Report

Current Biology

Dogs Can Discriminate Emotional Expressions of Human Faces

Highlights

- We demonstrate that pet dogs can discriminate emotional expressions in human faces
- We can rule out that discrimination was based on simple local cues
- This ability may depend on extensive interaction with humans and/or domestication
- Dogs probably use their memories of real emotional human faces to accomplish the task

Authors

Corsin A. Müller, Kira Schmitt, Anjuli L.A. Barber, Ludwig Huber

Correspondence

corsin.mueller@vetmeduni.ac.at (C.A.M.),
ludwig.huber@vetmeduni.ac.at (L.H.)

In Brief

Müller et al. demonstrate that pet dogs can discriminate emotional expressions in human faces. With an innovative paradigm, they can rule out that discrimination was based on simple cues, such as the visibility of teeth. Their study provides the first solid evidence for the ability of a non-human animal to discriminate emotions of another species.

Müller et al., 2015, Current Biology *25*, 1–5
March 2, 2015
http://dx.doi.org/10.1016/j.cub.2014.12.055

Please cite this article in press as: Müller et al., Dogs Can Discriminate Emotional Expressions of Human Faces, Current Biology (2015), http://dx.doi.org/10.1016/j.cub.2014.12.055

Current Biology 25, 1–5, March 2, 2015 http://dx.doi.org/10.1016/j.cub.2014.12.055

Report

Dogs Can Discriminate Emotional Expressions of Human Faces

Corsin A. Müller,[1,*] Kira Schmitt,[1] Anjuli L.A. Barber,[1] and Ludwig Huber[1,*]
[1]Messerli Research Institute, University of Veterinary Medicine Vienna, Medical University of Vienna and University of Vienna, 1210 Vienna, Austria

Summary

The question of whether animals have emotions and respond to the emotional expressions of others has become a focus of research in the last decade [1–9]. However, to date, no study has convincingly shown that animals discriminate between emotional expressions of heterospecifics, excluding the possibility that they respond to simple cues. Here, we show that dogs use the emotion of a heterospecific as a discriminative cue. After learning to discriminate between happy and angry human faces in 15 picture pairs, whereby for one group only the upper halves of the faces were shown and for the other group only the lower halves of the faces were shown, dogs were tested with four types of probe trials: (1) the same half of the faces as in the training but of novel faces, (2) the other half of the faces used in training, (3) the other half of novel faces, and (4) the left half of the faces used in training. We found that dogs for which the happy faces were rewarded learned the discrimination more quickly than dogs for which the angry faces were rewarded. This would be predicted if the dogs recognized an angry face as an aversive stimulus. Furthermore, the dogs performed significantly above chance level in all four probe conditions and thus transferred the training contingency to novel stimuli that shared with the training set only the emotional expression as a distinguishing feature. We conclude that the dogs used their memories of real emotional human faces to accomplish the discrimination task.

Results and Discussion

Emotions in animals have developed into a hot topic in biological research, not only because they are of major relevance for our understanding of animal behavior but also because they are relevant for animal welfare and thus also for policy makers. It is now widely accepted that mammals, other vertebrates, and even some invertebrates have emotions very similar to some of our own and that they have adaptive value as they allow these animals to respond to various situations quickly and appropriately, which facilitates survival [1–6]. As emotional states are commonly expressed outwardly with behavioral and somatic responses [5], it is likely adaptive for animals to discriminate emotional expressions in others because this allows them to anticipate the behavioral response of the observed individual and to adjust their own behavior accordingly. This is the case not only for interactions with conspecifics but also for interactions with relevant individuals of different species, for example in mutualistic mixed-species associations or in predator-prey interactions (e.g., a predator discriminating fear and anger in a potential prey animal). Compared to emotion recognition in conspecifics (cf. [7, 10–12]), discriminating emotional expressions in heterospecifics is particularly challenging as emotions are not necessarily expressed in similar ways across species (indeed, although emotional expressions are generally very similar across cultures in humans, they are not expressed universally in the same way even within the species [13]). Therefore, the ability to recognize emotional expressions in individuals of a different species is likely dependent on experience. Similar experience effects have previously been shown, for example, for the ability to discriminate individual faces of another species [14–16].

The most promising species pair for investigating emotion recognition between heterospecifics is domestic dogs and their human owners. On the one hand, emotional expressions are best understood in humans, and on the other hand, a wealth of data shows that dogs excel at reading human behavioral cues [17–19]. In addition, previous work in our laboratory and other laboratories has shown that dogs pay attention to subtle cues in human faces: they can discriminate 2D representations of familiar and unfamiliar human faces and can do so even if only parts of the faces are shown [20–22]. However, previous studies that aimed to test whether dogs discriminate between human emotional expressions did not give conclusive results. Racca and colleagues [23] found evidence of a differential gaze bias in dogs when shown dog faces with a threatening or friendly expression, but not when shown human faces with an angry or happy expression. Custance and Mayer [9] suggested that dogs show responses reminiscent of empathic-like behavior when encountering a crying human, but not when encountering a talking or humming human. However, live presentations like those used by Custance and Mayer lack the level of control necessary to determine whether the dogs really responded to the emotional expression or whether they responded to some other cue. The latter possibility is also true for a study by Nagasawa and colleagues [8] in which dogs learned to discriminate between happy (smiling) faces and neutral faces of their owner and subsequently transferred the contingency to novel faces of unfamiliar people. The subjects in this study may simply have used a salient discriminatory cue, such as the visibility of teeth in the happy faces, but not in the neutral faces, to solve both the training and the transfer task.

To avoid the weaknesses of the earlier studies, we conducted a meticulously controlled experiment that the subjects could only solve by discriminating the emotional expression in the presented human faces. After pre-training with picture pairs of a face with a neutral expression and the back of the head of the same person (as in [8]), a group of pet dogs (cf. Table S1) learned to discriminate between faces of the same person with a happy or angry emotional expression presented on a touch screen monitor (Figure 1; see also Movie S1). Importantly, in this training phase, the subjects were shown only the upper halves or only the lower halves of the pictures (see Figure 2, upper part) and were rewarded either for touching the happy stimulus or for touching the angry stimulus. With this

*Correspondence: corsin.mueller@vetmeduni.ac.at (C.A.M.), ludwig.huber@vetmeduni.ac.at (L.H.)

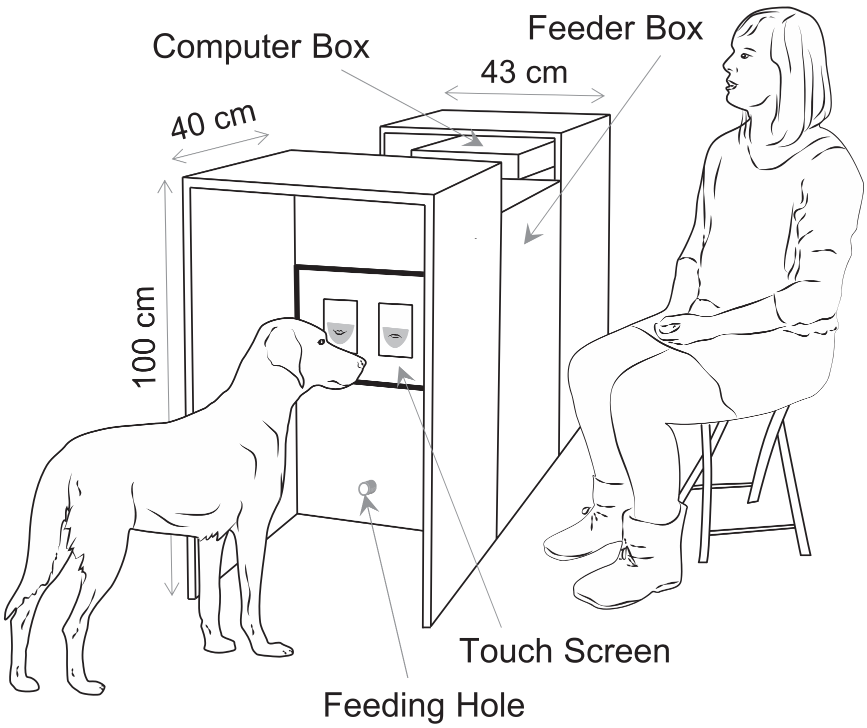

Figure 1. Touch Screen Apparatus with Dog and Experimenter

The dog owner sat on a chair at the opposite end of the room, facing the experimenter (not shown). When looking at the stimuli, the dog's nose was within, at most, 30 cm of the screen but could be considerably closer.

approach, we could subsequently test the subjects' ability to spontaneously categorize novel pictures that shared with the training stimuli only the emotional expression as the distinguishing feature. We used four types of probe trials (see Figure 2, lower part): the same half as during training but of novel faces, the other half of the faces used in training, the other half of novel faces, or the left half of the faces used in training. To exclude learning across probe trials, we used ten different face pairs, resulting in ten unique trials for each probe condition. If the dogs learned to discriminate the training stimuli based on the presence or absence of simple cues, such as teeth or frown lines, we expected that they would be able to transfer the training contingency to the conditions novel face/same half and training face/left half, which shared at least some of these cues with the stimuli in the training set (like in [8]), but not to the conditions training face/other half and novel face/other half, which did not share at least some of these cues with the training stimuli. If, in contrast, the dogs learned to discriminate the training stimuli based on their emotional expression, which is provided globally on the whole face and not just by local cues, we expected that the dogs would be able to transfer the training contingency to all four probe conditions, as they all share the two emotional expressions with the stimuli in the training set.

In the training phase, the subjects that were rewarded for touching the angry stimulus reached the learning criterion at a slower rate than the subjects rewarded for touching the happy stimulus (Figure 3A; proportional hazards model: N = 18,

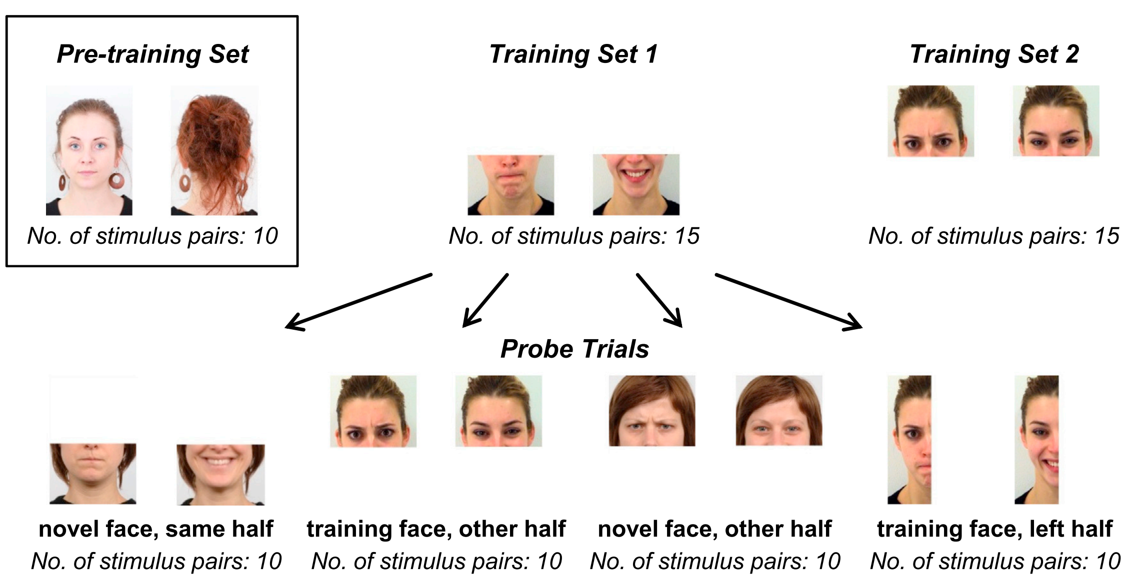

Figure 2. Example Stimuli

Example stimulus pairs of the pre-training set and the two training sets (top row) and example stimulus pairs of the probe trials for a subject trained with the lower halves of the faces (bottom row). All pictures were of adult Caucasian women. The pre-training stimuli were photographs of ten laboratory members (the shown picture pair is reproduced with permission of the person depicted); the 25 picture pairs for the test stimuli were obtained from validated online databases [24–26]. For further details, see Supplemental Experimental Procedures.

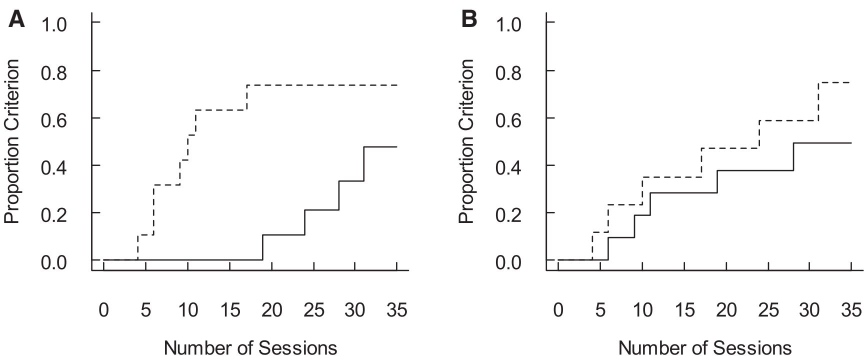

Figure 3. Results of Training Phase

(A) Cumulative proportion of subjects that reached the learning criterion for dogs rewarded for touching the happy stimulus (dashed line) or the angry stimulus (solid line).

(B) Cumulative proportion of subjects that reached the learning criterion for dogs shown the upper halves (dashed line) or the lower halves (solid line) of the faces.

z = 2.48, p = 0.01). This effect would be predicted if the dogs recognized the emotional expression presented and, at least initially, responded to an angry face as they would respond to an aversive stimulus; in that case, the dogs had to overcome their natural tendency to move away from aversive (or threatening) stimuli in order to reach the learning criterion (and failure to overcome this tendency may for some of the subjects in the angry-rewarded group explain the failure to reach the learning criterion). As previous results suggested that dogs [22, 27], like primates [28] but unlike pigeons [29], attend particularly to the eye region of human faces, one might also have expected that learning would be faster for subjects presented with the upper rather than with the lower halves of the faces during training. However, we found no evidence to support this (Figure 3B; proportional hazards model: N = 18, z = 1.57, p = 0.12), and, also, no interaction between the two predictors was apparent (z = 1.00, p = 0.31).

In the test phase, the 11 dogs that had reached the learning criterion maintained their level of accuracy in the standard trials (identical to the training trials) and also performed above chance level in all four probe conditions (Figure 4; generalized linear models: all $p \leq 0.002$, cf. Table S2 for details). Furthermore, the test performance did not differ between probe conditions (Figure 4; generalized linear mixed model with likelihood ratio test: $\chi^2_{(3)} = 3.98$, p = 0.26), indicating that the dogs did not rely purely on the presence or absence of simple local cues when learning the discrimination task. Instead, they must have used the emotional expression of the stimuli to solve this task, as this was the only distinguishing feature shared by the training stimuli and the stimuli of all four probe conditions. Our interpretation that the subjects transferred the contingency they had learned during training to the four types of probe trials is also supported by the significant correlation between performance in the standard trials and in the probe trials in the test phase (Figure S1 and Supplemental Results).

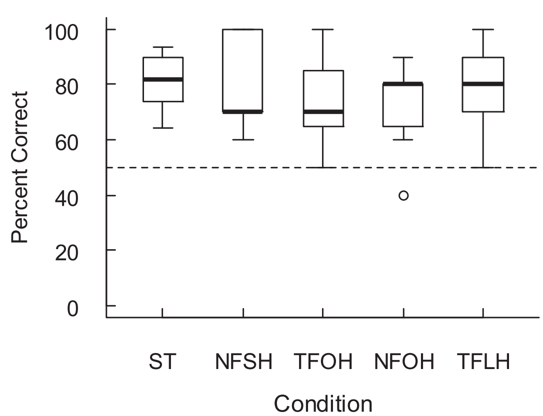

Figure 4. Results of Test Phase

Proportion of correct choices by condition for the 11 subjects in the test phase, in standard trials (ST, 200 trials per subject), and in trials of the four probe conditions (10 trials per subject and condition). NFSH, novel face, same half as in training; TFOH, training face, other half; NFOH, novel face, other half; TFLH, training face, left half. Boxplots indicate median, inter-quartile range, and range. An outlier is shown as a circle. The dashed line indicates chance level.

To our knowledge, these results represent the first solid evidence that a non-human animal can discriminate between emotional expressions in a different species. We suggest that the successful subjects, while living in intimate relationships with their owners and also in regular contact with other humans, formed memories of human emotional expressions in a global manner (as has been suggested previously for face perception in dogs [20, 22, 27] and in non-human primates [30–32]) and/or associations between different parts of the face with the same expression. With reference to such memories, the dogs in our study could have realized that a happy expression in the lower half of the face has the same meaning as a happy expression in the upper half of the face and generalized this association to similar but novel faces that express the same emotions in the same way. Although the performance in the probe trials does not necessarily mean that the dogs recognized the emotional content of the presented stimuli, it remains possible that, with extensive experience, the subjects formed richer memories of human expressions that go beyond the purely perceptual level and include information about their meaning (e.g., about the behavior of the human that will typically follow or the emotional state the perceiver will experience thereafter). Our finding that the dogs learned the association more slowly if required to touch the angry stimulus is consistent with the suggestion that the dogs, at least initially, considered the stimuli with an angry expression as aversive and therefore associated a particular meaning with these stimuli.

Our results raise the question of whether the excellent performance of some subjects in our study is largely due to their extensive experience with human emotional expressions, whether it is an ability favored by selection pressures during domestication and artificial selection thereafter, or, indeed, whether the capacity to read emotional expressions in other species is an ability that occurs commonly in mammals. The role of experience can be explored, for example, by using human faces of the gender opposite to the owner's and of different ethnic groups as stimuli in the task introduced here, by presenting the task to dogs with limited exposure to humans (e.g., young pet dogs, laboratory dogs, or feral dogs), and also by presenting the task to subjects of other species with different exposure to humans. The potential influence of artificial selection on the ability described here can be assessed, for example, by presenting our task to wolves with extensive exposure to humans (e.g., hand-raised ones) and to other domesticated and non-domesticated species and also by exploring breed differences. One may, for example, predict that dog breeds that were selected for a purpose that involves close interaction with humans, such as the Border Collies represented prominently in our sample, perform better in the task presented here than dog breeds that were selected for human-independent work [33] (see also [34, 35]). In addition, the study of emotion contagion within and across species (e.g., [9, 36–39]) is a promising way to determine whether animals not only discriminate between emotional expressions in others but also perceive the emotional content of these expressions.

Supplemental Information

Supplemental Information includes Supplemental Results, Supplemental Experimental Procedures, one figure, two tables, and one movie and can be found with this article online at http://dx.doi.org/10.1016/j.cub.2014.12.055.

Author Contributions

C.A.M., A.L.A.B., and L.H. conceived the experiments; K.S. performed the experiments; C.A.M. and K.S. analyzed the data; and C.A.M., A.L.A.B., and L.H. wrote the paper.

Acknowledgments

All procedures were approved by the institutional ethics committee in accordance with GSP guidelines and national legislation (Ref. 08/02/97/2014). We thank the dog owners for participating in this study; Denise Ocampo and Karin Bayer for help with the experiments; Christian Palmers and Claus Lamm for discussions; Nadja Kavcik for drawing Figure 1; and three anonymous reviewers for comments on the manuscript. This work was supported by WWTF grant CS11-005 to L.H.

Received: October 27, 2014
Revised: December 3, 2014
Accepted: December 23, 2014
Published: February 12, 2015

References

1. Panksepp, J. (1998). Affective Neuroscience: The Foundations of Human and Animal Emotions (Oxford: Oxford University Press).
2. Panksepp, J. (2011). The basic emotional circuits of mammalian brains: do animals have affective lives? Neurosci. Biobehav. Rev. *35*, 1791–1804.
3. Paul, E.S., Harding, E.J., and Mendl, M. (2005). Measuring emotional processes in animals: the utility of a cognitive approach. Neurosci. Biobehav. Rev. *29*, 469–491.
4. Mendl, M., Burman, O.H.P., and Paul, E.S. (2010). An integrative and functional framework for the study of animal emotion and mood. Proc. Biol. Sci. *277*, 2895–2904.
5. Anderson, D.J., and Adolphs, R. (2014). A framework for studying emotions across species. Cell *157*, 187–200.
6. Watanabe, S., and Kuczaj, S., eds. (2013). Emotions of Animals and Humans: Comparative Perspectives (Tokyo: Springer).
7. Parr, L.A. (2003). The discrimination of faces and their emotional content by chimpanzees (*Pan troglodytes*). Ann. N Y Acad. Sci. *1000*, 56–78.
8. Nagasawa, M., Murai, K., Mogi, K., and Kikusui, T. (2011). Dogs can discriminate human smiling faces from blank expressions. Anim. Cogn. *14*, 525–533.
9. Custance, D., and Mayer, J. (2012). Empathic-like responding by domestic dogs (*Canis familiaris*) to distress in humans: an exploratory study. Anim. Cogn. *15*, 851–859.
10. Parr, L.A., Waller, B.M., and Heintz, M. (2008). Facial expression categorization by chimpanzees using standardized stimuli. Emotion *8*, 216–231.
11. Quaranta, A., Siniscalchi, M., and Vallortigara, G. (2007). Asymmetric tail-wagging responses by dogs to different emotive stimuli. Curr. Biol. *17*, R199–R201.
12. Siniscalchi, M., Lusito, R., Vallortigara, G., and Quaranta, A. (2013). Seeing left- or right-asymmetric tail wagging produces different emotional responses in dogs. Curr. Biol. *23*, 2279–2282.
13. Jack, R.E., Garrod, O.G.B., Yu, H., Caldara, R., and Schyns, P.G. (2012). Facial expressions of emotion are not culturally universal. Proc. Natl. Acad. Sci. USA *109*, 7241–7244.
14. Sugita, Y. (2008). Face perception in monkeys reared with no exposure to faces. Proc. Natl. Acad. Sci. USA *105*, 394–398.
15. Martin-Malivel, J., and Okada, K. (2007). Human and chimpanzee face recognition in chimpanzees (*Pan troglodytes*): role of exposure and impact on categorical perception. Behav. Neurosci. *121*, 1145–1155.
16. Dufour, V., and Petit, O. (2009). Recognition of monkey faces by monkey experts. J. Ethol. *28*, 231–238.
17. Hare, B., Brown, M., Williamson, C., and Tomasello, M. (2002). The domestication of social cognition in dogs. Science *298*, 1634–1636.
18. Hare, B., and Tomasello, M. (2005). Human-like social skills in dogs? Trends Cogn. Sci. *9*, 439–444.
19. Bräuer, J., Kaminski, J., Riedel, J., Call, J., and Tomasello, M. (2006). Making inferences about the location of hidden food: social dog, causal ape. J. Comp. Psychol. *120*, 38–47.
20. Racca, A., Amadei, E., Ligout, S., Guo, K., Meints, K., and Mills, D. (2010). Discrimination of human and dog faces and inversion responses in domestic dogs (*Canis familiaris*). Anim. Cogn. *13*, 525–533.
21. Huber, L., Racca, A., Scaf, B., Virányi, Z., and Range, F. (2013). Discrimination of familiar human faces in dogs (*Canis familiaris*). Learn. Motiv. *44*, 258–269.
22. Pitteri, E., Mongillo, P., Carnier, P., Marinelli, L., and Huber, L. (2014). Part-based and configural processing of owner's face in dogs. PLoS ONE *9*, e108176.
23. Racca, A., Guo, K., Meints, K., and Mills, D.S. (2012). Reading faces: differential lateral gaze bias in processing canine and human facial expressions in dogs and 4-year-old children. PLoS ONE *7*, e36076.
24. Lundqvist, D., Flykt, A., and Öhman, A. (1998). Karolinska Directed Emotional Faces (KDEF). http://www.emotionlab.se/resources/kdef.
25. Langner, O., Dotsch, R., Bijlstra, G., Wigboldus, D.H.J., Hawk, S.T., and van Knippenberg, A. (2010). Presentation and validation of the Radboud Faces Database. Cogn. Emot. *24*, 1377–1388.
26. van der Schalk, J., Hawk, S.T., Fischer, A.H., and Doosje, B. (2011). Moving faces, looking places: validation of the Amsterdam Dynamic Facial Expression Set (ADFES). Emotion *11*, 907–920.
27. Somppi, S., Törnqvist, H., Hänninen, L., Krause, C.M., and Vainio, O. (2014). How dogs scan familiar and inverted faces: an eye movement study. Anim. Cogn. *17*, 793–803.
28. Kanazawa, S. (1998). What facial part is important for Japanese monkeys (*Macaca fuscata*) in recognition of smiling and sad faces of humans (*Homo sapiens*)? J. Comp. Psychol. *112*, 363–370.
29. Jitsumori, M., and Yoshihara, M. (1997). Categorical discrimination of human facial expressions by pigeons: a test of the linear feature model. Q. J. Exp. Psychol. B *50*, 253–268.
30. Parr, L.A., Heintz, M., and Akamagwuna, U. (2006). Three studies on configural face processing by chimpanzees. Brain Cogn. *62*, 30–42.
31. Dahl, C.D., Logothetis, N.K., and Hoffman, K.L. (2007). Individuation and holistic processing of faces in rhesus monkeys. Proc. Biol. Sci. *274*, 2069–2076.
32. Hirata, S., Fuwa, K., Sugama, K., Kusunoki, K., and Fujita, S. (2010). Facial perception of conspecifics: chimpanzees (*Pan troglodytes*) preferentially attend to proper orientation and open eyes. Anim. Cogn. *13*, 679–688.
33. Gácsi, M., McGreevy, P., Kara, E., and Miklósi, A. (2009). Effects of selection for cooperation and attention in dogs. Behav. Brain Funct. *5*, 31.
34. Udell, M.A.R., Ewald, M., Dorey, N.R., and Wynne, C.D.L. (2014). Exploring breed differences in dogs (*Canis familiaris*): does exaggeration or inhibition of predatory response predict performance on human-guided tasks? Anim. Behav. *89*, 99–105.
35. Jakovcevic, A., Elgier, A.M., Mustaca, A.E., and Bentosela, M. (2010). Breed differences in dogs' (*Canis familiaris*) gaze to the human face. Behav. Processes *84*, 602–607.

36. Palagi, E., Leone, A., Mancini, G., and Ferrari, P.F. (2009). Contagious yawning in gelada baboons as a possible expression of empathy. Proc. Natl. Acad. Sci. USA *106*, 19262–19267.
37. Romero, T., Konno, A., and Hasegawa, T. (2013). Familiarity bias and physiological responses in contagious yawning by dogs support link to empathy. PLoS ONE *8*, e71365.
38. Langford, D.J., Tuttle, A.H., Brown, K., Deschenes, S., Fischer, D.B., Mutso, A., Root, K.C., Sotocinal, S.G., Stern, M.A., Mogil, J.S., and Sternberg, W.F. (2010). Social approach to pain in laboratory mice. Soc. Neurosci. *5*, 163–170.
39. Reimert, I., Bolhuis, J.E., Kemp, B., and Rodenburg, T.B. (2013). Indicators of positive and negative emotions and emotional contagion in pigs. Physiol. Behav. *109*, 42–50.