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What influences a pet dog's first impression of a stranger?

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Abstract

Dogs live in the dynamic human social networks full of strangers, yet they form strong and selective bonds with familiar caretakers. Little is known about how a bond is initially formed between a dog and a complete stranger. The first-impression hypothesis suggests that interacting with strangers can present an opportunity to form a mutualistic partnership. It predicts that dogs should respond positively toward a complete stranger to facilitate bonding (Prediction 1) and adjust their preferences in response to the perceived risk and benefit of interacting with strangers (Prediction 2). We examine the social preferences of pet dogs toward a complete stranger whom they have never met before and several other potential partners – the owner with whom subjects have had a positive, long-term bond (Experiment 1), and an exposed stranger with whom they have had a positive short-term interaction (Experiment 2) or a negative one (Experiment 3). In support of Prediction 1, subjects were exceptionally trusting across contexts. Mixed results were found with regard to Prediction 2. Subjects preferred their owner over a stranger when following social cues and (to a lesser degree) when approaching and feeding in close proximity. However, relative to a complete stranger, subjects did not consistently prefer the positively exposed stranger or avoid the negatively exposed one. The lack of clear selectivity might be due to pet dogs' high baseline level of trust of complete strangers or reflect the strength of their existing bonds that negated the need for another positive bond with a new human partner.

Keywords comparative cognition · avoidance

Introduction

Social animals living in stable social groups form bonds with familiar individuals. Strangers generally present a threat since they compete for resources, and competition can quickly turn into aggression. This means that in many social species, encounters between unfamiliar conspecifics are accompanied by high tension and hostility. Some species do not follow this pattern and instead engage peacefully or even help strangers (Ganem & Bennett, 2004; Patzelt et al., 2014; Raihani et al., 2012; Tan & Hare, 2013; Tan et al., 2017). Among these species, humans are "ultra-social" as they form extensive and fluid social networks full of unfamiliar cooperators (Seabright, 2010; Hill et al., 2011, 2014).

Why are some species nice to strangers? The first impression hypothesis proposes that even though an encounter with strangers might incur the risks of aggression and the costs of resource competition, it may also come with the benefits of forming a new mutualistic partnership (e.g., a new ally or source of information). When such benefits outweigh the risks and, affiliative behaviors should occur to facilitate bonding (Tan et al., 2017). For example, in bonobos, immigration and intergroup encounters with strangers are generally peaceful, but strong alliances are frequently formed among unrelated individuals who were once immigrants (Furuichi, 2011). Human strangers from different bands within a linguistic group can interact peacefully and cooperate extensively (Hill et al., 2014; Wiessner, 2014). With the low risk of xenophobic aggression and the high reward of bonding, bonobos and

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humans predictably help and share with strangers (Delton et al., 2011; Tan & Hare, 2013). The cost-and-benefit tradeoff of a new bond is central to the first impression hypothesis, and social preferences toward strangers should be adjusted based on the relative amount of social risk and benefit. In humans, social perception toward strangers is in part dependent on two universal dimensions – warmth and competence – that are analogous to the risk to safety and the benefit of bonding (Fiske et al., 2007; see also emotional and cognitive profiles in trust of young children, Harris, 2007)

Domestic dogs provide a promising candidate to test the first impression hypothesis. First, like us, dogs are also embedded into the dynamic human network where social fluidity is high and peaceful encounters with unfamiliar humans are frequent (Hill et al., 2011, 2014). Second, bonding with humans is important for dogs, and they are able to form strong and selective bonds with familiar caretakers. Dogs demonstrate attachment-like behaviors toward their owners (Prato-Previde et al., 2003; Topál et al., 1998, 2005), pay more attention to them than unfamiliar experimenters (Mongillo et al., 2010), and show a higher sensitivity to the emotions of the owners than strangers (Merola et al., 2014). It seems that the human-dog bond is mediated by the same oxytocin pathway that facilitates cooperation and trust among humans (Maclean & Hare, 2015). Dogs that have received friendly physical contact and social gaze from their owners experience an increase in the level of endogenous oxytocin (Odendaal & Meintjes, 2003; Nagasawa et al., 2015; Rehn et al., 2014). Dogs that have inhaled exogenous oxytocin demonstrate heightened level of contact seeking and social gaze toward their owners (Nagasawa et al., 2015; Romero et al., 2014).

Despite this growing literature on the importance of bonding with humans and the dynamic nature of the human network in which bonds are frequently and flexibly formed, adjusted and broken, little is known about how a bond is formed at the beginning between a dog and a complete stranger. In most research on dog cognition, the experimenter was unfamiliar to the subjects, but dogs usually became comfortable with the experimenter after a warm-up session and reliably followed social cues from him/her (see reviews in Hare & Woods, 2013; Miklosi, 2015). Dogs may also discriminate between generous and stingy experimenters who differ in their motivations to share food (Bray et al., 2014; Kundey et al., 2011; Marshall-Pescini et al., 2011; but see Nitzschner et al., 2014), between friendly and threatening experimenters (Vas et al., 2005), and between two equally familiar caretakers who differ in how frequently they feed and interact with the dogs (Horn et al., 2013). This suggests pet dogs quickly become comfortable with unfamiliar humans and in some context prefer strangers who behave more positively toward them. What remains unknown is the influence that a stranger's relative level of warmth or competence toward a dog influences how pet dogs come to trust and prefer them during their first interactions. Essentially, it remains unclear how pet dogs come to trust strangers.

As summarized in Table 1, the current study examines the social preferences of dogs toward different humans – the owner with whom the dogs have had a long-term bond (Experiment 1), an *exposed stranger* with whom the dogs have had a positive or a negative short-term interaction, and a *complete stranger* whom the dogs have never met before (Experiments 2 and 3). In Experiment 1, we establish that pet dogs are able to discriminate between the owner (i.e., a human with a long-term, positive interaction) and a stranger. Then in Experiments 2 and 3, we systematically manipulate the types of the short-term interaction with the exposed stranger that represent the cost-and-benefit tradeoff of an encounter with a stranger. The behavior of the exposed stranger can signal *competence* – the benefit of bonding by providing (accurate or inaccurate) information about hidden food; it can also signal *warmth* - the risk to safety by initiating or avoiding friendly, physical contacts. Correspondingly, we measure two types of dogs' preferences that are well documented in primate and canine research: feeding in proximity and following social cues (e.g., Schroepfer-Walker et al., 2015; Topál et al., 2005). The former gauges subjects' willingness to approach and feed near a human and is used as an index of subjects' perceived risk to safety; the latter gauges subjects' tendency to obtain desirable rewards by following social cues from a human and is used as an index of subjects' perceived benefits of associating with the human.

The first impression hypothesis predicts that dogs should demonstrate positive responses toward a complete stranger to facilitate bonding (i.e., they should follow social cues and feed near the complete stranger in Experiments 1–3). It further predicts that dogs should adjust their preferences in response to the perceived risk and benefit of interacting with strangers (i.e., they should follow social cues and feed near a positively exposed stranger, and they should avoid a negatively exposed stranger in Experiments 2 and 3). As reviewed above, oxytocin appears to affect the owner-dog bond in a relatively short time window (e.g., Nagasawa et al., 2015; Odendaal & Meintjes, 2003). Dogs thus may be able to quickly adjust their preferences toward the exposed stranger based on the short-term interaction.

General methods

All subjects were adult dogs living in owner's homes and brought to Duke University for test sessions. Owners self-enrolled their dogs in an online database and dogs of all breeds and ages were then selected randomly to participate in each experiment (see Supplementary Table 1 for the complete list of subjects). Subjects were tested individually and each dog only participated in one experiment. All testing took place in

Table 1 Summary of Experiments 1, 2, and 3

Exp.	Subjects chose between a complete stranger and…	Subjects' experience with this relatively familiar person was…	Test for social preferences and sample size	Hypothesis 1: Tests with the complete stranger should be above chance	Hypothesis 2: Relative to the complete stranger, subjects should prefer someone with a positive experience, and avoid someone with a negative one
1	the owner	a positive, long-term bond	approaching (68), following pointing cue (53)	Supported	Supported
2a	a positively exposed stranger	a short-term interaction -- competence or warmth	approaching (49), following pointing cue (47)	Supported	Mixed
2b	a positively exposed stranger	a short-term interaction -- warmth	approaching (57)	Supported	Not supported
3	a negtively exposed stranger	a short-term interaction -- incompetence or coldness	approaching (19), following front-back cue (16)	Mixed	Mixed

the Duke Canine Cognition Center (DCCC) at Duke University in a testing room (6.2 m × 3.2 m). Both the dog and their owner were allowed approximately 10 min to explore the testing room prior to the start of testing. During this time owners signed a consent form allowing their dog to participate in the test session. All procedures adhered to the regulations set forth by the Duke Institutional Animal Care and Use Committee (IACUC # 303-11-12).

Each experiment involved multiple experimenters to play different roles. They could be female or male. Except when the owner played a role, all other experimenters were recruited from a pool of research assistants at DCCC. They were assigned to play different roles randomly once they were trained. Sample sizes were determined based on previous studies on dogs' abilities to follow cues and to selectively interact with humans (e.g., Merola et al., 2012; Mongillo et al., 2010)

Experiment 1

In this experiment each subject participated in an approach test and a pointing test with the owner and a stranger (see Fig. 1). The approach test presented each subject with three options: to feed near its owner, near the stranger, or alone. The subject could risk their own safety by approaching the stranger who could have harmful intentions. In the pointing tests, each subject could rely on accurate information from either the owner or the stranger to locate hidden food. Subjects had no experience with the accuracy of the stranger's cues, and thus risked the loss of food reward when following his/her social cues.

Method

Subjects

Seventy experimentally-naïve dogs participated in this study. Two dogs were excluded from all the tests due to a lack of food motivation. Another 15 dogs were excluded from the pointing test because they could not pass the pre-tests or did not complete the test trials (see Procedure). This yielded a total sample of 68 (42 F:26 M) dogs for the approaching test. A sub-sample of 53 (33 F:20 M) dogs also participated the pointing test.

Setup and materials

There were three experimenters involved in the experiment. The dog handler (DH) held the dog on a leash and was instructed to refrain from petting the subject or giving gestural/vocal cues. The neutral experimenter (NE) set up the trials. The stranger was introduced in the test phase where he/she would, together with the owner, interact with the subject in a specific way (see below).

The testing room is 6.2 m × 3.2 m with two doors where the experimenters can enter and exit. The subject started a trial in a pre-determined spot and was held by DH who was standing behind. The subject was released to find food once DH dropped the leash and gave the release command (usually "OK," depending on the subject's training history). Food rewards were chosen from a variety of training-sized treats according to the subject's preference reported by the owner. Opaque, plastic cups (opening: 10 cm; height: 15 cm) were used to hide the food, and a cardboard occluder (40 × 60 cm) was used to block the view of the subject while baiting. Note that numerous studies have shown that dogs do not regularly rely on olfactory cues to locate hidden food in similar contexts (reviewed by Kaminski & Nitzschner, 2013).

Procedure

The approach test and pointing test were administered in counter-balanced order between subjects.

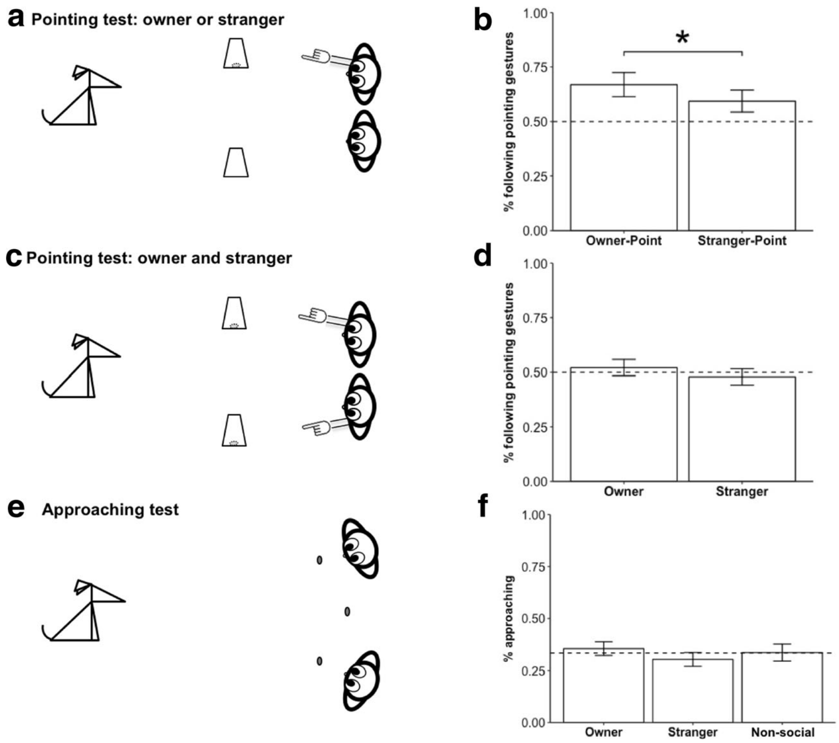

Fig. 1 Overview of Experiment 1: the setup (**a**) and the results (**b**) of the Owner-Point and Stranger-Point conditions of the pointing test; the setup (**c**) and the results (**d**) of the Conflicting-Point condition of the pointing test; the setup (**e**) and the results (**f**) of the approaching test. In each setup diagram, the two persons are the owner and the stranger. Gray dots represent food pieces. Error bars represent standard errors

Pointing test – one-cup introduction This pre-test was designed to introduce subjects to finding food treats hidden under the cups. The owner and the stranger were asked to leave the room and would not return until the beginning of the pointing test. NE called the subject's name, placed one piece of food under a plastic cup 1.2 m from the subject, and then returned to the back of the testing room, facing away from the subject. The subject could see the entire baiting process and was then released to find (and eat) the food. Each subject was required to locate the food (i.e., to touch the cup with their paw/muzzle or to sit in front of the cup within reach of its muzzle) for four out of five consecutive trials before moving on to the next pre-test. If a subject failed in ten consecutive attempts or they did not pass the criterion within 24 trials, it was excluded from the study.

Pointing test – two-cup introduction This pre-test was designed to introduce the concept of choice. NE first placed two cups on opposite sides of the subject, both 1.2 m away from the subject. NE then called the subject's name and placed a piece of food under one of the two cups in full view of the subject. The placement of the food was counterbalanced but one cup was not baited for more than two trials in a row (i.e., pseudo-counterbalancing). To proceed to the test phase, the subject was required to pick correctly in four out of five consecutive trials. If the subject did not choose one cup in 60 s, the trial was repeated. A subject was excluded from the study following the same criteria as the one-cup introduction.

Pointing test – main test In this test, the subject could follow pointing cues from human pointers to locate hidden food. At the beginning of this phase, the stranger and the owner entered the testing room to play the role of "pointer." In all trials, the owner and the stranger were seated side by side in two chairs arranged in the center of the room, 1.2 m from the subject. Both were facing and looking at the subject. At the start of each trial the pointer on the subject's right side rested his/her right hand on the lap, and crossed his/her left arm (a.k.a. the pointing arm) on the right shoulder; the pointer on the left side did the opposite. The locations of the owner and the stranger were pseudo-counterbalanced across trials. The cups were situated 1.2 m on either side of the dog.

There were three types of pointing trials alternating within the session: Owner-Point, Stranger-Point, and Conflicting-Point (Fig. 1a, c, Fig. S1 (see Supplementary Materials). In all trials NE showed the subject a food treat and baited either one or both cups. An opaque occluder was used to prevent the dogs from observing NE's actions while she either hid food or sham baited each cup. NE always started from the cup to the subject's left and moved onto the right cup. NE then returned to the back of the room, stood behind the two chairs with his/her back facing the subject. After the owner or stranger gestured, the DH released the subject to search, saying "OK" and gave her 60 s to make a choice. In the Owner-Point condition NE baited the cup nearest the owner and gave the command "Owner point" once she was standing with her back turned at the back of the room. The owner quickly gestured at the baited cup by extending her arm and index finger, and moved his/her head to fixate attention to the cup (Fig. S1). No gesture or gaze-alternation was made. Meanwhile, the stranger focused on the wall behind the subject, but did not make any other moves. The Stranger – Point condition, followed the same procedure with the exception that: (1) NE baited the cup proximal to the stranger, (2) the command NE gave was "Stranger point," and (3) the stranger pointed at the baited cup while the owner stared at the back wall. In these two conditions, when subjects chose a baited cup on their first choice they received the food reward; when subjects chose an unbaited cup first, they did not receive the hidden reward and were shown where it had been hidden. In the Conflicting-Point condition, NE baited both cups and cued both the owner and the stranger to point at the baited cup nearest to them by saying "Both point" (Fig. 1c). This meant in this condition there was no differential rewarding and we could measure whose gesture the subjects preferred to follow. Subjects completed eight of each trial type for a total of 24 trials. The type of the first trial was counterbalanced between subjects. If the subject did not make a choice in 60 s, the trial was repeated. If the subject failed to make a choice in ten consecutive trials, the subject was excluded from the study. To help maintain the subject's motivation they were given a 90-s break after every block of eight trials.

Approach test In this test the subject could choose to approach and eat a visible piece of food placed near the feet of its owner, near the feet of the stranger, or on an empty spot (a.k.a. the non-social option, Fig. 1e, Fig. S2). Three spots were marked in the testing room in the shape of an arc: the middle spot was 0.9 m from the two side spots, and all spots were 2 m from the subject. Chairs were situated directly behind two of the spots and the third was left blank. The owner and the stranger sat in each chair, put both hands on their laps, and looked at the subject with a piece of food placed approximately 10 cm in front of the toe of their shoes (Fig. S2). The locations of three spots were pseudo-counterbalanced. DH centered the subject at the start point. NE called the dog's name and placed a piece of food in each of the marked spots (always from left to right). DH released the dog and gave them 60 s to make a choice by approaching and eating one piece of visible food readily accessible on the floor. Once the subject chose a food piece, DH removed the other two pieces. Each subject completed nine trials in this task. If a subject did not make a choice in 60 s, the trial was repeated. If the subject failed to make a choice in 10 consecutive repeats, it was excluded from the study.

Coding and analysis

In the pointing test, a choice was coded when a subject touched a cup with its paw or muzzle, or when it sat in front of the cup within the reach of its paw or muzzle. In the approach test, a choice was coded when a subject consumed food or directly touched the experimenter behind the food piece. Another rater blind to the experimental hypotheses coded 20% of the trials selected randomly. Inter-rater reliability for both choice measures was high (pointing: Cohen's kappa = 0.99; approaching: kappa = 0.99).

Based on previous evidence that dogs follow gestures from strangers but prefer to interact with their owners over strangers, we predicted that: (1) subjects would spontaneously follow the pointing cues from both the owner and the stranger, (2) they would show a preference for their owner's information, (3) they would be attracted to a feeding spot with a human instead of a non-social option, and (4) they would approach the spot near the owner more than the spot near the stranger. All statistics are two-tailed unless stated as "directed" throughout the paper. For statistics testing directional hypotheses, we adopted the conventional framework ($\delta = 0.01$, $\gamma = 0.04$) recommended by Rice and Gaines (1994). Accordingly, the null hypothesis should be rejected if the one-tailed p-value is $\leq$ 0.04 in the predicted direction, or $\geq$ 0.99 in the unanticipated direction.

Preliminary analyses revealed no effect of subject sex on either test. As a result, we collapsed data from male and female subjects for the following analyses.

Results

Pointing test

As shown in Fig. 1b, In Owner-Point and Stranger-Point where there was only one pointer, subjects' were above chance in following the pointing cues given by both the owner and the stranger (Owner-Point = 0.67 ± 0.03, $t(52) = 6.25$, $p < 0.001$; Stranger-Point = 0.59 ± 0.03, $t(52) = 3.75$, $p < 0.001$, one-sampled t-test, directed). Although subjects were above chance in both Owner-Point and Stranger-Point, a paired t-test reveals that they showed a higher accuracy in following the owner's gesture ($t(52) = 2.41$, $p = 0.01$, paired t-test, directed).

First-trial analyses yielded consistent results. Subjects were above chance in the first trial in Owner-Point (37 out of 53 subjects followed pointing, $p = 0.003$, binomial test, directed), but not in Stranger-Point (27 of 53 subjects followed pointing, $p = 0.5$, binomial test, directed). Comparing first trial results reveals a significantly higher first-trial accuracy in Owner-Point than in Stranger-Point ($\chi^2(1) = 3.85$, p = 0.025, McNemar's test, directed).

As shown in Fig. 1d, in the Conflicting-Point condition where both the owner and the stranger were pointing and both cups were baited subjects chose at chance levels (in all eight trials: rate of choosing the owner = 0.52 ± 0.02, t(52) = 1.14, p = 0.13, one-sample t-test; in the first-trial: 25 of 53 subjects followed the owner not the stranger, p = 0.39, binomial test, directed).

Subjects' performance did not change between the first and the second half of the test session [Owner-Point: t(52) = 0.68, p = 0.5; Stranger-Point: t(52) = -0.61, p = 0.54; Conflicting-Point: t(52) = 0.71, p = 0.48, paired t-test, two-tailed].

Approaching test

As shown in Fig. 1f, subjects neither preferred nor avoided the non-social option (percentage of approaching the non-social option = 0.34 ± 0.02, t(67) = 0.11, p = 0.91, one-sample t-test with chance set at 0.33, directed). When we analyzed only the trials where subjects did choose to approach a human, they did not show any preference but a trend to approach more often to the owner (percentage of approaching the owner when subjects approached a human = 0.54 ± 0.02, t(67) = 1.66, p = 0.051, one-sample t-test with chance set at 0.5, directed).

First-trial analyses found similar results. Subjects neither preferred nor avoided the non-social option (25 out of 68 subjects approached the non-social option, p = 0.61, binomial test with hypothesized probability set to 0.33). When they did approach a human, they showed no preference (26 out of 43 approached the owner, p = 0.22, binomial test with hypothesized probability set to 0.5).

Correlations

Subjects' Owner-Point and Stranger-Point accuracies were positively correlated (N = 53, r = 0.29, p = 0.04, Pearson's correlation, two-tailed). Finally, we subtracted subjects' Owner-Point accuracy from their Stranger-Point accuracy to create a *between-trial* index of their preference for the owner's information in trials where only one experimenter gestured. This between-trial index was positively correlated with their rate of following the owner's gesture in the Conflicting-Point trials, the *within-trial* index of owner preference (N = 53, r = 0.37, p = 0.02, Pearson's correlation, two-tailed). However, neither the between- or within-trial index of gesture preference is correlated with subjects' preference to approach their owner (both p = 1, Pearson's correlation, p-values corrected for multiple comparisons based on Holm (1979), two-tailed).

Discussion

We found that when there was a single pointer to help them locate hidden food, our subjects spontaneously followed the gesture provided by a stranger, but they followed the gesture from their owner more often. This selective preference in the owner's social cues was evident in the very first trial although the overall effect is relatively small (~8% difference in performance).

When the owner and the stranger simultaneously gave (conflicting but accurate) cues in the Conflicting-Point trials, subjects did not show a preference. However, there was a positive correlation in subjects' preference for the owner's cue between the Conflicting-Point trials and the single-pointer trials. This suggests that the Conflicting-Point trials might be more challenging and less sensitive than the single-point trials: First, subjects have already shown a tendency to follow the stranger's gesture in the Stranger-Point trials. Second, their accuracies in the Stranger-Point and the Owner-Point trials are positively correlated, which means those who tended to follow the owner's cue would likely follow the stranger's cue too. Third, both cups were baited in the Conflicting-Point trials, and thus there was no incorrect answer.

Similarly, the design of the approaching test might not be sensitive enough either. Subjects were not attracted to feed in proximity to a human. Nor did they selectively feed near their owner. However, like the Conflicting-Point trials, the setup had both the owner and the stranger present and there was no differential rewarding, which might make it difficult to detect any approaching preference. In remaining experiments, we adopted a single-person setup in the hopes of increasing our ability to detect any difference in preferences.

There was no relationship between subjects' selectivity in the pointing test and that in the approaching test. This is consistent with the idea that the two tests measure two independent dimensions – competence and warmth – in subjects' social preferences towards humans. In the following experiments, we explicitly manipulated the behaviors of strangers to further exaggerate these two social dimensions (see Fig. 2).

Experiment 2a

In Experiment 1, we found family dogs are influenced by the identity of the person gesturing to them. They were more likely to follow the gesture of their owner than that of a stranger. Meanwhile, in the approach test they were indiscriminate about who was near them as they retrieved food, although there was a small trend toward eating near their owner. In Experiment 2 we use similar methods to evaluate whether dogs form preferences between two different strangers (Fig. 2). Pet dogs frequently meet new humans, but it is unclear how quickly they develop preferences for one stranger over another. Here we introduce dogs to a stranger and allow them to have one of two types of positive short-term interaction. They either engage in affiliative behaviors (warmth exposure) or provide information that helps the dog find food (competence exposure). In the test session we then compare how dogs approach or follow the pointing gesture of the stranger they were exposed to in comparison to a completely novel stranger.

Method

Subjects

Ninety-six experimentally-naïve dogs (53 F:42 M, and one unknown) from DCCC database were randomly enrolled in this study. Another 67 dogs were excluded due to failure to pass introduction, exposure or test phases (see below).

Setup and materials

This study was conducted in the same testing room and used the same materials as Experiment 1 (opaque plastic cups, occluders, chairs, and dog treats).

Procedure

This experiment consisted of three phases: introduction, exposure, and test. There were two types of exposure (warmth vs. competence) and two types of test (approach vs. pointing), which created a 2 × 2 between-subjects design with four conditions (Warmth-Approach, Warmth-Point, Competence-Approach, Competence-Point). There were three roles in this experiment: a dog handler (DH), played by the owner, centered the subject; an exposed stranger (ES) was present throughout the experiment; a complete stranger (CS) entered the experiment only in the test phase.

Introduction – one cup This phase resembled the one-cup introduction in Experiment 1 with three exceptions. First, ES (not NE) set up the trials. Second, a trial was unsuccessful if the subject did not locate the food within 15 s or if it approached and touched ES directly. Third, a subject was dropped from the experiment after three (not ten) unsuccessful trials in a row.

Introduction – two cups This phase was similar to the two-cup introduction in Experiment 1 except that ES, not NE, set up the trials. The criteria for repeating a trial or dropping a subject were the same as in the previous phase.

To control for the amount of exposure to ES each subject has experienced, all subjects received the above one-cup and two-cup introduction even if they were in the warmth-approach condition where there was no cup involved in the test phase.

Exposure This phase allowed ES to establish a positive relationship with the subject through warmth or competence. In the *warmth* exposure, ES would engage the subject during a 15-min session of affiliative behaviors. ES sat on the floor, petted the subject with long strokes, talked softly, and scratched its body and ears. The attention of ES was completely focused on the subject. ES did not actively seek eye contact with the subject, but when it turned its head toward ES, ES would establish eye contact. If the subject walked away, ES would make persistent attempts to re-engage by calling the dog's name, turning his/her body toward the dog and reaching out to initiate physical contact. There was no feeding or object play. This method was based on Odendaal and Meintjes (2003), who reported an increase of oxytocin in dogs after receiving the above affiliative behaviors for an average of 15 min. Without any role in this exposure, DH was instructed to sit in the corner of the testing room, read a magazine, and refrain from interacting with the subject.

In the *competence* exposure, ES would give the subject accurate communicative cues to help it locate hidden food.

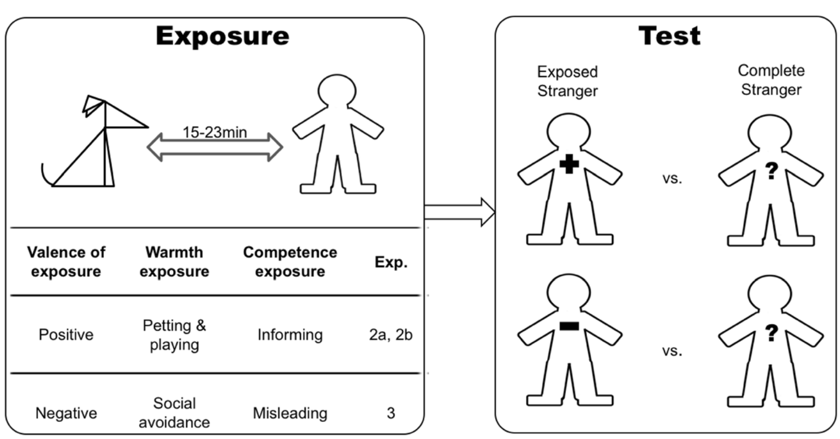

Fig. 2 Overview of Experiments 2 and 3

Like the two-cup introduction, ES placed two cups 0.9 m away from each other and 1.3 m away from the subject. A chair was placed 2.4 m away from the subject and 1.3 m away from each cup. As DH centered the subject, ES baited one cup and sham-baited the other using the occluder. ES then sat down in the chair, called the subject's name, and pointed at the baited cup. The pointing cue was a single upward motion from the lap with the index finger extended (Fig. S3). The experimenter pointed on each trial using their arm closest to the baited cup. ES fixed his/her gaze at the cup without any alternation, and then gave the release command to allow the subject to make a choice. The content of the un-chosen cup was never revealed to the subject. If the subjects did not make a choice within 15 s, the trial was repeated. After three consecutive repeated trials, the subject received four two-cup introduction trials as a reminder. After this reminder, the subject would be dropped from the experiment if they again did not make a choice in another three repeated trials in a row. Each subject completed 16 exposure trials that lasted for approximately 15 min.

Test This phase measured whether subjects had a preference for ES, with whom it just had a brief positive interaction, or a completely unknown stranger (CS). In the test session CS entered the experiment and met the subject for the first time. He/she refrained from petting, feeding, or playing with the subject throughout this phase.

In the *approach* test (Fig. 3c, Fig. S4), two chairs were placed side-by-side, 2.4 m away from the subject and 0.9 m away from each other. A spot was marked on the floor 30 cm in front of each chair (i.e., the two spots were 0.9 m apart). In each trial, ES or CS held a dog treat in each hand, showed the two pieces of food to the subject, placed one piece of food on the spot in front of each chair, and sat down in one chair, leaving the other empty. He/she looked straight ahead (but not at the subject) and gave the release command. The subject had 15 s to approach and choose to eat one piece of food, while ES/CS would quickly remove the other piece. ES and CS took turns as the experimenter every other trial. The identity and the location of the experimenter were counterbalanced within subjects. In addition, the identity and the location of the experimenter in the first trial were counterbalanced between subjects. Each subject received 16 trials (i.e., eight trials with each stranger in mixed design). If the subject did not approach, walked past, or jumped on ES/CS, the trial was repeated.

In the *pointing* test (Fig. 3a, Fig. S3), the procedure was identical to the competence exposure, except that ES and CS took turns as the pointer every other trial, with their order counterbalanced between subjects. Each subject received 16 trials (i.e., eight trials with each stranger). This test phase used the same introductory criterion as in the competence exposure.

Coding and analysis

The operational definitions of choice and approach were identical to those in Experiment 1. Inter-rater reliability was excellent (pointing: kappa = 0.99; approaching: kappa = 0.98)

We predicted that subjects would be above chance in following social cues and in approaching a human, regardless of identity. We also predicted that after a positive interaction,

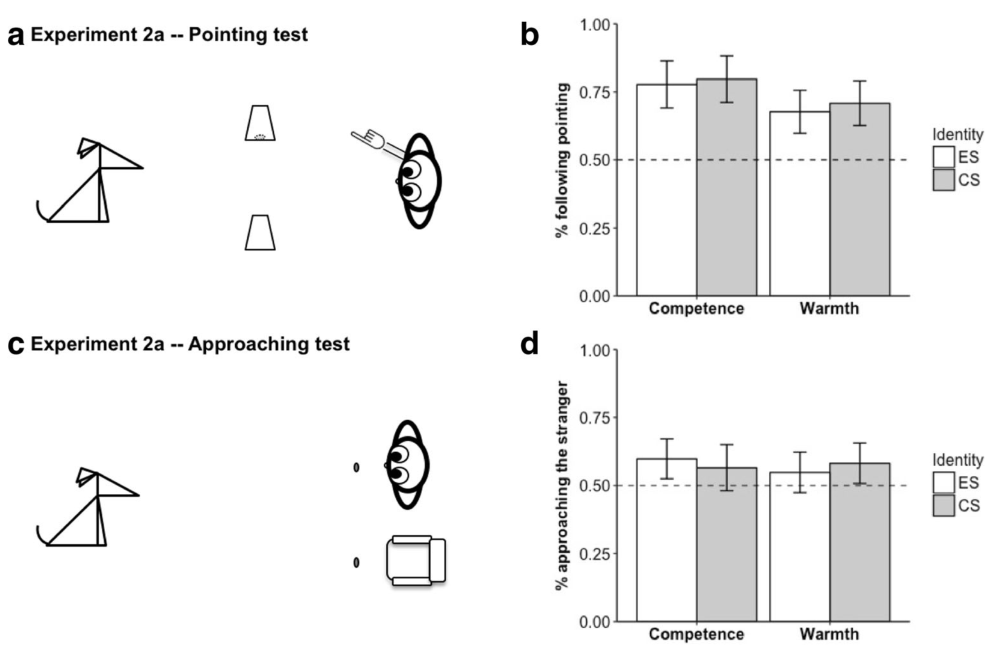

Fig. 3 Overview of Experiment 2a: the setup (**a**) and the results (**b**) of the pointing test; the setup (**c**) and the results (**d**) of the approaching test. Prior to the test, subjects experienced warm or competent exposure with ES. Gray dots represent food pieces. *ES* Exposed Stranger, *CS* Complete Stranger. Error bars represent standard errors

subjects would prefer ES relative to CS (Elgier et al., 2009; Marshall-Pescini et al., 2011; Vas et al., 2005). Like Experiment 1, all statistics are two-tailed unless otherwise indicated.

Preliminary analyses revealed no sex effect. As a result, we collapsed data from male and female subjects for the following analyses.

Results

Pointing test

As shown in Fig. 3b, when the test scores in the Competence-Point and Warmth-Point conditions are combined, subjects showed above-chance accuracy in following the pointing cue from both ES and CS (ES: accuracy = 0.73 ± 0.03, $t(46) = 7.83$, $p < 0.001$; CS: accuracy = 0.75 ± 0.03, $t(46) = 8.69$, $p < 0.001$, one-sampled t-test, directed). However, whether ES or CS was the pointer made no difference in subjects' accuracy ($t(46) = -1$, $p = 0.16$, paired t-test, directed). Furthermore, like Experiment 1, their accuracies of following the pointing cues from ES and CS were highly correlated (N = 47, r = 0.61, $p < 0.001$, Pearson's correlation, two-tailed).

First-trial analyses showed consistent results. Subjects spontaneously followed ES's and CS's pointing cue in the first trial (ES: 35 out of 47 subjects followed in the first trial, $p < 0.001$; CS: 34 out of 47 subjects followed, $p = 0.002$, binomial test, directed). They did not differ in their first-trial accuracy between the two strangers ($\chi^2(1) = 0.059$, $p = 0.41$, McNemar's test, directed).

Subjects' performance did not differ between the first and the second half of the test (ES: $t(46) = -1.78$, $p = 0.09$; CS: $t(45) = -1.18$, $p = 0.24$, paired t-test, two-tailed; note that one subject received only seven trials with CS due to experimenter error, so he was not included in this analysis).

An exposure (competence vs. warmth) × identity (ES vs. CS) mixed ANOVA revealed non-significant main effect of identity ($F(1,45) = 0.97$, $p = 0.33$, two-tailed). The main effect of exposure reveals a trend ($F(1, 45) = 3.46$, $p = 0.069$, two-tailed), suggesting that subjects who have received competence exposure tended to be more accurate in the subsequent pointing tests. However, there was no interaction effect between exposure and identity ($F(1,45) = 0.053$, $p = 0.82$, two-tailed).

Approach test

As shown in Fig. 3d, when Competence-Approach and Warmth-Approach are combined, subjects showed a significant preference for approaching either stranger over the empty chair (ES: percentage of ES approached = 0.57 ± 0.03, $t(48) = 2.83$, $p < 0.001$; CS: percentage of CS approached = 0.57 ± 0.03, $t(48) = 2.76$, $p < 0.001$, one-sampled t-test, directed). However, their preference for ES was not stronger than that for CS ($t(48) = -0.09$, $p = 0.93$, paired t-test, directed). Furthermore, their tendencies to approach ES and CS are positively correlated (N = 49, r = 0.44, $p < 0.001$, Pearson's correlation, two-tailed).

First-trial analyses revealed a slightly different pattern. Subjects did not prefer the chair occupied by either ES or CS to the empty chair (in the first trial, 30 out of 49 subjects approached ES instead of the empty chair, $p = 0.08$; 19 out of 49 subjects approached CS instead of the empty chair, $p = 0.08$, binomial t-test, directed). However, their first-trial approaches did reveal a significant preference for ES over CS ($\chi^2(1) = 4.17$, $p = 0.02$, McNemar's test, directed).

Subjects' performance did not differ between the first and the second half of the test (ES: $t(48) = -0.97$, $p = 0.34$; CS: $t(48) = -0.62$, $p = 0.54$, paired t-test, two-tailed).

An exposure (competence vs. warmth) × identity (ES vs. CS) mixed ANOVA revealed no significant main effects or interaction (exposure: $F(1,47) = 0.14$, $p = 0.71$; identity: $F(1, 47) = 0.0004$, $p = 0.98$; exposure × identity: $F(1, 47) = 1.44$, $p = 0.24$, two-tailed).

Discussion

In the pointing tests, we found that subjects, as predicted, spontaneously followed social cues from ES and CS. However, contrary to our predictions, they used gestures from ES and CS equally. This suggests that family dogs need more exposure with a stranger to develop the type of preference between owner and stranger we saw in Experiment 1. Given the relatively skilled performance of the dogs we also might see an effect with a more challenging or subtle gesture. It is also possible that dogs have a negativity bias – they are more sensitive to negative experience than a positive exposure with the stranger (Takaoka et al., 2014; see Experiment 3).

Consistent with our predictions, subjects in the approaching tests preferred feeding near a strange human to feeding alone, although this preference was weak: they chose to feed near a human at the average rate of 57% in a 16-trial test session. Interestingly, they did have a preference for the stranger they had been exposed to on the first trial, but this preference was not maintained over the session.

This suggests that subjects quickly become comfortable with CS. Like the pointing test, subjects might need more exposure with ES to develop a preference. Another possibility is that our manipulation was too subtle. Feeding near an empty chair also required approaching the strangers that were less than a meter away. Finally, although unlikely, it might be that the eye contact subjects made with ES and CS triggered the oxytocin loop leading to rapid bonding (Nagasawa et al., 2015). We examined these possibilities in Experiment 2b by modifying the setup of the approach test.

Experiment 2b

In the current experiment, we modified the approach test to address two questions remaining from the approach test of Experiment 2a (see Fig. 4a). We separated the empty chair and the chair occupied by the stranger (ES or CS) into two chambers divided by a tall, opaque barrier. Strangers avoided eyed contact with the subject by never facing them throughout the experiment. ES/CS sat at the entrance of a room forcing the subjects to pass him/her when retrieving food at the back of the chamber. We reasoned this would increase the salience of the social risk involved in eating near the stranger. We also increased the duration of affiliative interaction from 15 min in Experiment 2a to 23 min based on the maximum latency observed to trigger an increase in oxytocin in Odendaal and Meintjes (2003). This was done to maximize the potential for this type of physiological response to shape the subject's approach preference.

Subjects

Fifty-seven (31 F:26 M) experimentally-naïve dogs from DCCC database were randomly enrolled in this study. Another dog was excluded from the study after making an aggressive display.

Setup and materials

This study was conducted in the same testing room, and the subject started from the same spot. See Fig. 4a for an illustration of the set-up (see also Fig. S5). The experiments used the same chairs and dog treats. Two opaque dividers (1.85 m in height) made of cloth racks and shower curtains were set up in a T-shape to compartmentalize the testing room. One divider cut the testing room into a choice area (4.7 × 3.2 m) and a hiding area (1.5 × 3.2 m). The second divider started from the midpoint of the first divider and extended into the choice area for 1.2 m. As a result, the second divider created two side-by-side chambers (1.6 × 1.2 m) where the subject could choose to enter from the staring spot. In each chamber, there was a chair at the entrance placed with its back against the wall. If an experimenter sat in one of the chairs, he/she faced the second divider and did not make eye contact with the subject. The chairs narrowed the width of each entrance to 0.6 m. Two plastics dustpans (0.3 × 0.3 m) were used as food dishes. Each dish was on one side of the second divider and connected to a 1.5 m wooden rod. These rods lay on the floor along the second divider and extended behind the first divider into the hiding area. As a result, an experimenter in the hiding area could retract or push forward the food dishes by controlling the rods. When the dishes were retracted inside the chambers, they were in the corner created by the first and second divider (i.e., the subject had to fully enter the chamber to eat the food on the dish). The starting spot was 1.2 m to the second divider, 1.4 m to each chair, and 2.4 m to a retracted dish.

Procedure

The experiment consisted of three phases: exposure, introduction, and test. There were four experimenters. The owner was the dog handler (DH). The neutral experimenter (NE) was responsible for setting each trial. The exposed stranger (ES) engaged in affiliative behaviors with the subject during the exposure phase. ES and the complete stranger (CS) would also take turns participating in the test phase.

Exposure This phase was similar to the warmth exposure in Experiment 2a except that the duration increased to 23 mins.

Introduction This phase introduced the food dishes and the concept of choice to the subject. In this phase ES hid in the hiding area and controlled the food dishes. The food dishes were pushed to the entrance of each test room (i.e., 1.2 m away from the subject). As DH centered the subject at the starting spot, NE stood between the dishes, showed one piece of food to the subject, and dropped it in one of the dishes. NE then turned his/her back toward the subject, instructed ES to retract the dishes by saying "Pul,l" and told DH to release the subject by saying "OK." The

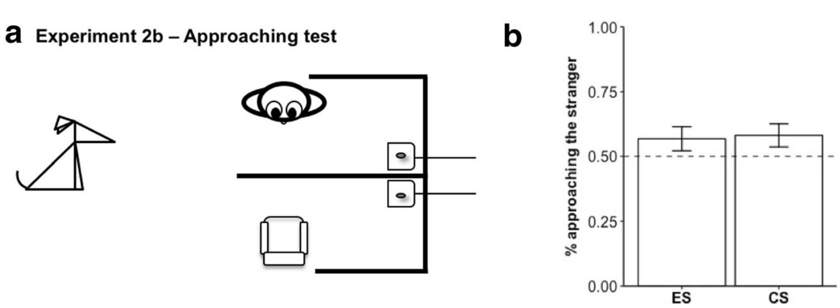

Fig. 4 Overview of Experiment 2b: the setup (**a**) and the results (**b**) of the approaching test modified to increase social risk. Prior to the test, subjects experienced warm exposure with ES. Bold lines represent dividers. Gray dots represent food pieces. White squares under the dots represent mobile dustpans. *ES* Exposed Stranger, *CS* Complete Stranger. Error bars represent standard errors

subject was given 15 s to approach the baited dish, and had to successfully retrieve the food in four consecutive trials to proceed to the test. If the subject did not retrieve the food within 15 s, the trial was repeated. If a subject needed five repeats in a row or did not reach the criterion within 20 trials, she was dropped from the experiment.

Test In this phase, the setup was identical to the introduction, except that both food dishes were baited, so there was no differential rewarding (see Fig. 4a, Fig. S5). CS and ES both entered the experiment. In alternating turns, one of them stayed in the hiding area controlling the dishes, and the other entered the choice area to sit in one of the chairs (see Fig. S5). ES and CS did not touch, call, or make eye contact with the subject throughout the test phase. The subject had 15 s to choose between obtaining food in the test room with the stranger sitting at the entrance (i.e., the stranger room) or feeding alone in the empty room. After a subject made their choice, NE removed the food in the un-chosen dish. The subject received eight trials with each stranger for a total of 16 trials. If the subject did not make a choice within 15 s, the trial was repeated. A subject was excluded from analysis if they needed five repeats in a row or a total of ten repeats across the entire test session.

Coding and analysis

A choice was coded when both of a subject's forelimbs crossed the entrance of a test room. Inter-rater reliability was good (kappa = 0.77, Fleiss et al., 2003, pp 604).

We predicted that, like Experiment 2a, subjects would prefer feeding in the stranger room over feeding alone in the empty chamber. We also predicted that subjects would show a stronger preference for the stranger chamber when ES rather than CS was at the entrance. All statistics were two-tailed unless otherwise indicated.

Preliminary analyses revealed no sex effect. As a result, we collapsed data from male and female subjects for the following analyses.

Results

As shown in Fig. 4b, for both ES and CS, subjects showed a preference for retrieving food in the stranger chamber over the empty chamber (ES: percentage of entry = 0.57 ± 0.02, t(56) = 2.93, p = 0.003; CS: percentage of entry = 0.58 ± 0.02, t(56) = 3.61, p < 0.001, one-sampled t-test, directed). However, they did not show a relative preference for ES or CS (t(56) = -0.55, p = 0.3, paired t-test, directed). Furthermore, their tendencies to enter the stranger chamber when ES or CS was present were significantly correlated (N = 57, r = 0.45, p < 0.001, Pearson's correlation, two-tailed).

First-trial analyses revealed that subjects showed a preference for ES over the empty chamber (39 out of 57 individuals approached ES instead of the empty chamber, p = 0.004, directed), but only a trend to choose CS over the empty chamber (35 out of 57 approached CS, p = 0.06, binomial test, directed). Unlike Experiment 2a, there was no difference in first-trial approach preference between ES and CS ($\chi^2(1) = 0.89$, p = 0.18; McNemar's test, directed).

Subjects' performance did not differ between the first and the second half of the test (ES: t(56) = 1.81, p = 0.08; CS: t(56) = -1.28, p = 0.21, paired t-test, two-tailed).

Discussion

Like Experiment 2a, subjects demonstrated a significant but weak preference for the stranger room over the empty room. This consistently supports the prediction that dogs have a positive regard for complete strangers. However, subjects did not differ in how often they took food from the stranger chamber based on which stranger was present. This was unexpected given that we extended the warmth exposure, increased the salience of the choice, and re-oriented the position of the strangers to minimize social gaze. The lack of selectivity suggests that family dogs have a high and positive baseline preference for people regardless of their relationship. To discriminate they may need a much longer exposure to develop the selectivity. Alternatively, they might be more sensitive to a negative exposure (Takaoka et al., 2014). We examined this possibility in the next experiment.

Experiment 3

In this experiment, subjects were exposed to a stranger that either rejected attempts to initiate social interactions, or gave subjects inaccurate information about the location of hidden food (Fig. 2). As in Experiment 2b, we then observed whether subjects would pass by or use the social cues of the cold or incompetent stranger to obtain food. We predicted the negative interactions would allow us to detect stronger preferences in the dogs for different experimenters than we observed in the previous experiments. We also changed the social cue provided by ES/CS from pointing cue to body-orientation cue. We reasoned that conceptually the latter was simpler than the former for subjects to understand.

Method

Subject

Thirty-five experimentally-naïve dogs (21 F:14 M) from DCCC database were randomly enrolled in this study. Another 13 dogs were tested but dropped from the experiment due to failure to pass the introduction phases, lack of motivation for food, or experimenter errors.

Design

Like Experiments 1 and 2, there were three phases (exposure, introduction, and test) and four roles (DH, NE, ES, and CS). The experiment consisted of two conditions: the *cold* condition (N=19) was similar to Experiment 2b, except that here ES actively *avoided* any positive affiliation with the subject (petting, encouraging with their voice, etc.); the *incompetence* condition (N=16) was similar to the Competence-Point condition in Experiment 2a, except that here ES consistently gave *incorrect* information about the location of hidden food. Hence ES here gave a negative experience to subjects.

Cold condition – exposure In this phase, ES was alone in the room with the subjects and repeatedly avoided any affiliative behavior with them. ES stood in one of four pre-determined spots in the room. Each spot was a square (1 × 1 m) with clear boundaries drawn on the floor. ES moved from one spot to another when the subject approached (defined as crossing the boundaries of the square) or after 60 s. If the subject simply sat in front of ES but did not entered the square, ES turned 90° to avoid eye contact. To increase the salience of social avoidance, every time ES moved, she said "No" to the subject in a stern voice and made a prohibitive gesture (i.e., a stop sign with the right palm facing the subject, following Herrmann & Tomasello 2006). ES moved 16 times in the exposure (i.e., 16 exposure trials) so that each subject experienced the same level of social rejection.

Cold condition – introduction This phase was identical to the introduction of Experiment 2b.

Cold condition – approaching test As shown in Fig. 5c, this phase was identical to the test phase of Experiment 2b (see also Fig. S6b). Each subject received eight trials with each stranger for a total of 16 trials.

Incompetence condition – introduction This phase was identical to the one-cup introduction plus the two-cup introduction in Experiment 1, except that: (1) we replaced the cups with semi-cylinder-shaped barriers (i.e., a cup split into halves, a.k.a. barrier), and (2) the duration of a trial was 15 s.

Incompetence condition – baseline This phase tested for the baseline tendency to follow human social cues. Only DH and NE were present. NE baited one barrier and sham-baited the other. NE then showed the subject her hands were empty, kneeled down on one knee, turned her body 90° to face the baited barrier, fixed her gaze at that barrier and said "Oh" in a calm voice. NE placed both hands on one knee and thus gave the subject only body-orientation cues. The subject was given 15 s to make a choice for a total of 16 trials. To familiarize the subject with this kind of social cue, it could explore the other barrier and consume the food there if it made a mistake.

Incompetence condition – exposure This phase was identical to the baseline phase except that: (1) it was ES not NE who gave the body-orientation cue, (2) ES's cue was always incorrect, and (3) the food piece was quickly removed by NE if the subject followed ES's incorrect cue. There were 16 trials in this phase.

Incompetence condition – front-back test As shown in Fig. 5a and Fig. S6a, this phase was similar to the exposure except that: (1) ES and CS took turns in giving the body-orientation cue to the subject, and (2) both strangers cued the baited barrier (i.e., both gave accurate information). The subject received eight trials with each stranger for a total of 16 test trials.

Coding and analysis

In the exposure trials of the cold condition, we coded a subject's behavior as *active* when it crossed the boundaries of ES's spot; correspondingly, a trial was coded *passive* when no active behaviors occurred within 60s. In the approaching test of the cold condition, a choice was coded the same way as in Experiment 2b. In the incompetence condition, a choice was recorded when a subject touched a barrier or when it retrieved the food from behind. Inter-rater reliability was good to excellent (incompetence condition – exposure: kappa = 0.93, test: kappa = 1; cold condition – exposure: kappa = 0.74; test: kappa = 0.87).

All statistics were two-tailed unless otherwise indicated. Preliminary analyses revealed no sex difference in subjects' responses toward ES versus toward CS. As a result, we collapsed data from male and female subjects for the following analyses.

Results

Incompetence condition

Consistent with our predictions, subjects were significantly above chance in following the accurate social cue from CS in the test (accuracy = 0.74 ± 0.05, $t(15) = 5.23$, $p < 0.001$, one-sampled t-test, directed) and from NE, who was also a complete stranger at the time, in baseline (accuracy = 0.85 ± 0.03, $t(15) = 10.55$, $p < 0.001$, one-sampled t-test, directed). They showed above-chance accuracy in following the cues from ES in the exposure (rate of following ES = 0.61 ± 0.04, $t(15) = 3.02$, $p = 0.005$, one-sampled t-test, directed) and, unexpectedly, in the test (accuracy = 0.66 ± 0.04, $t(15) = 4.61$, $p < 0.001$, two-tailed).

Because we used the same paradigm to measure subjects' trust across contexts (baseline, exposure, and test), we ran a

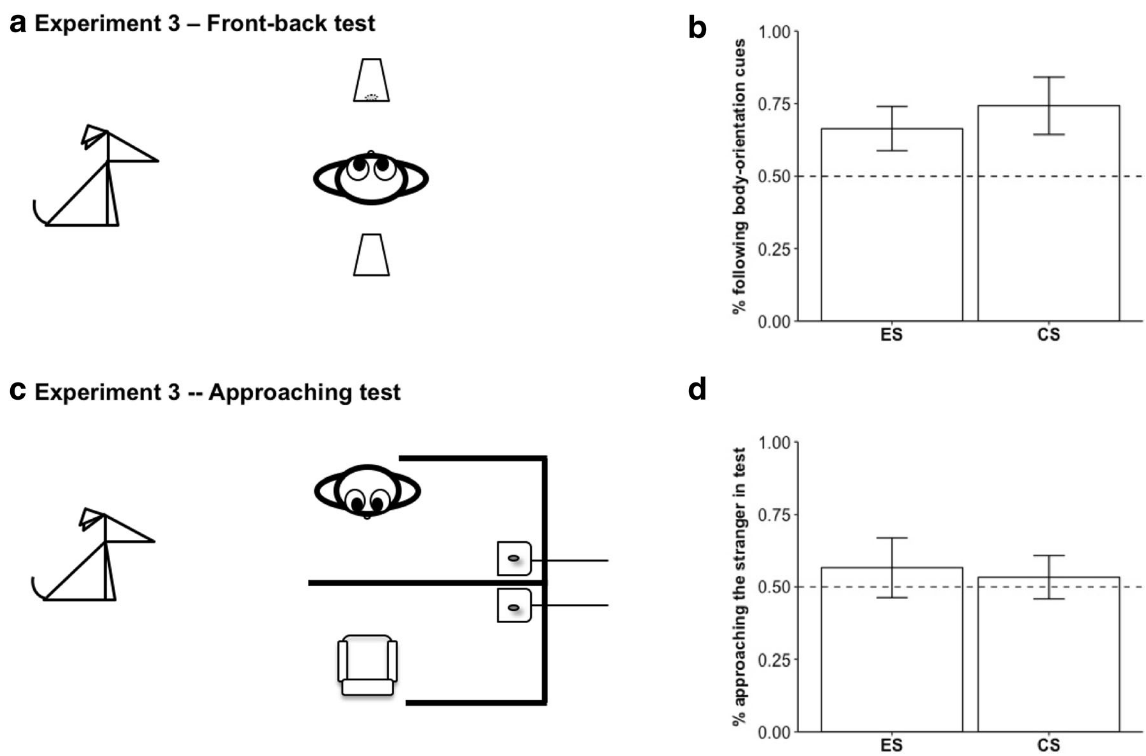

Fig. 5 Overview of Experiment 3: the setup (**a**) and the results (**b**) of the front-back test using body-orientation cues; the setup (**c**) and the results (**d**) of the approaching test. Prior to the test, subjects experienced warm exposure with ES. *ES* Exposed Stranger, *CS* Complete Stranger. Error bars represent standard errors

one-way repeated-measures ANOVA to compare subjects' tendencies to follow cues in different contexts. We set three planned contrasts based on the above directional predictions: (1) subjects should be less likely to follow the body-orientation cue in the exposure than in all other phases; (2) subjects should show higher accuracy in the baseline than in the test phase; and (3) subjects should be more likely to follow CS than ES in the test phase. Overall, there was a significant effect of context ($F(2, 45) = 10.51$, $p < 0.001$, two-tailed). Planned contrasts reveal that: (1) subjects showed a lower tendency to follow cues in the exposure relative to other phases ($t(15) = 3.76$, $p < 0.001$, directed); (2) subjects showed a higher tendency to follow cues in the baseline relative to the test phase ($t(15) = -3.8$, $p < 0.001$, directed); and (3) as shown in Fig. 5b, subjects showed a trend to follow cues more often from CS than from ES in the test phase ($t(15) = -1.7$, $p = 0.048$, directed, note that the p-value here is compared to 0.04 following Rice & Gaines, 1994).

First-trial analyses yielded similar results. Subjects were above-chance in following accurate cues in the baseline and the test phases, but not in the exposure (among 16 subjects, 16 followed the cue in the first baseline trial with NE, $p < 0.001$, directed; ten followed the cue in the first exposure trial with ES, $p = 0.23$, directed; 14 followed the cue in the first test trial with ES, $p = 0.004$, two-tailed; and 13 followed the cue in the first test trial with CS, $p = 0.011$, directed, binomial test). We were unable to compare the first-trial tendencies to trust ES and CS in the test phase because our data did not meet the assumptions of the McNemar's test.

Subjects' performance did not differ between the first and the second half of the test (ES: $t(15) = 1.86$, $p = 0.08$; CS: $t(15) = -0.52$, $p = 0.69$, paired t-test, two-tailed).

We calculated a difference score of subjects' tendency to follow cues between the first and the second half of the exposure as an index of how much subjects responded to inaccurate information. We also calculated another difference score of subjects' tendency to follow cues from ES versus from CS in the test phase as an index of how much subjects discriminated between the two strangers. These two scores did not correlate with each other ($N = 16$, $r = -0.32$, $p = 0.25$, Pearson's correlation, two-tailed).

Cold condition

As shown in Fig. 5d, subjects were not above chance in approaching ES or CS in the test phase (percentage of approaching ES = 0.57 ± 0.05, $t(18) = 1.34$, $p = 0.2$, two-tailed; percentage of approaching CS = 0.53 ± 0.04, $t(18) = 0.92$, $p = 0.19$, directed, one-sampled t-test). Furthermore, their tendencies to approach ES and CS did not differ ($t(15) = -1.46$, $p = 0.08$, paired t-test, directed).

First-trial analyses revealed similar results. Among 19 subjects, ten approached the stranger room instead of the empty room in the first test trial with ES (p = 1, binomial test, two-tailed); 11 of 19 subjects approached the stranger room in the first test trial with CS (p = 0.38, binomial test, directed). We were again unable to run McNemar's test because our data did not meet its assumption.

Subjects' performance did not differ between the first and the second half of the test (ES: t(18) = 0.42, p = 0.68; CS: t(18) = 0.18, p = 0.85, paired t-test, two-tailed).

In the exposure phase, subjects became more passive toward ES in the second half relative to the first half (t(18) = 3.43, p = 0.002, paired t-test, directed). We calculated a difference score of subjects' passivity to seek contact with ES between the first and the second half of the exposure as an index of how much subjects responded to ES's social avoidance. We also calculated another difference score of subjects' tendency to approach ES versus CS in the test phase as an index of how much subjects discriminated the two strangers. These two scores did not correlate with each other (N = 19, r = -0.12, p = 0.61, Pearson's correlation, two-tailed).

Discussion

Like in Experiments 1 and 2a, the subjects spontaneously followed social cues from a complete stranger. Their tendency to follow cues, however, remained above chance even when the cues were accurate but from an untrustworthy informant (i.e., ES). However, there is also evidence that dogs registered the negative experience with ES during the exposure. First, although they still followed social cues from ES in the exposure, they did so significantly less often than in other phases. Second, there was also a trend for subjects to follow cues of the CS more than from the unreliable ES.

In the cold condition, unlike in Experiments 2a and 2b, subjects did not prefer feeding near ES or CS to feeding alone. However, their mean tendencies to approach ES or CS were highly similar across the three experiments (percentage of feeding near ES: 57% ± 3% in Experiment 2a, 57% ± 2% in Experiment 2b; 57% ± 5% in Experiment 3; percentage of feeding near CS: 57% ± 3% in Experiment 2a; 58% ± 2% in Experiment 2b; 53% ± 4% in Experiment 3). Like Experiments 2a and 2b, there was no selectivity between ES and CS when they approached. These results suggest that at least in the current context, subjects who were socially rejected by a cold stranger showed the same level of motivation to approach him/her as a complete stranger.

General discussion

Our experiments represent relatively realistic evaluations of how pet dogs respond to their owner and different strangers. We modeled our manipulations on a number of common social interactions that pet dogs frequently encounter in their lives – whether it is taking dropped food off the floor near a human, following a gesture or responding to negative feedback from a stranger. In addition, our experiments allowed us to evaluate the first impression hypothesis by examining in which contexts the dogs did differentiate between different strangers. Overall, we found strong support of the first prediction of the first impression hypothesis that dogs should respond positively toward a complete stranger to facilitate bonding, but we found mixed support of the second prediction that dogs should adjust their preferences in response to the perceived risk and benefit of interacting with strangers.

The first finding of our experiments is that that pet dogs are extremely trusting of both their owners and strangers overall. While they can be sensitive to their previous experiences with different individuals in making decisions about who to approach or listen to when searching for food, in general, the dogs were exceptionally trusting of all people across all the different contexts.

The second finding of the current study is that family dogs demonstrate a preference for their owner over a stranger when following social cues and (to a lesser degree) when approaching and feeding in close proximity. This owner preference is strong enough in the pointing test that it is evident in the first trial. This finding adds to the growing literature that dogs establish long-term bonds with their owner and are selectively biased toward their owner in a wide range of social tasks (Elgier et al., 2009; Merola et al., 2014; Mongillo et al., 2010; Prato-Previde et al., 2003; Topál et al., 1998, 2005).

Given the evidence for a strong human-dog bond, we addressed two questions regarding the initiation of such a bond: how family dogs spontaneously respond to a complete stranger in their first encounter, and how they adjust their preferences toward the stranger based on his/her behaviors. The first impression hypothesis predicts that since dogs are adapted into the fluid and interconnected human network, they should show positive responses to a complete stranger to facilitate bonding. This positive preference was revealed in two different contexts – proximity seeking and social-cue following. We found that our subjects in general preferred feeding near a complete stranger to feeding alone, even though there was no behavioral indication that the stranger would be friendly to them. In addition, our subjects followed gesture and body-orientation cues from the complete stranger to locate hidden food, even though they had no way to know if this particular individual would gesture accurately. Importantly, in Experiments 2 and 3 we strictly controlled the timing of the appearance of the complete strangers to make sure that we were measuring true first encounters. It is clear that for our subjects, and likely most family dogs, the default response toward a complete stranger is positive. This is further corroborated by findings showing parallels in the genetic makeups of hypersociality between domestic dogs and human Williams-Beuren syndrome (VonHoldt et al., 2017). How exactly this positive preference from dogs facilitates human-dog bonding is open to further research. In the owner-dog bonds that have already been firmly established, social gaze from dogs can lead to higher level of endogenous oxytocin in humans (Nagasawa et al., 2009, 2015). Similar physiological effects may occur between pet dogs and strangers as well.

Another prediction of the first impression hypothesis was that subjects should be sensitive to the behaviors of a stranger and be able to quickly adjust their preferences. However, our results were mixed. When the strangers served as informants, subjects did not discriminate the competent stranger from the complete stranger (Experiment 2a), which is unsurprising given that they already followed the gestures of a complete stranger at a high level (i.e., a ceiling effect); subjects did show a trend to avoid gestures from the incompetent stranger relative to the complete stranger (Experiment 3), which is consistent with studies showing dogs can detect unreliable social cues (Kundey et al., 2010; Petter et al., 2009) and informants (Takaoka et al., 2014).

When the strangers served as social companions, overall subjects did not show any preference for the warm experimenter, the complete stranger, or the cold experimenter. There is first-trial evidence showing that they preferred the warm experimenter to the complete stranger (Experiment 2a, but not in Experiment 2b). One explanation is that subjects were insensitive to the warmth of strangers. However, according to Nitzschner et al. (2012), family dogs might indeed possess such sensitivity, but it is more subtle and manifested in the overall time spent near the preferred stranger, rather than an approaching preference (see also Bhattacharjee et al., 2017). In addition, such sensitivity might be masked by situational cues. Dogs are reported to use social-referencing towards their owners when they face uncertainty (Merola et al., 2012). In Experiments 2 and 3, the owner was always present in the testing room. Although the owner has been instructed to remain neutral throughout the study, a lack of negative response from the owner towards the strangers might be sufficient to encourage the dogs to interact with them.

Future studies are needed to determine whether such sensitivity is more pronounced when the need to bond with a new partner is the most urgent. For example, shelter dogs or feral dogs lack a long-term bond with an owner. This state might be when the first impression matters most (Bhattacharjee et al., 2017; Gácsi et al., 2001). Finally, it is important to note that our subjects showed a consistently positive response toward the complete stranger. This positivity is as strong as when they are interacting with a competent or warm stranger. This points to a potential gap in our knowledge about the role of oxytocin during the formation of the human-dog bond. On one hand, a short-term, positive interaction appears insufficient to increase subjects' (already positive) baseline preference towards a stranger. On the other, oxytocin appears to play an important role in *strengthening* the pre-existing affiliation between dogs and their owners (Nagasawa et al., 2015; Romero et al., 2014). More studies should be conducted to examine the effect of oxytocin on first impressions and the initiation of a bond. In addition, replicating our approach beyond family dogs might reveal much more sensitivity. Dingoes, feral dogs, or even dogs that tend to stray may be very sensitive to the type of exposure we used here – perhaps even independent of the socialization they received. This might help reveal one factor that isexplains why some dogs are preferred as family dogs over others. The ease with which family dogs interact with so many different strangers may be one of the main factors driving choices for which dogs are welcomed into our homes.

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