gaze and frequency of looking back	Communicative behavior, help-seeking behavior
Marshall-Pescini et al. (2013)	3	79%	Caregiver + experimenter	Wooden board (D)	1 min	Standing up, not stated, looking at the recipient and smiling if the dog looks/back turned and smiling if the dog looks	Frequency of gaze alternation	Communicative behavior, requesting behavior
Passalacqua et al. (2013)	5	84%	Caregiver + experimenter	Wooden board (D)	1 min	Standing up, 50 cm, looking ahead	Gaze duration, latency to gaze, frequency of gaze alternation	Communicative behavior, help-seeking behavior
Smith and Litchfield (2013)	5	86%	Caregiver	Rope in a cage (A)	2 min	Standing up, 2.5 m, not stated	Frequency of looking back, frequency of gaze alternation	Problem-solving strategies

Table 1 (continued)

References	Number of solvable trials	Achievement of training criterion	People available for communication	Apparatus	Duration of unsolvable trial	Humans' attitude (posture, distance, gazing)	Variables (proxies)	Theoretical variables
D'Aniello et al. (2015)	3	100%	Caregiver + experimenter	Wooden board (D)	1 min	Standing up, 30 cm, looking ahead	Gaze duration	Communicative behavior, help seeking
Scandurra et al. (2015)	3	100%	Caregiver + experimenter	Wooden board (D)	1 min	Standing up, 30 cm, looking ahead	Gaze duration, latency to gaze	Communicative behavior
Persson et al. (2015)	2	Other	Experimenter	Plates covered with a lid with simultaneous solvable and unsolvable trials (F)	3 min	Sitting on a stool, 1.5 m, not stated	Gaze duration, latency to gaze, frequency of looking back	Communicative behavior, help-seeking behavior
Konno et al. (2016)	6	100%	Caregiver + experimenter	Wooden board (D)	1 min	Standing up, 1.5, responding to eye contact	Gaze duration, latency to gaze	Communicative behavior, requesting behavior
D'Aniello and Scandurra (2016)	3	95%	Caregiver + experimenter	Wooden board (D)	1 min	Standing up, 30 cm, looking ahead	Gaze duration, latency to gaze	Communicative behavior, help-seeking behavior
Persson et al. (2015)	2	Other	Experimenter	Plates covered with a lid with simultaneous solvable and unsolvable trials (F)	3 min	Sitting on a stool, 1.5 m, not stated	Duration, latency, and frequency of human proximity; duration, latency, and frequency of physical contact	Attention seeking behavior, contact seeking behavior
Kovács et al. (2016)	4	100%	Caregiver + experimenter	Mesh cage (C)	1 min	Standing up, 1.5 m, watching the dog	Gaze duration, latency to gaze, frequency of gaze alternation	Communicative behavior, help seeking behavior, social sensitivity
Piotti et al. (2017)	3	Other	Two experimenters	Bottles, wooden board with a mesh cage, commercial feeder (G1, H)	2 min	Standing up, feet touching the apparatus, looking at the recipient	Gaze duration, latency to gaze, frequency of gaze alternation	Communicative behavior, help seeking behavior
Marshall-Pescini et al. (2017)	3	91%	Caregiver + experimenter	Wooden board (D)	3 min	Standing up, 50 cm to 75 cm, avoiding eye contact	Gaze duration, latency to gaze, frequency of looking back, frequency of gaze alternation	Communicative behavior, help seeking behavior, persistence

Table 1 (continued)

References	Number of solvable trials	Achievement of training criterion	People available for communication	Apparatus	Duration of unsolvable trial	Humans' attitude (posture, distance, gazing)	Variables (proxies)	Theoretical variables
Persson et al. (2017)	3	Other	Caregiver + experimenter	Plates covered with a lid with simultaneous solvable and unsolvable trials (F)	3 min	Standing up, 2.7 m to 2.85 m, looking at the recipient	Gaze duration, latency to gaze, frequency of looking back; duration, latency, and frequency of human proximity, duration, latency, and frequency of physical contact	Contact seeking behavior, social behavior
Sanford et al. (2018)	3	Not provided	Caregiver + experimenter	Wooden board (D)	1 min	Standing up, not stated, staring across the room	Gaze duration	Bond with owner
Rao et al. (2018)	0	Not applicable	None	Commercial feeder	Other	No humans present	Gaze duration and duration of touching the apparatus	Persistence
Persson et al. (2018)	2	Other	Caregiver + experimenter	Plates covered with a lid with simultaneous solvable and unsolvable trials (F)	3 min	Standing up, 2.7 m to 2.85 m, looking at the recipient	Gaze duration, frequency of looking back	Communicative behavior
Cavalli et al. (2018)	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Kiss et al. (2018)	6	Other	Two experimenters	Window ledge	2 min	Standing up; 1.5 m; watching the dog	Gaze duration, frequency of looking back	Attention towards humans
Lazzaroni et al. (2019)	0	Not applicable	None	Feeder ball and bottle (G)	Other	No humans present	Duration of touching the apparatus	Persistence
Cavalli et al. (2019)	3	91%	Caregiver + experimenter	Wooden board (D)	3 min	Standing up, not stated, looking ahead	Gaze duration, latency to gaze, frequency of gaze alternation	Communicative behavior, help-seeking behavior
Lazarowski et al. (2019)	3	Other	Caregiver + experimenter	Wooden board (D)	1 min	Standing up, not stated, looking at the recipient	Gaze duration, duration of touching the apparatus, frequency of 3-phased gaze alternation	Communicative behavior, help-seeking behavior, persistence
Maglieri et al. (2019)	6	77%	Caregiver + experimenter	Wooden board (D)	1 min	Standing up, 40 cm to 50 cm, looking ahead	Gaze duration, latency to gaze	Communicative behavior

Table 1 (continued)

References	Number of solvable trials	Achievement of training criterion	People available for communication	Apparatus	Duration of unsolvable trial	Humans' attitude (posture, distance, gazing)	Variables (proxies)	Theoretical variables
Sommese et al. (2019)	3	Not provided	Caregiver + experimenter	Wooden board (D)	1 min	Standing up, 50 cm, looking ahead	Gaze duration, latency to gaze, frequency of looking back, frequency of gaze alternation	Communicative behavior
Carballo et al. (2020)	3	89%	Two experimenters	Wooden board (D)	3 min	Standing up, 1 m, looking ahead	Gaze duration, frequency of gaze alternation	Communicative behavior, help-seeking behavior
Lazzaroni et al. (2020)	3	Other	Experimenter	Wooden board with simultaneous solvable and unsolvable trials (E)	Other	Sitting down, 1.5 m, looking at phone	Gaze duration, latency to gaze, frequency of gaze alternation, duration of touching the apparatus	Persistence
Kubinyi and Iotchev (2020)	2	Not provided	Caregiver + experimenter	Wooden board (D)	30 s	Standing up, 1 m, not stated	Frequency of looking back	Social behavior
Lazarowski et al. (2019)	4	Other	Caregiver + experimenter	Wooden board (D)	15 s (4 trials)	Standing up, 1 m, looking at other person	Gaze duration, physical contact, duration of touching the apparatus	Communicative behavior
Fraga et al. (2021)	5	63%	Caregiver + experimenter	Wooden board (D)	90 s	Kneeling down, 50 cm, looking at the recipient	Gaze duration, latency to gaze, frequency of gaze alternation, duration of touching the apparatus	Communicative behavior

"Not applicable" refers to a review, or to studies that did not use solvable trials, thus "achievement of training criteria" does not apply. "Other" refers to alternative methods of presenting solvable trials or training criteria and are discussed in the "apparatus and procedure" section. The letter next to apparatus refers to the representation of apparatus in Fig. 2

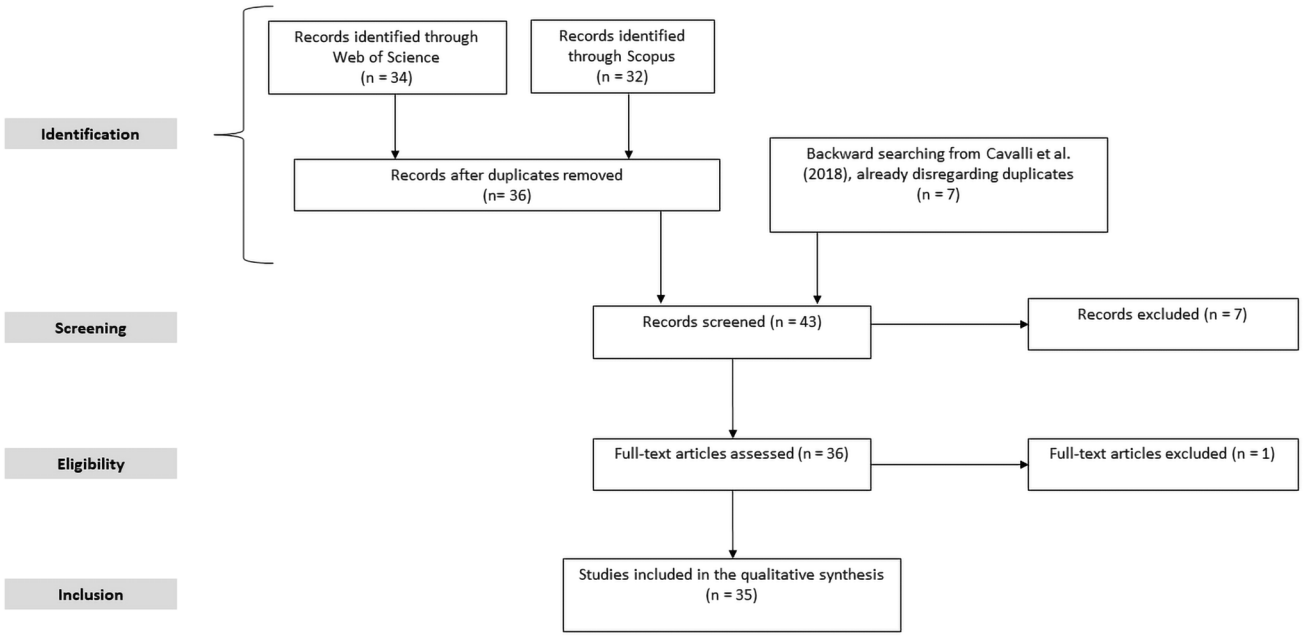

Fig. 1 Flow chart indicating the processes of articles inclusion. Adapted from Moher (2009)

Identification

(a) A search was made in the database Web of Science for the terms "dog*", "Canis", "dingo*", "wolf" or "wolves" in the title and "unsolvable task" or "impossible task" in the topic. We found 34 articles;
(b) The same search was made in the database Scopus. We found 32 articles;
(c) We removed duplicates and 36 articles remained;
(d) We performed a backward searching from Cavalli et al. (2018) and included any additional article that used the unsolvable task and had not been found in the previous steps. Seven articles were included, totalizing 43 articles.

Screening

We read the articles' abstracts and methodologies. Articles that used the unsolvable task paradigm were included. Seven articles did not use the paradigm and were excluded (these articles used solvable tasks or out-of-reach food paradigms and discussed results of works with the unsolvable task). Thus, 36 articles remained.

Eligibility

We read thoroughly the 36 articles, and every article that presented details of procedure and proxies used for the unsolvable task was considered eligible. One article was excluded because the unsolvable task was part of a long experimental battery and details could not be found. Therefore, 35 articles were included in this review.

Results and discussion

Thirty-five studies using the unsolvable task were included in this review. Thirty-one studies analyzed dogs (*Canis familiaris)*, three analyzed both wolves (*Canis lupus)* and dogs, and one assessed dingoes (*Canis dingo*). Out of the studies that analyzed dogs, 29 assessed pet dogs, seven assessed working dogs, and three analyzed free-ranging dogs. Three studies assessed dogs bred and kept at the Wolf Science Center, where they lived in packs and went through training and testing sessions (Marshall-Pescini et al. 2017), and another three studies analyzed dogs bred for research purposes living in kennels. In Table 1 we present the references included and its main characteristics.

Apparatus and procedure

The apparatus used in the unsolvable task paradigm varied substantially across studies (Fig. 2). In Miklósi et al. (2003), dogs and human-socialized wolves were tested in two tasks: opening a bin and pulling a rope. In the bin task, subjects had to open the lid of a 30 cm high container after watching a demonstrator do it 10 times. There were six solvable trials before the lid was mechanically fixed. For the rope pulling task, a piece of food attached to a rope was put inside of a wire mesh cage. After an experimenter offered a piece of

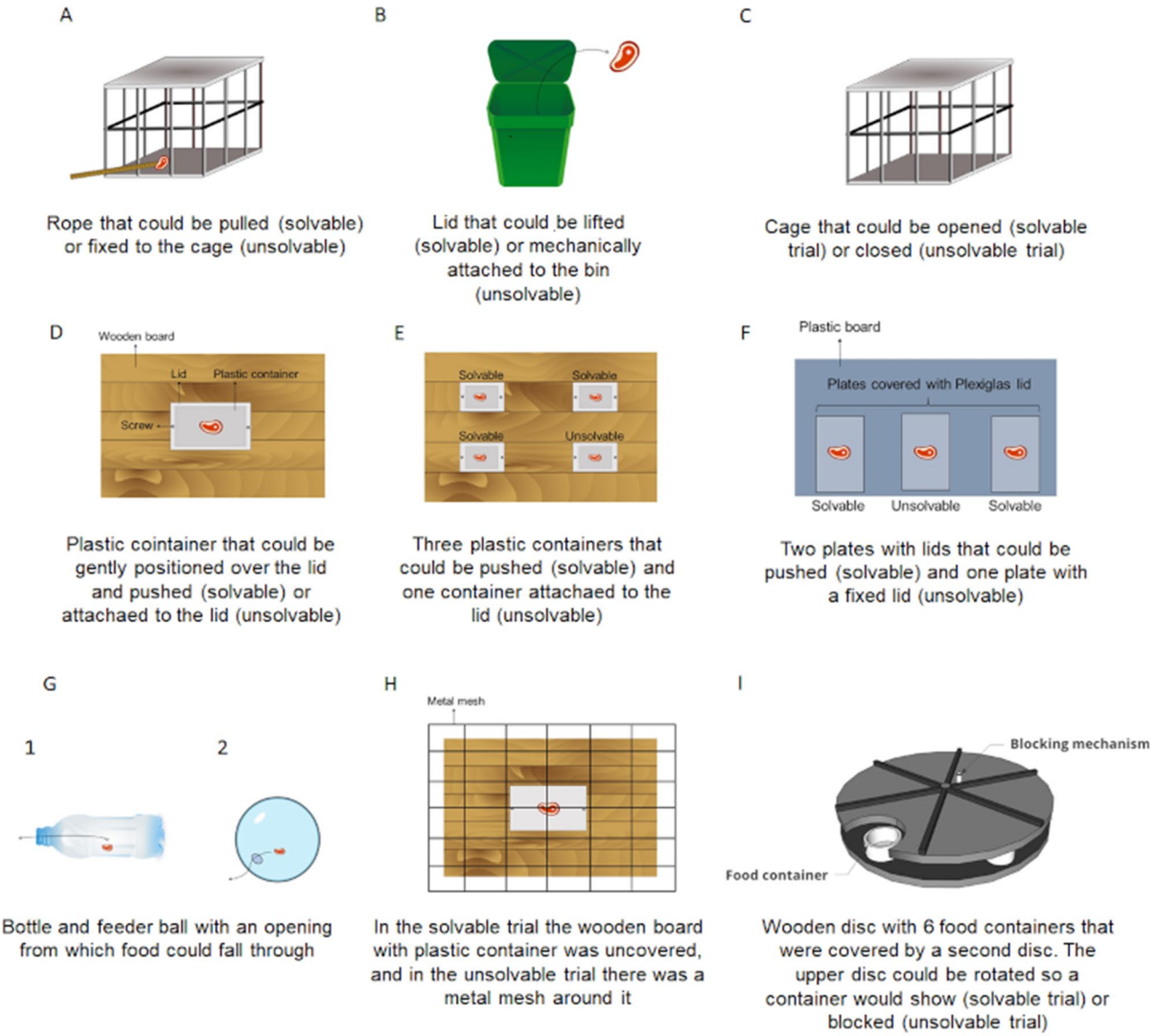

Fig. 2 Scheme of different types of apparatus used in unsolvable task paradigm. **a** A wire mesh cage with a rope attached to it. Used in two studies; **b** bin with a lid. Used in two studies; **c** a mesh cage that could have its door open or closed. Used in one study; **d** wooden board with a plastic lid attached to it. Used in 20 studies; **e** wooden board with four plastic lids attached to it. Used in one study; **f** a plastic board with three lids attached to it. Used in four studies; **g1** a plastic bottle, used in two studies, and **g2** a feeder ball with an opening, used in one study; **h** wooden board covered with a plastic lid attached to it and covered by wire mesh. Used in one study; **i** wooden disc with six food containers. Used in one study. Other experiments not included in the scheme used commercial dog feeders (see Table 1 that described which apparatus was used in each study)

food through the mesh, the dog was released and could pull the rope to obtain the food six times. In the unsolvable trial, the rope was fixed to the cage. Then, the subject's behavior was recorded in this situation.

A few years later, in 2008, Gaunet used the bin-opening task, with slight changes in the size of the apparatus (30 cm high and 30 cm in diameter compared to 30 cm and 20 cm in diameter in Miklósi et al. 2003), to examine the effect of the visual status of the owner in the use of humans' eyes as a cue during human–dog interactions. The rope-pulling task was replicated by Smith and Litchfield (2013) to study dingoes (*Canis dingo*), also with slight changes in the size of the apparatus (90 cm × 60 cm × 66 cm compared to 100 cm × 50 cm × 50 cm in Miklósi et al. 2003). Even though the apparatus size may, depending on the situation, be crucial for solving the task, no studies to our knowledge have assessed possible behavioral differences due to apparatus size, or adjusted apparatuses accordingly to dogs'

size, as it has been done with puzzle boxes and out-of-reach paradigms for instance (Range et al. 2014; Cabral 2019). A mesh cage was used by Kovács et al. (2016), however, in the solvable trials the door was open so the food could be directly assessed without pulling a rope, and the door was closed in the unsolvable trial. But the most commonly used version of the task is a small transparent container on top of a wooden board, with the container being fixed to the board in the unsolvable trial (used in 20 out of 35 studies). This has the advantage of turning the task from solvable to unsolvable using the same container.

With the bin, a different bin has to be pre-prepared with a mechanically fixed lid; moreover, Gaunet (2008) previously presented demonstration trials in which humans lifted the lid and showed food to the dog. With the rope-pulling, the rope has to be attached to the cage, which requires different movements and time for preparing the apparatus; and with the mesh cage with no rope, the door has to be open in some trials and closed in others, changing size and configuration of the object. With a container on a wooden board, the lid can be previously fixed on the board; in the solvable trials, the experimenter can position the container on top of the lid without fixing it, and the dog can turn it or push it until it reaches the end of the board, freeing the food. In the unsolvable trial, the experimenter can fixate the same container against the lid prior to the starting of the trial, making it impossible to move with practically the same procedure. As it is a simpler task, it arguably dismisses human demonstrations, allowing the dog to directly learn from trial and error.

Variations of the board with containers have been used, for instance, a plastic board with three wells covered with plexiglass lids, where two lids were possible to move and one was fixed (Persson et al. 2015, 2016, 2017, 2018). Lazzaroni et al. (2020) used a wooden board with four containers attached, three of which were possible to move and one fixed. Differently from most other apparatuses, these versions present both the solvable and unsolvable trial simultaneously, which could have significant implications for dogs' behavior when facing the task. For instance, dogs could approach the impossible bowl at first, or open one, two or three others at first, which could arguably affect their persistence in the unsolvable bowl and willingness to communicate.

Another variation of the apparatus used by Horn et al. (2012) consisted of two wooden disks screwed on top of each other, with six round food containers built on the lower disc. The upper disk had holes of the same size of the food containers, and it could be rotated to allow the food to be accessible. In the unsolvable trial, a blocking mechanism was engaged so the upper disk could rotate only half a turn, allowing the dog to eat three treats and blocking the remaining three. Therefore, the task consisted of fully solvable trials and a partially solvable trial.

Hori et al. (2013) used a container in which the lid could be gently placed or firmly closed, with the difference that the container was not attached to any board. Miller et al. (2010), Rao et al. (2018), and Lazzaroni et al. (2019) used commercial dog-feeding toys; commercial items could make studies harder to replicate, as the same toys are not necessarily available in different countries. However, the context and goal have to be considered. For instance, Lazzaroni et al. (2020) aimed at testing dogs with a novel object for free-ranging dogs, which was achieved by using a commercial feeder. The authors additionally used a bottle as a food dispenser in a condition with a familiar object.

A variation of the unsolvable task was used by Kiss et al. (2018). The authors used toys as the desirable object, and the toy was thrown by an experimenter onto a window ledge rather than using an apparatus. In the solvable trials, an experimenter picked the toy up and returned it to the dog, and in the unsolvable trial the toy remained on the out-of-reach ledge. In this experimental design, the human acts as a tool to solve the problem from the beginning, which could potentially stimulate dogs' human-directed communication when the task becomes unsolvable. This enhancement of communication could be interesting to some research questions, but it has to be considered that it hinders comparisons with other studies where dogs solve the tasks by themselves in the solvable trials.

Overall, as Cavalli et al. (2018), we argue that the lack of consistency in the use of apparatuses obstructs the comparison of results from different studies (see column Apparatus in Table 1). The wooden board with a plastic container seems appropriate since, as mentioned above, it allows that the same apparatus is used, with similar procedures in both solvable and unsolvable trials. We argue that the presentation of sequential solvable and unsolvable trials, rather than simultaneous trials, facilitates the distinction of perseverance-related and communication-related behaviors.

The number of solvable trials presented to dogs also varies (see column Number of solvable trials in Table 1). Most (14) studies used three solvable trials before the unsolvable trial. Two studies that focused on persistence went directly to the unsolvable task. One study used one solvable trial, four studies used two solvable trials, two used four trials, three used five trials, and five studies provided six attempts. In Sanford, Burt, and Meyers-Manor (2018), the number of solvable trials varied as many times as necessary until dogs succeeded three times. In Horn et al. (2012), the number of trials was as many necessary for the dog to obtain all pieces of food in under 1 min. In Miller et al. (2010), owners were given the feeding toy and dogs could use it for 20 min every day for a week before the experiment. In most studies, it was required at least two successes (the dog getting the food) for dogs to move on to the unsolvable trial. The success rate (dogs that go on to the unsolvable trial, named in Table 1

as Achievement of training criterion) provided information about the appropriate number of solvable trials, but many other factors affected these results and were not controlled in those different studies. For instance, younger dogs might need more attempts to grasp the task, while too many trials can satiate some dogs or decrease their motivation due to the simplicity of the task. Three trials appear to be enough for adult dogs to learn how to solve the task, as in three studies all dogs went on to the unsolvable trial (Marshall-Pescini et al. 2009; D'Aniello et al. 2015; Scandurra et al. 2015) and in three others the success rate was close to 90% (D'Aniello and Scandurra 2016; Marshall-Pescini et al. 2017; Carballo et al. 2020). Only in Passalacqua et al. (2011) was the success rate relatively low (66%), as they tested pups. Moreover, the task with three trials has been widely used, favoring comparisons. When a different number of solvable trials is used due to particularities of subjects or research aim (for instance studies with young pups that need more exposition) it should be clearly stated.

In 22 studies, both the owner (or caregiver in case of non-pet animals) and an unfamiliar experimenter were available for the dog to communicate with (see column People available for communication in Table 1). The duration and frequency of gazes towards both were summed up, and which person the dog gazed at first was registered. Variations included two unfamiliar experimenters (Piotti et al. 2017; Kiss et al. 2018; Carballo et al. 2020), just the experimenter (Persson et al. 2015, 2016; Lazzaroni et al. 2020), just the caregiver (Miklósi et al. 2003; Gaunet, 2008; Horn et al. 2012; Smith and Litchfield 2013), or the caregiver and two experimenters (Horn et al. 2012). In their review, Cavalli et al. (2018) point out that results are mixed regarding to whom dogs direct visual communication when both familiar and unfamiliar people are present, considering that this could be modulated by dogs' bond with the owner. Therefore, it could be interesting to apply attachment questionnaires to better understand the role of relationship between dog and owner on gazing behavior and compare it to gazing towards the unfamiliar person. In studies assessing persistence, no one person was available for communication. It was not discussed in these studies how the absence of the owner could trigger separation-related behaviors and influence results. Moreover, it has been shown that owner presence increases dogs' interactions with problem-objects (Horn et al. 2013; Udell 2015). We argue that when studies aim at assessing dogs' communication, the owner/caregiver (when existent) should be present, as s/he presents dogs' primary recipient of communicative signals in naturalistic daily situations.

Moreover, the posture, distance, and attitude of human participants varied across studies (see column Humans' attitude (posture, distance, gazing) in Table 1). In most studies, people were looking ahead and ignoring the dog. In one study, the caregiver was even asked to wear sunglasses (Horn et al. 2012). Only in four studies, the people were asked to watch the dog and/or respond to eye contact (Marshall-Pescini et al. 2013; Konno et al. 2016; Kovács et al. 2016; Kiss et al. 2018). Marshall-Pescini et al. (2013)'s study is particularly interesting, as it directly tested the effect of the visual state. In one condition, the caretaker and experimenter had their back turned to the apparatus, and in the other they looked ahead, but smiled briefly if the dog made eye contact. Dogs used more gaze alternation in the attentive condition, showing the importance of visual availability of the receptor. Although Cavalli et al. (2018) point out in their review that the mere presence of people is enough to elicit communicative behaviors, we argue that in a task that aims at assessing communication, availability for the signal to emerge fits best. As for posture, in most studies, the people present were standing up. In four the people were sitting down (Horn et al. 2012; Persson et al. 2015, 2016; Lazzaroni et al. 2020) and in one they were kneeling down (Fraga et al. 2021). In Hori et al. (2013) people could be standing up or sitting down. In Passalacqua et al. (2011), people were standing up with dogs 4-months-old or older but kneeling down when 2-months old pups were tested. Sitting or kneeling down could arguably facilitate dogs' physical contact with the caretaker and experimenter. Since the main goal of the task is to assess visual communication rather than physical contact, we suggest that the posture used is standing up, unless the context dictates differently. Passalacqua et al. (2011)'s use of the task exemplified a situation in which the great distance between the person's eyes and the young pup could be detrimental to their performance. Looking at the distance from the apparatus, it varied from none (feet touching the apparatus) to 2.5 m, with many options in between and none being extensively used. Therefore, there is not enough data to propose the most appropriate setting regarding this distance. A study directly comparing the effect of distance between the recipient and the apparatus could help bring more insight to this point.

Most (13) studies presented the unsolvable task for 1 min (see column Duration of unsolvable trial in Table 1). Five studies used 2 min (but Smith and Litchfield interrupted earlier in case the subject tried to release itself from the leash), and seven studies used 3 min. Other alternatives used by only one study each were 30 s (Kubinyi and Iotchev 2020), 90 s (Fraga et al. 2021), 5 min (Horn et al. 2012), and four trials of 15 s each (Lazarowski et al. 2020). In four studies, there was no fixed time limit: the trial lasted until the dog stopped interacting with the apparatus for a fixed amount of time (maximum of 2 min in Miller et al. 2010 and 5 min in Rao et al. 2018 and Lazzaroni et al. 2020) or left a predefined area of two-body-lengths radius from the apparatus (Lazzaroni et al. 2019). When no constraints dictate the ideal duration, we suggest the use of 1 min for the unsolvable trial, as it has been used by most studies, allowing for a

better comparison, and has been shown to be sufficient time to evoke communicative behaviors (Marshall-Pescini et al. 2009; Passalacqua et al. 2011; Cavalli et al. 2018). However, some research questions may demand adaptation on the duration of the unsolvable task. For instance, when investigating persistence, the task could demand a longer time as to not finalize the test while the subject is still persisting in interacting with the apparatus. On the other hand, when dogs are separated from their owners, the task needs to be shorter to avoid stress in dogs. Practical reasons could also interfere, such as the time available when doing research in shelters or kennels. Therefore, it is important to justify the duration of the trial.

Variables and operationalizations

In Miklósi et al. (2003), dogs looked sooner and for longer than wolves when the task became impossible, leading the authors to conclude dogs had a lower degree of attraction to the food, as they were more likely to interrupt their efforts to obtain it. As for the wolves, it was argued that they were less prone to look at humans, even when socialized, while dogs would have a predisposition to look back at humans. In that discussion, we can point out two different variables: attraction to food as a reward and tendency to gaze at humans.

When Gaunet (2008) compared pet dogs of sighted owners with guide dogs of blind owners, no difference in gazing behaviors was found between groups, which led the author to conclude that dogs did not understand their owners' visual status. Furthermore, since the first interactive modality was gazing in both groups, it was discussed that gazing would be the key factor in human–dog communication, especially in help-seeking behaviors. It can be argued, then, that this was the first study to use the unsolvable task to explicitly discuss help-seeking.

In total, 22 studies explicitly mentioned using the task in a communicative context, and the task was used to investigate how communication would be affected by factors such as age (Passalacqua et al. 2011), breed (Konno et al. 2016; Maglieri et al. 2019), specific training (Marshall-Pescini et al. 2009; D'Aniello et al. 2015), experiences (D'Aniello and Scandurra 2016), anxiety (Passalacqua et al. 2013), evolution (Marshall-Pescini et al, 2017; Rao et al. 2018), genetic differences (Persson et al. 2015, 2017), and perception of human characteristics (Piotti et al. 2017). Among them, 15 considered the gazing behaviors in the task as help-seeking or requesting behavior (please refer to Table 1). In one study it was suggested that dogs that gazed at their owners for longer would have a stronger bond with them, therefore the gazing was interpreted as a measure of closeness (Sanford et al. 2018). As for persistence, Hall (2017) mentioned the use of the unsolvable task in a review of persistence in dogs, describing it as "another rapid way to measure persistence in the dog, and allows for the observation of alternative behaviors that occur when a previously reinforced response is placed on extinction". The author additionally discussed the importance of persistence in Miklósi et al. (2003)'s experiment, where it was not explicitly taken into consideration, and pointed out that perhaps dogs were more likely to turn to different food-obtaining behaviors that could have been more reinforced throughout their lives (i.e.: gazing at humans) than persisting is the task.

When using the unsolvable task to investigate the effect of domestication and exposure to humans, Marshall-Pescini et al. (2017) accounted for persistence as a potential explanatory factor of different behaviors during the task. The authors compared similarly raised dogs and wolves, pet dogs, and free-ranging dogs, and found that less persistent animals looked at humans sooner, longer, and more frequently, regardless of species or level of socialization. Looking back was considered as a social and communicative behavior used to gain "human cooperation" and strongly linked to persistence. These authors stated that future studies should take that into consideration, in addition to designing different tasks that allow for the assessment of communication and persistence more independently.

The effect of persistence was also noticed by Udell (2015) in a problem-solving task (with only solvable trials). The author compared pet dogs, shelter dogs, and wolves, and found that wolves were more persistent in manipulating the apparatus and had an 80% success rate, while dogs had a 5% success rate. Moreover, dogs spent significantly more time gazing at the human than wolves. Udell argued that perhaps dogs give up prematurely in tasks due to a hypersensitivity to human cues and proposes that different types of problem-solving tasks should be employed to further understand dogs' abilities.

Some studies have used the unsolvable task to primarily evaluate persistence. Rao et al. (2018) tested equally raised dogs and wolves at the task using only the unsolvable part and in the absence of humans, aiming to assess the effect of motivational drive in the performance. Even though turning to humans was not an option in this study, dogs persisted less than wolves in the task. The authors discussed that these differences might be related to the species socioecology, pointing out that dogs evolved in scavenging near human context, and wolves are hunters with low hunting success rate, which would favor the selection of higher persistence. Using the same methodology, Lazzaroni et al. (2019) compared the persistence of free-ranging dogs, pet dogs, and captive pack dogs, and found that pet and captive dogs manipulated the apparatus for longer than free-ranging dogs. They suggested that previous human-mediated experiences in manipulating objects may have led to increased motivation in pet dogs and captive dogs to engage in the task even in the absence of humans. In both studies, the main variable used to assess

persistence was the duration of touching the apparatus with snout or paw.

To further understand dogs' behavior during the unsolvable task, Lazzaroni et al. (2020) proposed to test whether dogs' looking back at the humans is indeed a social problem-solving strategy. They presented pet dogs and free-ranging dogs with an apparatus containing simultaneously the solvable and unsolvable task: four containers were attached to a wooden board, three of them possible to move, giving access to the food, and the other one fixed. Dogs could be tested in four conditions: alone, with a human, with an object, and with a human-imitating dummy. In the human condition, the person was looking at the phone. No differences were found between groups and conditions regarding persistence or latency to look back. However, pet dogs alternated looks more often and gazed for a longer period at humans than at objects. In the human condition, there were no differences between pet dogs and free-ranging dogs concerning gaze alternation.

Firstly, it is important to point out that Lazzaroni and collaborators' study employed considerable modifications in the methodology, such as the apparatus with simultaneous solvable and unsolvable tasks and the fact that, when present, the experimenter was looking at her phone, when in previous studies the experimenter looked straight ahead or back at the dog. A person's inattentiveness has been shown to decrease communicative attempts (Marshall-Pescini et al. 2013), therefore dogs' attempts to communicate could be inhibited by an inattentive recipient of dogs' communicative cues. Additionally, these changes may impair comparison with previous experiments. As mentioned before, the possibility to directly approach the impossible bowl or interact with one, two, or three other possible containers first could affect their persistence. Persson et al. (2015, 2016, 2017, 2018) have used simultaneous solvable and unsolvable trials as well in more than one occasion, however they had two possible trials rather than three. The comparison of these different possibilities could be confounding.

Lazzaroni et al. (2020) argued that, since dogs' persistence to interact with the apparatus was the same when there was a person available compared to when there was not, their subsequent looking back behavior was a consequence of giving up rather than a request for help. And, as there was also no difference in latency to gaze, that this was more related to the subject's persistence than to communication. However, we argue that reduced persistence in the face of an observer is not an indication of referential communication; dogs' persistence could be the same with or without a potential helper, but it is their behavior *after* "giving up" that contains indications of communicative intent or not.

Common indicators of referential behavior are (1) an audience is required to exhibit the signal; (2) there are successive gaze alternations between the recipient and the object of interest; (3) the sender displays apparent attention-getting behaviors; (4) there is an influence of the recipient's attentional status; (5) there is persistence and (6) elaboration of communication when previous attempts fail (Leavens et al. 2005). These criteria have been observed in dogs in a food-requesting situation (Savalli et al. 2014).

In Lazzaroni et al. (2020)'s study, pet dogs did alternate more looks and gazed for longer at humans than at objects, which would be an indication of these behaviors meeting the first indicator. Other indicators cannot be assessed through the data displayed in this study. However, a review of other studies can help bring that into light: in Marshall-Pescini et al. (2013), the authors showed that dogs used less gaze alternation when the person was inattentive (fourth indicator) and concluded that it is intentional and referential behavior. In Marshall-Pescini et al. (2009), search and rescue dogs (who have a positive reinforcement history with barking) barked in the unsolvable trial, always concurrently gazing at the experimenter or apparatus, considered by the authors as an attention getting behavior (third indicator) and an elaboration of communication (sixth indicator). Numerous studies showed gaze alternation between the apparatus and the human, meeting the second criteria (Gaunet 2008; Passalacqua et al. 2011; Piotti et al. 2017; Marshall-Pescini et al. 2017; Cavalli et al. 2019; Lazarowski et al. 2019; Sommese et al. 2019; Carballo et al. 2020).

Smith and Litchfield (2013) had previously pointed out the lack of operationalization and clarity of "looking back" in the unsolvable task affects the results and interpretations. They argued that descriptions of the behavior are too diverse and lack details, leading to the account of non-referential looking back. When testing dingoes (*Canis dingo*) in the unsolvable task and using the definition in Miklósi's seminal work (2003) ("turning its head to its side with its head/nose oriented towards any part of the caretaker"), eight out of the 12 dingoes looked back. According to Smith and Litchfield (2013) this behavior happened often when the subject was not looking or interacting with the apparatus, considered by the authors to be non-referential and likely part of the process of gathering information, or when the dingo was struggling to free itself from the leash, considered to be related to escaping behavior. After considering "looking back" only in the context of interacting with the task and in the sequence task-person or vice versa, three dingoes used this "referential looking back".

In agreement with Smith and Litchfield (2013) and other studies as Passalacqua et al. (2011), we argue that "referential looking back" with the sequence of target-human or human-target and within a specific time frame (usually 2 s) is the most appropriate measure of communicative behavior in this context. This behavioral sequence is also commonly called "gaze alternation", which may cause confusion with Merola et al. (2012)'s definitions.

In that work, authors called this two-steps sequence "referential gazing" while the "gaze alternation" referred to a three-steps sequence: target-human-target or human-target-human. We argue that the two-step process is enough to account for referential communication since it already promotes the triangulation among communicator, receptor, and referent. Nonetheless, whichever authors choose to use, it should be clearly specified. A standardized operationalization would benefit our understanding of communicative behaviors, facilitating comparisons and meta-analyzes of the results. At this point, a diverse kind of methodology did not assure that studies are comparable. In their review, Cavalli et al. (2018) pointed out as well that the current use of gazing behavior should be used with caution and that there should be unified criteria for different types of gaze. Additionally, we echo Smith and Litchfield (2013)'s note of the advantages of studies providing raw scores. By doing so, other researchers could access measures that were not necessarily used by the authors and perform meta-analyzes with matching standards.

In addition to different definitions of "looking back" being used, sometimes different variables are employed to account for communication. In fact, 14 out of 35 studies used two-steps referential looking back (target-human or human target; described in Table 1 as "frequency of gaze alternation") and one used three-phased referential looking back (target-human-target or human-target-human; described in Table 1 as "frequency of 3-phased gaze alternation"). The remaining studies used non-referential looking back (described in Table 1 as "frequency of looking back"), gaze at human duration, and latency to first look. Although informative and complementary, we propose that duration and latency should not be the main focus of the analyzes, as they are not shown to be necessarily communicative. If latency is related to time manipulating the apparatus, which needs more investigations, as it happens in Marshall-Pescini et al. (2017) and Lazzaroni et al. (2020) but not in Konno et al. (2016), perhaps it is indeed more appropriate to discuss persistence. It is additionally important to point out that latency could be described for the first gaze, as it happens in all studies in this review, or latency to first *gaze alternation*. If the first gaze is associated with looking at the most salient stimulus or to gathering information, perhaps latency to first alternation can be more indicative of time elapsed before an attempt to communicate. As for the duration of gazing at human, it could be related to attraction to the human face, as discussed by Miklósi et al. (2003), and/or to the process of gathering information, according to Smith and Litchfied (2013)'s proposition. We present an ethogram with well identifiable criteria of the behaviors generally assessed in the unsolvable task and propose proxies for each of them based on current data and on the qualitative analyses performed in this review, as well as in Cavalli et al. (2018).

Future perspectives

In sum, the unsolvable task has been shown to be a useful tool in the investigation of dogs' cognitive and communicative behavior, with enough evidence to characterize it as communicational when employing appropriate variables. A more precise operationalization of "looking back", as proposed since by Smith and Litchfield (2013), and standardization of methodological procedures for this paradigm would provide more comparable results and consequently contribute even further to our understanding of dogs' behavior, ontogeny, domestication process and their relationship with humans.

For the methodological standardization, we propose that the apparatus used is the wooden board with just one plastic container attached to it, with solvable trials followed by the unsolvable trial; that three solvable trials are presented to dogs; that both the caretaker (when existent) and an experimenter are present during the experiment; and that the optimal duration for the unsolvable trial is 1 min. Moreover, we propose well-defined criteria to each variable used to assess communicative behavior (please see Table 2) and argue that the most appropriate variable to measure communicative behavior is "frequency of gaze alternation", that happened in a short time (2 s) between one direction and the other. Although the size and form of apparatus should be species-specific to better assess each species, the operationalizations for visual behaviors proposed in this work can benefit the use of this paradigm with animals other than canids.

Although we proposed these forms of standardization based on the available data and on a qualitative analysis, perhaps specific research testing the effect of methodological variations could offer more robust arguments for the use of each choice. If future studies do use more standardized methodologies, a meta-analyzes could be performed in the future. Additionally, it should be noticed the most appropriate methods depend on each research question. Therefore, it is important that authors elucidate why they are using variations when doing so.

Table 2 Ethogram of commonly assessed behaviors during the unsolvable task, their proposed description, and proposed standardization for proxies

Behavior	Description	Proxy for
Frequency of gaze alternation	Gaze at the human's face followed by gaze at the food (or vice-versa) within 2 s	Communicative behavior, help-seeking behavior
Frequency of 3-phased gaze alternation	Gaze at the human's face followed by gaze at the food, then again followed by gaze at the human's face (or vice-versa) within 2 s	Communicative behavior, help-seeking behavior
Frequency of looking back	The dog turns its head and nose in the direction of the human's face, regardless of where the dog was gazing immediately before	Looking at the most salient stimulus
Gaze duration	The dog's head and nose are oriented towards the human's face	Gathering information, attraction to human face
Latency to first gaze alternation	Time elapsed until the first gaze at the human's face followed by gaze at the food (or vice-versa) within 2 s	Time elapsed to communicate
Latency to gaze	Time elapsed until the first time the dog's head and nose are oriented towards the human's face	Time elapsed to give up on the task
Touching apparatus	The dog is in contact with the apparatus with the snout or paws	Persistence

Acknowledgements This research was supported by funds from the Coordination for the Improvement of Higher Education Personnel (CAPES) and São Paulo Research Foundation (FAPESP). We would like to thank LECA-Laboratório de Etologia Canina (Canine Ethology Laboratory) for the discussions that fuelled this work, professor Dr. Glauco Machado (Institute of Biosciences of the University of São Paulo) for his guidance with methodological aspects, and MSc. Francisco Giugliano de Souza Cabral for contributing with a figure.

Author contributions JWWM and CS contributed to the study's conception and design. JWWM performed the search and analysis of articles included and wrote the first draft of the manuscript. BR and CS contributed to improving the manuscript. All authors read and approved the final manuscript.

Funding This research was funded by CAPES (Coordination for the Improvement of Higher Education Personnel) (Grant no. 88882.333303/2019-01) and FAPESP (São Paulo Research Foundation): process #2018 25595 0.

Declarations

Conflict of interest The authors declare no conflicts of interest.

Consent for publication JWWM, BR, and CS consent to the publication of the manuscript "A review of the unsolvable task in dog communication and cognition: comparing different procedures" in the journal Animal Cognition.

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