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Dogs recognise dog and human emotions

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20 **Abstract:** The perception of emotional expressions allows mammals to evaluate the social
21 intentions and motivations of each other; this usually takes place within species; however in the
22 case of domestic dogs, it might be advantageous to recognise the emotions of humans as well as
23 other dogs. In this sense, the combination of visual and auditory cues to categorise others'
24 emotions facilitates the information processing and indicates high-level cognitive
25 representations. Using a cross-modal preferential looking paradigm, we presented dogs with
26 either human or dog faces with different emotional valences (happy/playful vs angry/aggressive)
27 paired with a single vocalization from the same individual with either a positive or negative
28 valence or Brownian noise. Dogs looked significantly longer at the face whose expression was
29 congruent to the valence of vocalization, for both conspecifics and heterospecifics, an ability
30 previously known only in humans. These results demonstrate that dogs can extract and integrate
31 bimodal sensory emotional information, and discriminate between positive and negative
32 emotions from both humans and dogs.

33
34 **Keywords:** *Canis familiaris*, cross-modal sensory integration, emotion recognition, social
35 cognition

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41 **1. Introduction**

42 The recognition of emotional expressions allows animals to evaluate the social intentions
43 and motivations of others (1). This provides crucial information about how to behave in different
44 situations involving the establishment and maintenance of long-term relationships (2). Therefore
45 reading the emotions of others has enormous adaptive value. The ability to recognise and
46 respond appropriately to these cues has biological fitness benefits for both signaller and the
47 receiver (1).

48 During social interactions, individuals use a range of sensory modalities, such as visual
49 and auditory cues to express emotion, with characteristic changes in both face and vocalization,
50 which together produce a more robust percept (3). Although facial expressions are recognised as
51 a primary channel for the transmission of affective information in a range of species (2), the
52 perception of emotion through cross-modal sensory integration enables faster, more accurate and
53 more reliable recognition (4). Cross-modal integration of emotional cues has been observed in
54 some primate species with conspecific stimuli, such as matching a specific facial expression with
55 the corresponding vocalisation or call (5-7). However, there is currently no evidence of
56 emotional recognition of heterospecifics in non-human animals. Understanding heterospecific
57 emotions is of particular importance for animals such as domestic dogs, who live most of their
58 lives in mixed species groups and have developed mechanisms to interact with humans (8).
59 Some work has shown cross-modal capacity in dogs relating to the perception of specific
60 activities (e.g. food-guarding) (9) or individual features (e.g. body size) (10), yet it remains
61 unclear whether this ability extends to the processing of emotional cues, which inform
62 individuals about the internal state of others.

63 Dogs can discriminate human facial expressions and emotional sounds (e.g. 11-18),
64 however, there is still no evidence of multimodal emotional integration and these results relating
65 to discrimination could be explained through simple associative processes. They do not
66 demonstrate emotional recognition, which requires the demonstration of categorisation rather
67 than differentiation. The integration of congruent signals across sensory inputs requires internal
68 categorical representation (19-22) and so provides a means to demonstrate the representation of
69 emotion.

70 In this study, we used a cross-modal preferential looking paradigm without
71 familiarization phase to test the hypothesis that dogs can extract and integrate emotional
72 information from visual (facial) and auditory (vocal) inputs. If dogs can cross-modally recognise
73 emotions, they should look longer at facial expressions matching the emotional valence of
74 simultaneously presented vocalizations, as demonstrated by other mammals (e.g. 5-7,21-22).
75 Due to previous findings of valence (5), side (22), sex (11,22) and species (12,23) biases in
76 perception studies, we also investigated whether these four main factors would influence the
77 dogs' response.

78

79 **2. Materials and Methods**

80 Seventeen healthy socialised family adult dogs of various breeds were presented
81 simultaneously with two sources of emotional information. Pairs of grey-scale gamma-corrected
82 human or dog face images from the same individual but depicting different expressions
83 (happy/playful vs angry/aggressive) were projected onto two screens at the same time as a sound
84 was played (Fig. 1A). The sound was a single vocalization (dog barks or human voice in an
85 unfamiliar language) of either positive or negative valence from the same individual or a neutral

86 sound (Brownian noise). Stimuli (Fig. 1B) were taken from one female and one male of both
87 species. Unfamiliar individuals and languages (Brazilian Portuguese) were used to rule out the
88 potential influence of previous experience with model identity and human language.

89 Experiments took place in a quiet, dimly-lit test room and each dog received two 10-trial
90 sessions, separated by two weeks. Dogs stood in front of two screens and a video camera
91 recorded their spontaneous looking behaviour. A trial consisted of the presentation of a
92 combination of the acoustic and visual stimuli and lasted five seconds (see Supplementary
93 Information for details). Each trial was considered valid for analyses when the dog looked at the
94 images for at least 2.5 seconds. The 20 trials presented different stimulus combinations: 4 face-
95 pairs (2 human and 2 dog models) \times 2 vocalizations (positive and negative valence) \times 2 face
96 positions (left and right), in addition to 4 control trials (4 face-pairs with neutral auditory
97 stimulus). Therefore, each subject saw each possible combination once.

98 We calculated a congruence index $= (C-I)/T$ where C and I represent the amount of time
99 the dog looked at the congruent (facial expression matching emotional vocalization, C) and
100 incongruent faces (I), and T represents total looking time (looking left + looking right + looking
101 at the centre) for the given trial, to measure the dog's sensitivity to audiovisual emotional cues
102 delivered simultaneously. We analysed the congruence index across all trials using a General
103 Linear Mixed Model (GLMM) with individual dog included in the model as a random effect.
104 Only emotion valence, stimulus sex, stimulus species and presentation position (left vs right)
105 were included as the fixed effects in the final analysis because first and second order interactions
106 were not significant. The means were compared to zero and confidence intervals were presented
107 for all the main factors in this model. A backward selection procedure was applied to identify the
108 significant factors. The normality assumption was verified by visually inspecting plots of

109 residuals with no important deviation from normality identified. To verify a possible interaction
110 between the sex of subjects and stimuli, we used a separate GLMM taking into account these
111 factors. We also tested whether dogs preferentially looked at a particular valence throughout
112 trials and at a particular face in the control trials (see Supplementary Material for details of index
113 calculation).

114

115 **3. Results**

116 Dogs showed a clear preference for the congruent face in 67% of the trials (n=188). The
117 mean congruence index was 0.19 ± 0.03 across all test trials, and was significantly greater than
118 zero ($t_{167}=5.53$; $p<0.0001$), indicating dogs looked significantly longer at the face whose
119 expression matched the valence of vocalization. Moreover, we found a consistent congruent
120 looking preference regardless of the stimulus species (dog: $t_{167}=5.39$, $p<0.0001$; human:
121 $t_{167}=2.48$, $p=0.01$; Fig. 2A), emotional valence (negative: $t_{167}=5.01$, $p<0.0001$; positive:
122 $t_{167}=2.88$, $p=0.005$; Fig. 2B), stimulus gender (female: $t_{167}=4.42$, $p<0.0001$; male: $t_{167}=3.45$,
123 $p<0.001$; Fig. 2C) and stimulus position (left side: $t_{167}=2.74$, $p<0.01$; right side: $t_{167}=5.14$,
124 $p<0.0001$; Fig. 2D). When a backwards selection procedure was applied to the model with the
125 four main factors, the final model included only stimulus species. The congruence index for this
126 model was significantly higher for viewing dog than human faces (dog: 0.26 ± 0.05 , human:
127 0.12 ± 0.05 , $F_{1,170}=4.42$; $p=0.04$, Fig 2A), indicating that dogs demonstrated greater sensitivity
128 towards conspecific cues. In a separate model, we observed no significant interaction between
129 subject sex and stimulus sex ($F_{1,169}=1.33$, $p=0.25$) or main effects (subject sex: $F_{1,169}=0.17$,
130 $p=0.68$; subject stimulus: $F_{1,169}=0.56$, $p=0.45$).

131 Dogs did not preferentially look at either of the facial expressions in control conditions
132 when the vocalization was the neutral sound (mean: 0.04 ± 0.07 ; $t_{16} = 0.56$; $p = 0.58$). The mean
133 preferential looking index was -0.05 ± 0.03 that was not significantly different from zero ($t_{16} = -1.6$,
134 $p = 0.13$), indicating that there was no difference in the proportion of viewing time between
135 positive and negative facial expressions across trials.

136

137 **4. Discussion**

138 The findings are the first evidence of the integration of heterospecific emotional
139 expressions in a species other than humans, and extend beyond primates the demonstration of
140 cross-modal integration of conspecific emotional expressions. These results show that domestic
141 dogs can obtain dog and human emotional information from both auditory and visual inputs, and
142 integrate them into a coherent perception of emotion (21). Therefore, it is likely that dogs
143 possess at least the mental prototypes for emotional categorisation (positive *vs* negative affect)
144 and can recognise the emotional content of these expressions. Moreover, dogs performed in this
145 way without any training or familiarisation with the subjects, suggesting that these emotional
146 signals are intrinsically important. This is consistent with this ability conferring important
147 adaptive advantages (24).

148 Our study shows that dogs possess a similar ability to some non-human primates in being
149 able to match auditory and visual emotional information (5), but also demonstrates an important
150 advance. In our study, there was not a strict temporal correlation between the recording of visual
151 and auditory cues (e.g. relaxed dog face with open mouth paired with playful bark), unlike the
152 earlier research on primates (e.g. 5). Thus the relationship between the modalities was not

153 temporally contiguous, reducing the likelihood of learned associations accounting for the results.
154 This suggests the existence of a robust categorical emotion representation.

155 Although dogs showed the ability to recognise both conspecific and heterospecific
156 emotional cues, we found that they responded significantly more strongly towards dog stimuli.
157 This could be explained by a more refined mechanism for the categorization of emotional
158 information from conspecifics, which is corroborated by the recent findings of dogs showing a
159 greater sensitivity to conspecifics' facial expressions (12) and a preference for dog over human
160 images (23). The ability to recognise emotions through visual and auditory cues may be a
161 particularly advantageous social tool in a highly social species such as dogs and might have been
162 exapted for the establishment and maintenance of long-term relationships with humans. It is
163 possible that during domestication, such features could have been retained and potentially
164 selected for, albeit unconsciously. Nonetheless, the communicative value of emotion is one of
165 the core components of the process and even less-social domestic species, such as cats, express
166 affective states such as pain in their faces (25).

167 It has been a long-standing debate as to whether dogs can recognise human emotions.
168 Studies using either visual or auditory stimuli have observed that dogs can show differential
169 behavioural responses to single modality sensory inputs with different emotional valences
170 (e.g.14,16). For example, Müller and colleagues (13) found that dogs could selectively respond
171 to happy or angry human facial expressions; when trained with only the top (or bottom) half of
172 unfamiliar faces they generalized the learned discrimination to the other half of the face.
173 However, these human-expression-modulated behavioural responses could be attributed solely to
174 learning of contiguous visual features. In this sense, dogs could be discriminating human facial
175 expressions without recognizing the information being transmitted.

176 Our subjects needed to be able to extract the emotional information from one modality
177 and activate the corresponding emotion category template for the other modality. This indicates
178 that domestic dogs interpret faces and vocalizations using more than simple discriminative
179 processes; they obtain emotionally significant semantic content from relevant audio and visual
180 stimuli that may aid communication and social interaction. Moreover, the use of unfamiliar
181 Portuguese words controlled for potential artefacts induced by a dog's previous experience with
182 specific words. The ability to form emotional representations that include more than one sensory
183 modality suggests cognitive capacities not previously demonstrated outside of primates. Further
184 the ability of dogs to extract and integrate such information from an unfamiliar human stimulus,
185 demonstrates cognitive abilities, not known to exist beyond humans. These abilities may be
186 fundamental to a functional relationship within the mixed species social groups in which dogs
187 often live. Moreover, our results may indicate a more widespread distribution of the ability to
188 spontaneously integrate multimodal cues amongst non-human mammals, which may be key to
189 understanding the evolution of social cognition.

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256 **Figure captions**

257 Fig. 1. (A) Schematic apparatus. R2: researcher, C: camera, S: screens, L: loudspeakers, P:
258 projectors, R1: researcher; (B) Example of stimuli used in the study: faces (human angry vs
259 happy, dog aggressive vs playful) and their correspondent vocalizations.

260 Fig. 2. Dogs' viewing behaviour (calculated as congruence index). (A) Species of stimulus; (B)
261 Valence of stimulus; (C) Sex of stimulus; (D) Side of stimulus presentation.

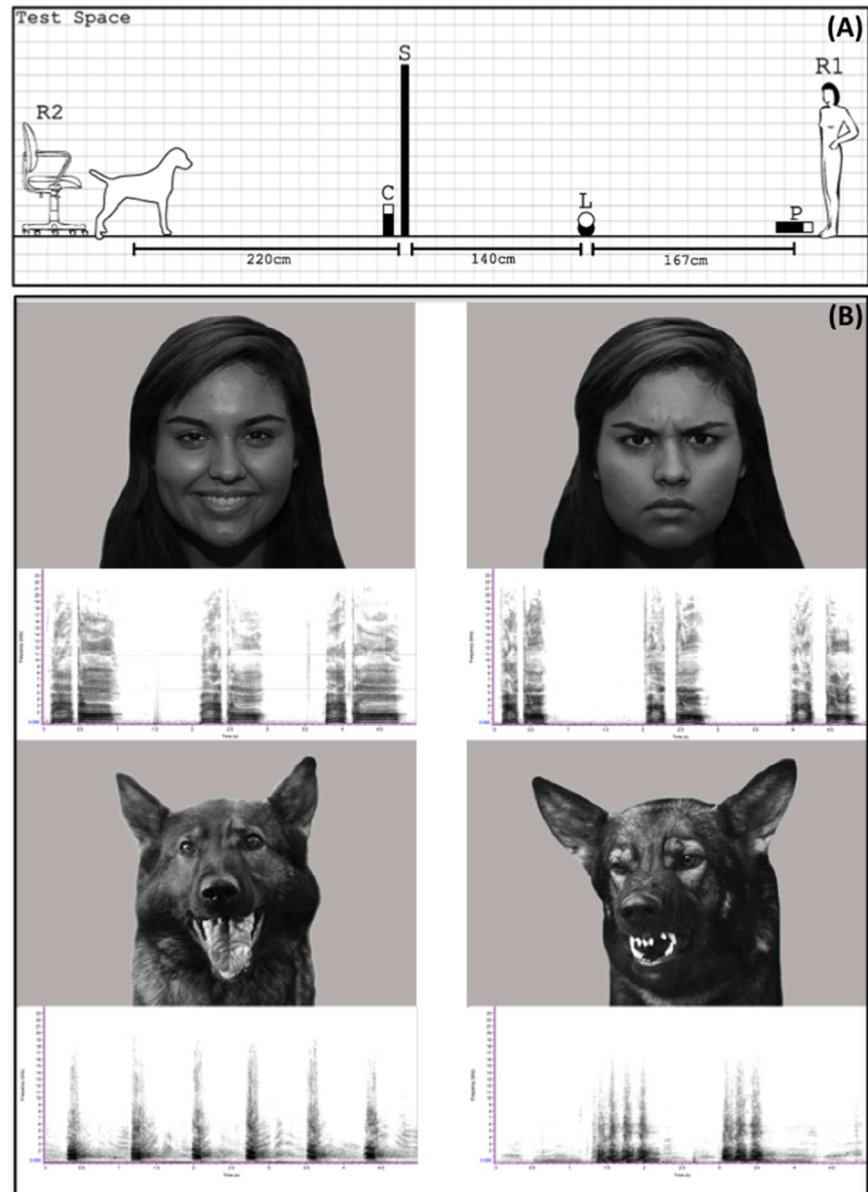


Fig. 1. (A) Schematic apparatus. R2: researcher, C: camera, S: screens, L: loudspeakers, P: projectors, R1: researcher; (B) Example of stimuli used in the study: faces (human angry vs happy, dog aggressive vs playful) and their correspondent vocalizations.
254x338mm (72 x 72 DPI)

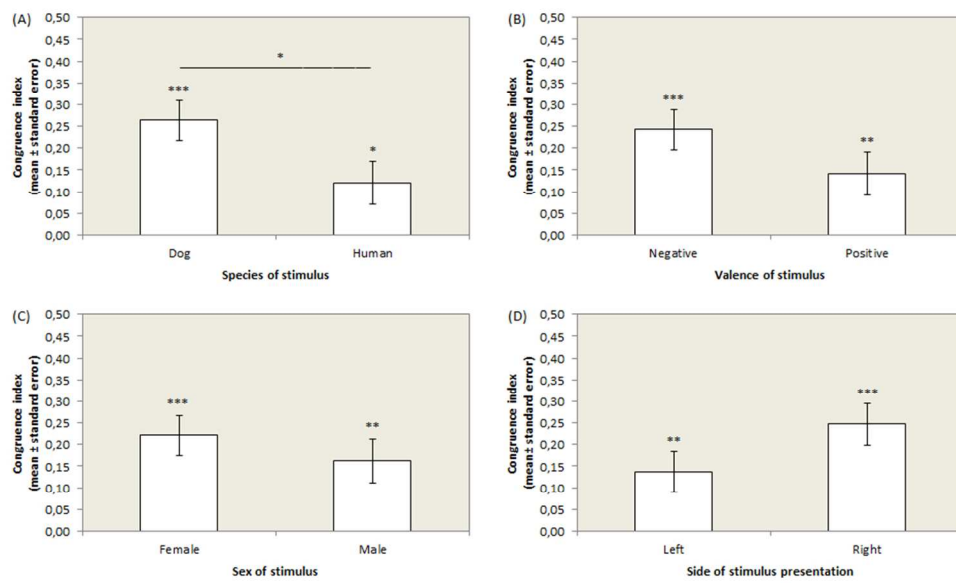


Fig. 2. Dogs' viewing behaviour (calculated as congruence index). (A) Species of stimulus; (B) Valence of stimulus; (C) Sex of stimulus; (D) Side of stimulus presentation.
343x205mm (72 x 72 DPI)