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1 **Humans (*Homo sapiens*) judge the emotional content of piglet (*Sus***
2 ***scrofa domestica*) calls based on simple acoustic parameters, not**
3 **personality, empathy, nor attitude toward animals**

4
5 Iva L. Maruščáková^{1,2}, Pavel Linhart¹, Victoria F. Ratcliffe³, Céline Tallet^{4,5}, David Reby³, and Marek
6 Špinka¹

7 ¹Department of Ethology, Institute of Animal Science, Prague, Czechia

8 ²Department of Zoology, Charles University, Prague, Czechia

9 ³ School of Psychology, University of Sussex, Brighton, United Kingdom

10 ⁴INRA, UMR1348 PEGASE, Saint-Gilles, France

11 ⁵Agrocampus Ouest, UMR1348 PEGASE, Rennes, France

12

13 Corresponding author: Marek Špinka

14 Address: Ethology Department, Institute of Animal Science, Přátelství 815, 104 00, Praha Uhřetěves,

15 Czech Republic

16 e-mail: spinka.marek@vuzv.cz

17 tel.: +420 267 009 596

18

19 **Abstract**

20 The vocal expression of emotion is likely driven by shared physiological principles among species.
21 However, which acoustic features promote decoding of emotional state and how the decoding is
22 affected by listener's psychology remain poorly understood. Here we tested how acoustic features of
23 piglet vocalizations interact with psychological profiles of human listeners to affect judgments of
24 emotional content of heterospecific vocalizations. We played back 48 piglet call sequences recorded
25 in 4 different contexts (castration, isolation, reunion, nursing) to 60 listeners. Listeners judged the
26 emotional intensity and valence of the recordings and were further asked to attribute a context of
27 emission from 4 proposed contexts. Further, listeners completed a series of questionnaires assessing
28 their personality (NEO-FFI personality inventory), empathy (Interpersonal Reactivity Index IRI) and
29 attitudes to animals (Animal Attitudes Scale). None of the listeners' psychological traits affected the
30 judgments. On the other hand, acoustic properties of recordings had a substantial effect on ratings.
31 Recordings were rated as more intense with increasing pitch (mean fundamental frequency) and
32 increasing proportion of vocalized sound within each stimulus recording and more negative with
33 increasing pitch and increasing duration of the calls within the recording. More complex acoustic
34 properties (jitter, harmonic-to-noise ratio, and presence of subharmonics) did not seem to affect the
35 judgements. The probability of correct context recognition correlated positively with the assessed
36 emotion intensity for castration and reunion calls, and negatively for nursing calls. In conclusion,
37 listeners judged emotions from pig calls using simple acoustic properties and the perceived
38 emotional intensity might guide the identification of the context.

39 Key words:; emotional valence, emotional intensity, vocalizations, personality, empathy

40 **Introduction**

41 Whilst emotions are subjective, affective feelings experienced autonomously (J. Panksepp, 2011),
42 they also have a strong social dimension (J. B. Panksepp & Lahvis, 2011; Špinka, 2012; Van Kleef,

43 2009; Van Kleef, De Dreu, & Manstead, 2010). The social dimension of emotions resides in the fact
44 that emotions are expressed in cues and signals (for instance, in vocalisations) that are readily
45 perceived by conspecifics and can also be discriminated by heterospecific individuals. In comparison
46 to the now extensive body of research investigating the physiological correlates of emotional states
47 in various vertebrate species, the social dimension of animal emotions has been less intensely
48 studied (Špinka, 2012). Specifically, there are few studies addressing the human decoding of
49 emotional content from animal-emitted vocalisations (Belin et al., 2008; Faragó et al., 2014). Human
50 perception of animal emotions is important as this can help in assessing animal welfare (Dawkins,
51 2008; Mendl, Burman, & Paul, 2010; J. Panksepp, 2011) and enable more effective interactions
52 between humans and animals (Hemsworth, Coleman, Barnett, & Borg, 2000).

53 Besides the more traditional concept of identifying discrete basic emotions (Ekman, 1992; J.
54 Panksepp, 2005; J. Panksepp & Panksepp, 2013; Sauter, Eisner, Ekman, & Scott, 2010), one of the
55 main alternative approaches to the study of emotion uses quantitative dimensions to define emotions
56 (Laukka, Juslin, & Bresin, 2005; Mendl et al., 2010; Russell, 1980; Sauter, Eisner, Ekman, et al., 2010).
57 The dimensional approach has the advantage of providing a framework for the study of a wide range
58 of emotional states and their overt manifestations. Moreover, the dimensional approach is
59 applicable across different taxa and therefore suitable for comparative studies (Mendl et al., 2010).
60 Different emotional dimensions have been identified: valence (the degree of pleasure/displeasure),
61 arousal (activation, degree of excitation), intensity (how strong is the emotion) and potency (coping
62 potential) (Laukka et al., 2005). In some cases, using all of these dimensions may be redundant, as,
63 for instance, perception of arousal and intensity in human verbal expressions have been found to be
64 highly correlated (Laukka et al., 2005) and hence interchangeable for listeners. Combination of
65 valence dimension and one of the two, either arousal or intensity dimension, can describe most of
66 the emotions for listeners. We accept the assumption that emotional intensity is expressed in higher
67 level of activity of an animal and hence is interchangeable with arousal. In our study, we will

68 henceforth use the terms *emotional valence* and *emotional intensity*. We will however continue use
69 the term "arousal" when referring to previous studies that utilized this term.

70 The dimensional approach has been used to study how emotions are expressed in animal and
71 human vocalisations (Briefer, 2012; Gogoleva, Volodin, Volodina, Kharlamova, & Trut, 2010;
72 Scheiner, Hammerschmidt, Jurgens, & Zwirner, 2002). Both emotional intensity (arousal) and
73 emotional valence were found to correlate with temporal and spectral call features. For example, in
74 young piglets (*Sus scrofa*), the more negative the situation is, the longer is the duration of the
75 emitted calls (Tallet et al., 2013). Vocalizations of squirrel monkeys (*Saimirisciureus*), change in
76 response to increasingly aversive stimuli by shifting the frequency spectrum higher (peak frequency,
77 distribution of frequency amplitudes) and by increasing frequency range, whilst decreasing in tonality
78 (Fichtel, Hammerschmidt, & Jurgens, 2001; Jürgens, 1979). Transition to higher frequencies (F0, peak
79 frequency, frequency spectrum) and louder expression in human speech also characterize increased
80 arousal (either negative or positive) (reviewed in Bachorowski & Owren, 2008). Correspondingly,
81 human listeners can use the variation in the acoustic qualities of vocalisations to infer emotional
82 context in which various types of human verbal and nonverbal vocalisations were emitted
83 (Hammerschmidt & Jurgens, 2007; Sauter, Eisner, Calder, & Scott, 2010; Soltis, 2004). Listeners are
84 also capable of discriminating above chance levels between basic emotionally-loaded situations (such
85 as pain, fear, feeding and social contact) from recorded calls of mammalian species such as domestic
86 dogs *Canis lupus familiaris*, cats *Felis catus*, and pigs (Nicastro & Owren, 2003; Pongrácz, Molnár, &
87 Miklósi, 2006; Tallet, Špinka, Maruščáková, & Šimeček, 2010). Spectral and temporal cues
88 considerably influence the human perception of emotional content in auditory stimuli (reviewed in:
89 Bachorowski & Owren, 2008; Scherer, 2003), and the cognitive mechanisms involved in processing
90 human and animal affective vocalisations may have a similar basis. Using fMRI scans, Belin et al.
91 (2008) detected significant common activation of ventro-lateral-orbital-frontal cortex when people
92 listened to affectively valenced vocalizations of cats, rhesus monkeys and human non-verbal
93 vocalizations. Direct comparison of how people assess emotional content in conspecific and

94 heterospecific vocalizations suggests that humans might use similar assessment rules within and
95 across species (Faragó et al., 2014). If so, this would resonate with theories of shared emotional
96 systems across mammalian species, first postulated by Darwin in his theory of common emotional
97 expressions across mammals (Darwin, 1872), and later described in Morton's structural-acoustic
98 rules (August & Anderson, 1987; Briefer, 2012; Morton, 1977).

99 Besides attributing emotional dimensions in animal vocalisations, humans have also been
100 shown to have some ability to identify the context in which heterospecific calls are emitted. For
101 example, Pongrácz, Molnár, Miklósi, and Csányi (2005) found that humans were able to assign dog
102 barks to the correct situation (out of six possible situations that varied in emotional valence) in more
103 than twice as many cases as would be predicted by chance, and that this ability was probably
104 influenced by the tonality, pitch and inter-bark time intervals – with the pitch of the sound being the
105 most influencing factor. In a study where cats' meows were played to humans, Nicastro and Owren
106 (2003) found that human listeners could infer the context of cat meows and that this ability
107 increased with their experience of cats. In a study by Tallet et al. (2010), the successful identification
108 of context from playbacks of piglet vocalizations exceeded chance for all four of the presented
109 situations, even in naïve listeners with minimal experience with pigs. However, it is not known
110 whether this classification ability is guided by the perceived emotional dimensions in the call.

111 In our previous study (Tallet et al., 2010), we found that listeners' experience with pigs and
112 listeners' gender could both affect the classification of the calls. The question arises whether
113 individual psychological variables such as empathic abilities, attitudes towards animals or general
114 personality dimensions can affect the decoding of animal sounds by human listeners. In human
115 psychology, the understanding of emotional content of another human's nonverbal signals depends
116 to some degree on empathy (Dziobek et al., 2008) as well as other factors such as emotional stability
117 (Guarino, Roger, & Olason, 2007). In human studies, distinction is often made between cognitive
118 empathy and emotional empathy (Cohen & Strayer, 1996; Lawrence, Shaw, Baker, Baron-Cohen, &

119 David, 2004; Mehrabian & Epstein, 1972; J. Panksepp & Panksepp, 2013), the former being defined
120 as the capacity of individuals to take the perspective of others and the latter as the emotional
121 response to the emotional state of another person. We hypothesise that higher cognitive empathy
122 might enable humans to more precisely judge the situational context in which the call was emitted,
123 while the higher emotional empathy might shift the valence and intensity judgments towards more
124 extreme values.

125 Another psychological factor which can affect human decoding of animal vocalisations is
126 their attitude towards animals (Armstrong & Hutchins, 1996). Attitudes towards animals are
127 influenced by factors such as upbringing (urban vs. rural), religious affiliation, type of education,
128 gender, sex-roles, some personality traits (Driscoll, 1992; Furnham, McManus, & Scott, 2003) and
129 even empathy levels (Taylor & Signal, 2005). However, all these factors account for only a small part
130 of the inter-individual variability in attitude towards animals and, therefore, it is of interest to
131 examine this trait on its own. Attitude towards animals affects how people treat animals (Breuer,
132 Hemsworth, Barnett, Matthews, & Coleman, 2000; Coleman, Hemsworth, Hay, & Cox, 2000). Also,
133 empathetic farmers with a positive attitude to animals have more healthy animals (Kielland, Skjerve,
134 Osteras, & Zanella, 2010). However, it is unknown whether attitudes towards animals can influence
135 how people perceive cues emitted by animals.

136 The aim of this study was to investigate how human assessments of pig vocalisations are
137 affected by acoustic qualities of the calls and by the human listeners' psychological properties.
138 Specifically, four hypotheses were tested (Fig. 1): H1) Acoustic properties of the particular vocal
139 stimulus affect the perceived emotional intensity and valence. Specifically, recordings with longer
140 and higher and less harmonic calls will be judged as more negative and / or more intense. H2)
141 Psychological attributes of the listener influence the perceived emotional intensity and valence. In
142 particular, people with high emotional empathy, people scoring high on neuroticism and people with
143 positive attitudes towards animals will rates the emotional intensity higher. H3) The perceived

144 emotional intensity and valence of a particular vocal stimulus affect the correct identification of the
145 situation. Specifically, recordings perceived as more intense will be more easy to assign to the correct
146 situation. H4) Psychological attributes of the listener affect the accuracy of identifying situations from
147 the vocalisations. In particular, we expected listeners with higher cognitive empathy and those with
148 more positive attitudes towards animals to identify the situations more accurately.

149 **Materials and methods**

150 *Participants*

151 A sample of 60 listeners aged 21 – 29 years and balanced in gender (30 women, 30 men) was
152 examined. The listeners were undergraduate and graduate students of humanities recruited during
153 the courses and during the breaks between lectures at Charles University in Prague. A reward of 100
154 Czech koruna (about € 4) was promised before and paid after the questionnaire was filled.

155 *Procedure*

156 The testing proceeded through a set of four electronic questionnaires run from notebooks owned by
157 the researchers in a university room. The computers were not connected to internet during the
158 testing.

159 *Vocalisation decoding questionnaire*

160 This questionnaire used 48 recordings (12 per 4 situations) of piglet vocalisations. This set of acoustic
161 stimuli was identical to those used in our previous study (see Tallet et al., 2010 for recording
162 description). The recordings had been obtained in two positive situations – at the end of a nursing
163 bout and during reunion with the mother after a period of separation – and in two negative
164 situations – during castration and during isolation from the mother and the littermates. More
165 precisely, "nursing" vocalizations were emitted by a piglet near the head of the sow just after the
166 milk intake phase of the nursing. "Reunion" vocalisations were emitted by a piglet immediately at the

167 reunion of the piglet and its dam, after 30s of separation. "Castration" vocalizations were emitted
168 during the cutting of the spermatic cords. Finally, "isolation" vocalizations were emitted between the
169 8th and 9th minute of isolation from litter and dam.

170 Each of the 48 recordings was obtained from a different piglet. Experimental stimuli were
171 constructed from the recordings by selecting a representative high quality sequence from each
172 recording. Our choice was based on the quality of the recordings, avoiding single calls, background
173 noise and vocalizations of other animals. We standardized the length and amplitude of the stimuli.
174 Each stimulus lasted mean \pm SD = 2.36 \pm 0.49 seconds, and consisted of mean \pm SD = 5.6 \pm 2.6
175 individual calls. The length of the stimuli did not differ between the 4 situations, ANOVA: $F_{3,44} = 0.13$,
176 $p = 0.939$). When presented to listeners, these sequences were played back twice with a 0.75s silence
177 interval between each presentation. The amplitudes of the stimuli were also standardized before
178 testing. The peak amplitude of each stimulus was standardised for all recordings using the
179 'Normalize' function of Avisoft-SASLabPro (R. Specht, Berlin).

180 The questionnaire consisted of three subsections. In the first part, listeners were asked about
181 their personal data including their gender, age and experience with pigs. In the second part, each
182 listener was required to evaluate the emotional intensity of 12 different recordings (3 per situation),
183 and the emotional valence of 12 different recordings (3 per situation), using 5-point Likert scale. Only
184 at the start of the third part were the listeners informed about the four situations, and they were
185 then asked to judge, for yet another new 12 stimuli (3 per situation), in which of the four situations
186 each of them was recorded. A software module was included in the questionnaire that assigned the
187 recordings to the listeners. For the first listener, three unique sets of 12 recordings were randomly
188 selected for judgement on intensity, valence and situation, respectively, using the rule that none of
189 the recordings were used twice for the same listener. For the following listeners, the same procedure
190 was applied, however the selection was made only from those recordings that had not yet been
191 assessed for that particular purpose. By the fourth listener, all the recordings were evaluated for all

192 three purposes, and the cycle began anew. Thus, each recording was evaluated by 15 listeners for
193 intensity, by another 15 listeners for valence and yet another 15 listeners for situation.

194

195 *Acoustic analysis of stimuli*

196 The calls within a single stimulus could be of very similar or very different quality (i.e. several call
197 types might be presented, Fig 2). Acoustic analyses were carried out in Avisoft SASLab Pro (Raimund
198 Specht, Berlin) and PRAAT version 5.3.02 (Boersma & Weenink, 2013). Three basic temporal
199 parameters were used in the analyses, namely, the amount of vocalised sound within each stimulus
200 (labelled as "proportion vocalized", calculated as the summed duration of all calls within the stimulus
201 divided by the stimulus duration), the average call duration for each stimulus and average inter-call
202 interval (from the end of the call to the beginning of the following call). Call onsets and offsets were
203 identified by visual inspection of call spectrograms and amplitude envelopes in AvisoftSASLab Pro.
204 Calls had clear onsets and offsets, resulting in their reliable identification. The number of calls and
205 sum of call durations per recording were highly correlated between two independent observers:
206 Pearson's $r = 0.93$ for number of calls and 0.95 for sum of call durations. Mean fundamental
207 frequency (F0; labelled as "pitch") for each call was detected by the PRAAT 'To Pitch' command with
208 following settings: window length = 0.01 – 0.05; voicing threshold = 0.15; silence threshold = 0.03;
209 pitch range for F0 = 30 – 6000Hz. Window length and pitch range for F0 were set up for each call
210 separately based upon likely range of the pitch of the call determined by measuring the periods and
211 calculating the multiplicative inverse to obtain the frequency ($F=1/T$). Final settings were adjusted for
212 each particular call based on the comparison of detected pitch trace at the spectrogram. Finally,
213 three parameters characterizing the tonal quality of calls were also measured: jitter, harmonic-to-
214 noise ratio, and presence / absence of subharmonics. Jitter, which measures cycle-to-cycle variability
215 in F0 across the call, was calculated by averaging three measurement values of jitter: local, relative
216 average perturbation, and 5-point period perturbation quotients (Charlton et al., 2011). The

217 harmonic-to-noise ratio was obtained from the 'voice report' function, which uses an automatic
218 cross-correlation algorithm to detect acoustic periodicity in voiced sections of the call (detailed in
219 Boersma, 1993). The presence or absence of subharmonics was judged based on visual inspection of
220 the spectrograms (by VFR). To check reliability of subharmonics identification, the presence of
221 subharmonics was assessed independently by a second person and the agreement was compared
222 using Cohen's kappa coefficient which revealed 'substantial agreement' between observers (kappa =
223 0.67). The call parameters were averaged within each stimulus.

224 *Personality test*

225 The Czech version of NEO-FFI personality inventory (Hřebíčková & Čermák, 1996) was used to assess
226 the personality profiles of listeners. This test is based on the concept of the "Big Five" personality
227 factors (Neuroticism, Extraversion, Openness to Experience, Agreeableness, Conscientiousness). The
228 concept of the Big Five is considered a universal personality structure across human cultures (De
229 Raad et al., 2010; McCrae & Costa, 1997). The NEO-FFI is the shortened version (60 statements) of
230 the larger NEO-PI-R inventory (McCrae & Costa, 1997). Within the normal population, the five factor
231 scores appear to be internally consistent, stable and valid. Administration and assessment was done
232 on the HTS - Hogrefe Test System 4.0 system (Hogrefe – Testcentrum, s.r.o., Prague, Czech Republic),
233 used for psychology testing worldwide, in Czech language. The raw scores of each factor of every
234 listener were used for the analysis.

235 *Empathy test*

236 The Interpersonal Reactivity Index (IRI) test was chosen to measure the situational empathy of
237 listeners (Davis, 1994). The IRI consists of 28 questions divided equally among four subscales. For the
238 purposes of our study, we used two subscales for the final analysis. Perspective Taking, described as
239 the tendency to spontaneously adopt the psychological view of others in everyday life, was taken as
240 a measure of cognitive empathy and Empathic Concern, defined by the author as the tendency to
241 experience feelings of sympathy or compassion for unfortunate others, was used as a measure of

242 emotional empathy (Davis, 1983). We hypothesized that the former may affect more strongly the
243 situational judgement of piglets' calls whereas the latter may influence to the valence and/or
244 intensity judgments. The raw score for the two subscales, as well as the total raw score, was used for
245 the statistical analysis.

246 *Attitudes towards animals:*

247 For quantification of attitudes towards animals, we administered the AAS – the Animal Attitudes
248 Scale (Herzog, Betchart, & Pittman, 1991; Signal & Taylor, 2007; Taylor & Signal, 2005). The scale
249 assesses individual differences in listeners' attitudes towards the treatment of animals in various
250 areas. It contains 20 items and has a high internal consistency. Again, the total raw score of each
251 listener was used for statistical analysis.

252 *Statistical analysis*

253 The effects of the acoustic and psychological variables on the perceived emotional intensity and
254 valence (Hypotheses H1 and H2) were tested through stepwise multiple linear regression mixed
255 models. We started with a full model containing the following predictors: 7 acoustic variables
256 (proportion vocalized, inter-call interval, call duration, mean pitch, mean jitter, harmonic-to-noise
257 ratio, subharmonics) and 10 psychological variables (Neuroticism, Extraversion, Openness to
258 Experience, Agreeableness, Conscientiousness, IRI total score, IRI empathetic concern score, IRI
259 perspective taking score, AAS Attitude towards animals score and gender of the listener). The
260 scatterplots did not indicate non-linear effects and therefore we did not include quadratic terms in
261 the full model. The random factors of vocal stimulus identity and the listener identity were included
262 in the model. Using the backward selection model on a randomly selected half of the dataset, we
263 gradually reduced the model by removing the least significant predictor until all the remaining
264 predictors were significant at the $p < 0.05$ level. Utilizing the hold-out method of cross-validation, the
265 second half of the dataset was then used for assessment of the p values of predictors contained in
266 the final model. Simple correlations between average intensity and valence ratings for each stimulus

267 and acoustic variables were also calculated to help the interpretation of the model results. Since
268 castration calls were quite different from the vocalisations in the other three situations, this process
269 was accomplished first for all four situations and then for the three situations excluding castration.

270 Next we assessed which predictors affected the correct identification of the context from the
271 heard playbacks. First we tested whether the probability of the correct identification depended on
272 the perceived intensity and valence of the particular vocal stimulus (Hypothesis H3). The dependent
273 variable was the proportion of correct context identifications for the particular stimulus. Second, we
274 investigated the influence of the psychological variables on correct identification (Hypothesis H4). A
275 backward stepwise model reduction procedure was applied similarly as in tests for Hypotheses H1
276 and H2. The models were generalised linear models with binary distributions. The full model
277 contained situation, the 9 psychological variables and gender and was iteratively reduced by
278 omission of the least significant factor until all remaining factors were significant at $p < 0.05$. The final
279 model was constructed using a randomly selected half of the observations and the second half was
280 used for significance testing of the variables in the final model. The effect sizes were estimated using
281 Cohen's f^2 according to Selya, Rose, Dierker, Hedeker, and Mermelstein (2012).

282 **Results**

283 *The effect of vocalisations' acoustic properties on intensity and valence judgements (Hypothesis 1)*

284 For the emotional intensity judgements, the final model contained two significant acoustic variables.
285 The perceived intensity increased with increasing pitch of the vocal stimulus ($F_{1,266} = 38.00$, $p <$
286 0.0001 , Fig 3A) and with increasing proportion vocalized in the stimulus ($F_{1,266} = 11.46$, $p < 0.001$, Fig
287 3B). Cohen's f^2 for the global effect of fixed variables in the final model was 0.11, indicating that the
288 two acoustic variables together had a medium effect on perceived intensity. When castration
289 recordings were omitted from the data set, the pitch ceased to be significantly related to judged

290 intensity (Fig 3A), but proportion vocalized was still positively affecting the perceived intensity (Fig
291 3B, $F_{1,176} = 3.90$, $p < 0.05$). Nevertheless, the effect was small ($f^2=0.01$).

292 For valence judgements, the final model consisted of two predictor variables. The perceived
293 valence decreased, i.e. changed to more negative with increasing pitch of the stimulus($F_{1,240} = 41.23$,
294 $p < 0.0001$, Fig 3C) and with increasing duration of the calls ($F_{1,240} = 21.87$, $p < 0.0001$, Fig 3D). The
295 effect of the two acoustic variables on perceived valence was large ($f^2=0.37$). The same predictor
296 variables were significant and had medium effect ($f^2=0.17$) also for the reduced data set from which
297 the castration stimuli were omitted (pitch effect $F_{1,155} = 4.65$, $p < 0.05$, Fig 3C; call duration effect $F_{1,155}$
298 $= 35.38$, $p < 0.0001$, Fig 3D).

299 Overall, results of multiple regression were in agreement with the results of the simple
300 correlations (Table 1), with few exceptions: the duration and proportion vocalized were both
301 associated with intensity and valence judgements, which mirrored strong association between these
302 two acoustic variables. Further, presence of subharmonics was associated with both intensity and
303 valence judgements. In the reduced dataset without castration calls, harmonic-to-noise ratio and call
304 interval were associated with valence. On the other hand, none of the acoustic variables were
305 significantly correlated to intensity in the reduced dataset but proportion vocalized showed the
306 strongest association with intensity among acoustic variables, followed by call duration and call pitch.

307

308 *The effect of psychological variables on intensity and valence judgements (Hypothesis 2)*

309 The final models contained no significant effect of any of the psychological variables on either the
310 perceived intensity or valence ($p > 0.05$). The listeners' gender also did not exert a significant effect
311 on either the perceived intensity or the valence ($p > 0.05$).

312

313 *The effect of perceived intensity and valence on the correct identification of context (Hypothesis 3)*

314 An interaction between type of situation and perceived intensity affected the proportion of stimuli
315 that were assigned correctly to the situation (Fig 4, $F_{3,36} = 8.58$, $p < 0.001$). The effect size of this factor
316 was very large (local $f^2 = 1.06$). Specifically, the probability that a particular castration stimulus would
317 be correctly assigned to the castration situation increased with the perceived intensity of that
318 stimulus ($t = 2.67$, $p < 0.05$). Similarly, for the reunion vocal stimuli, correct identification of context
319 increased with perceived intensity ($t = 2.90$, $p < 0.01$). The opposite was true for nursing vocal
320 stimuli, where less intensively perceived vocal stimuli were more often correctly classified ($t = -3.07$,
321 $p < 0.01$). Neither the estimated valence nor the situation*valence interaction affected the accuracy of
322 context identification ($p > 0.05$).

323

324 *The effect of psychological variables on the correct identification of context (Hypothesis 4)*

325 The final model contained none of the psychological attributes, nor the gender of the responder,
326 showing that these personal variables had no significant effect on the success rate of the individual
327 listeners in context identification ($p > 0.05$).

328 *Relationship between intensity and valence; differences between contexts*

329 The correlation between the mean judged intensity and valence was high ($r = -0.86$, $p < 0.0001$, $N =$
330 48 , Table 1). Without the castration stimuli, the relationship between intensity and valence became
331 much weaker ($r = -0.39$, $p < 0.05$, $N = 36$). Castration stimuli had much higher judged intensity than
332 any of the remaining three situations (ANOVA followed by paired t-tests, $p < 0.0001$). Castration calls
333 were also judged as more negative (of lower valence) than the other three situations (ANOVA
334 followed by paired t-tests, $p < 0.05$) while isolation was perceived as more negative than reunion and
335 nursing ($p < 0.05$).

336 Discussion

337 Effect of acoustic characteristics on perception of stimuli

338 Our study indicates that listeners rated the intensity and valence of the stimuli based on very simple
339 acoustic criteria. Judgments were affected by the mean pitch of the stimuli and two macroscopic
340 temporal features of stimuli, namely the proportion of sound within stimulus and the duration of
341 calls. The more complex acoustic variables (jitter, harmonics-to-noise ratio, subharmonics) seemed to
342 be much less, if at all, important for listeners' judgments. While none of these variables were
343 retained in the multiple regression models, simple correlations indicated that listeners may have
344 used the presence of subharmonics to detect the higher emotional intensity and lower emotional
345 valence in castration calls (the subharmonics variable was dropped from the multiple regression
346 model because it was highly correlated with other time- and pitch-related variables. Also, harmonic-
347 to-noise ratio showed a simple correlation with valence and therefore, listeners could have used it
348 for ratings despite the fact that it was not a significant predictor of valence ratings in final model.

349 It is worth noting that each of our stimuli consisted of several calls. Some of the stimuli
350 contained calls that were quite similar to each other (e.g., the reunion example in Fig. 2A) while
351 others consisted of calls that differed substantially in quality, e.g. in duration, pitch and frequency
352 modulation (the isolation example in Fig. 2D). This reflects the natural variation in the piglet vocal
353 repertoire, where in some situations, calls of one predominant type are used while in other
354 situations, a rich mixture of call types are emitted (Tallet et al., 2013). It is unknown whether humans
355 are affected in their judgment of vocalizations by this uniformity-versus-diversity dimension. Our
356 results indicate that simple average acoustic properties that do not take account of the variability of
357 call types within a stimulus may be used by humans to judge the emotional content of juvenile
358 mammal vocalizations.

359 **Stimuli features and intensity rating**

360 We found that the perceived emotional intensity increased with an increasing proportion of vocal
361 sound ("proportion vocalized"). Proportion vocalized may involve both longer call durations and
362 shorter inter-call intervals. Both of these two components were also associated with emotional
363 intensity, according to the simple correlations. Due to the correlative nature of our study, it is
364 impossible to determine which of the time variables were truly used by listeners to judge the
365 emotional content. Nevertheless, temporal variables clearly are potential cues for emotional
366 judgements. This is in agreement with Laukka et al. (2005) who found that pause proportion (silence
367 between syllables and words within a phrase) decreased with perceived increasing intensity. They
368 further report decreasing speech rate with increasing intensity, suggesting that longer syllable
369 durations during speech might indicate increased emotional intensity. On the other hand, in striking
370 contrast to the strongly positive relationship in our study, the duration of non-verbal sounds in
371 humans was reported to be negatively correlated (longer utterances = lower intensity) with perceived
372 intensity (Sauter, Eisner, Calder, et al., 2010) and duration of dog calls was found to be negatively
373 associated to human-perceived emotional intensity (Faragó et al., 2014).

374 Pitch was related to perceived emotional intensity in our data but only in the full dataset. In
375 previous studies, too, the perceived emotional intensity has been found to correlate positively with
376 pitch (fundamental frequency, energy distribution) both for verbal (Laukka et al., 2005) as well as for
377 non-verbal (Sauter, Eisner, Calder, et al., 2010) human utterances. Also, dog calls of higher
378 fundamental frequency were perceived as more intensive in the study of Faragó et al. (2014) and the
379 solicitation purrs of cats that have conspicuous high frequency components were perceived as more
380 urgent, i.e. as having higher intensity, than non-solicitation purrs (McComb, Taylor, Wilson, &
381 Charlton, 2009). However, after castration calls were removed from our dataset, there was no
382 relation between pitch and intensity. The reason for that may be that the very stark contrast in pitch
383 between the castration and non-castration calls over shadowed the more subtle differences in pitch
384 among the stimuli from the other three situations. One way to test this assumption would be a

385 similar study in which the listeners are not exposed at all to the high pitched, high intensity playback
386 stimuli.

387 Vocal production (encoding) studies, i.e. investigations that relate the acoustic quality of
388 vocalizations to objective differences in the arousal of animals, are also in agreement with our
389 decoding results. In her review, Briefer (2012) documents that the majority of studies have found
390 increased call durations and decreased inter-call intervals (leading to larger vocalization proportions
391 within a sample) in situations with higher emotional intensity. Also, the pitch of calls invariably
392 increased with emotional intensity (Briefer, 2012).

393 **Stimuli features and valence rating**

394 Calls of shorter duration were perceived as more positive in our study. This is consistent with the
395 decoding studies of Faragó et al. (2014) on dog calls. Also, in their study on human speech, Laukka et
396 al. (2005) reported that perceived valence increases with speech rate, suggesting that the duration of
397 syllables/words decreased with increasing valence (the pause proportion did not decrease with
398 valence). However, the duration of human non-verbal sounds did not correlate with the perceived
399 valence in the study of Sauter, Eisner, Calder, et al. (2010). Also, humans seemingly ignored growl
400 duration when attempting to distinguish between play and aggression in dog vocalizations, and used
401 vocalization rate as a cue instead (McComb et al., 2009). Published studies on valence encoding
402 confirm the relationship between increased emotional valence and shorter call duration in some
403 non-human species, such as dogs (McComb et al., 2009), but not in others (see Briefer, 2012 for
404 review; e.g. african elephants *Loxodonta africana*: Soltis, Blowers, & Savage, 2011). In piglets, the
405 average call duration has been found to correlate negatively with emotional valence across 11
406 different situations (Tallet et al., 2013). In contrast, Weary, Braithwaite, and Fraser (1998) did not
407 find any difference in the call durations of castrated and sham-castrated piglets, which may be due to
408 the fact that both situations were near to the very negative end of the valence spectrum. In human
409 infants, both elongation of cries (Scheiner et al., 2002) and shortening of cries (Porter, Miller, &

410 Marshall, 1986) have been reported as responses to negative situations and their varying intensity.
411 This might indicate a non-linear relationship between valence and call duration with calls from
412 positive and very negative situations being shorter than calls from mildly negative situations.
413 However, we found no indication of non-linear relationships in the scatterplots of our data.
414 Therefore, we did not test for quadratic effects because our full models anyway started with a
415 numerous set of explanatory variables.

416 We further found that higher pitch piglet vocalizations were judged as more negative. During
417 decoding of human vocalizations, higher pitched verbal and non-verbal utterances were also
418 assigned more negative valence ratings (Laukka et al., 2005; Sauter, Eisner, Calder, et al., 2010).
419 Humans also associated higher pitched animal calls with negative emotions in several previous
420 studies. Higher pitched solicitation purrs of cats are rated as less pleasant (McComb et al., 2009).
421 Furthermore, human listeners associated high pitched dog barks with emotions such as despair and
422 fear (Pongrácz et al., 2006); high pitch was also a common attribute of macaque calls assigned to
423 anger and fear contexts by listeners (Leinonen, Linnankoski, Laakso, & Aulanko, 1991). On the other
424 hand, no relationship was found between human-perceived valence and fundamental frequency in
425 dog calls (Faragó et al., 2014).

426 Emotion encoding studies across many species found shifts to higher frequencies in
427 vocalizations emitted in negatively loaded situations (squirrel monkeys: Fichtel et al., 2001; humans:
428 Porter et al., 1986; Scheiner et al., 2002; African elephants: Soltis et al., 2011). Piglets also use more
429 vocalizations of higher pitch in more negative situations (Tallet et al., 2013). Nevertheless, examples
430 in different species exist as well when calls associated with positive states have higher pitch (Briefer,
431 2012; Brudzynski, 2007; Millot & Brand, 2001).

432 **Situation recognition through perceived intensity**

433 Our results match previous evidence for cross-species understanding of vocalization contexts and
434 specifically for the human ability to recognize the contexts in which vocalizations are emitted by

435 other species (Leinonen et al., 1991; Pongrácz et al., 2005; Tallet et al., 2010). Our novel findings
436 indicate that situational recognition may be mediated by the perceived intensity of emotion. It is not
437 surprising that the most intensive castration calls were the most successfully recognized. Less
438 intuitively, reunion vocalizations were also more correctly identified if they were perceived as more
439 intense and the opposite pattern (easier recognition of less intense stimuli) was found in nursing
440 vocalizations. One potential mechanism by which perceived call intensity might be used to identify
441 context is that listeners have a preconception of the emotional impact / intensity of the different
442 situations. For example, they may assume that castration, as a situation including strong pain, and
443 also reunion as a situation involving active greeting are relatively high intensity events whilst nursing,
444 presumable experienced as contentment, is a low intensity event. These preconceptions may
445 originate from their personal experience with similar situations, including social situations with other
446 humans. Similar mechanisms may be at work when human adults decode vocalizations of preverbal
447 children (Zeifman, 2001; Lindová et al. in prep.).

448 The listeners had little experience with live pigs. Therefore, their recognition of the situation
449 was most likely based on some general judgement procedure rather than on specific knowledge
450 about the species. Together with our finding that intensity is estimated through simple acoustic cues,
451 our results point to the possibility that humans apply simple algorithms when they estimate
452 situations from vocalizations in a species they are not well acquainted with.

453

454 **Castration vocalizations different from other situations**

455 The vocalizations emitted during castration were very different from the three other situations, both
456 in their objective acoustic properties and in the intensity and valence values assigned by the
457 listeners. The results based on full dataset were different from results based on three situations after
458 the exclusion of castration. Castration calls were perceived as very intensive and very negative, with
459 little overlap with other situations. Therefore it seems that the main information decoded from piglet

460 vocalisations is whether the piglet is in pain and therefore whether there is a need for urgent action.
461 The very intensive and very negative values of castration calls created a strong correlation between
462 the intensity and valence values across the whole dataset. When the castration stimuli were
463 excluded, the relationship became much weaker. Thus when the most urgent situation is excluded,
464 valence and intensity became perceived as separate characteristics of vocal stimuli. In this restricted
465 dataset, valence judgements were much better explained by acoustic properties than intensity
466 judgements. Taken together, these results indicate a two-layer system of encoding and decoding of
467 emotions from vocal stimuli. The first layer is a quick-and-rough identification of the most urgent
468 very negative calls that should incite immediate action without delaying deliberation. This notion
469 corresponds to the fact that sows' reactions to these most urgent calls are rather unspecific, for
470 example, sows react readily to calls of alien piglets (Held, Mason, & Mendl, 2007; Spinka et al., 2000).
471 The second layer is a finer (and less precise) distinction between not-so-urgent calls arising from
472 other situations.

473 **Lack of effect of psychological attributes on listeners' judgements about pig** 474 **vocalizations**

475 The ability of humans to recognize the context of vocalizations emitted by other animals is
476 apparently present from an early age (Linnankoski, Laakso, Aulanko, & Leinonen, 1994; Pongrácz,
477 Molnár, Doka, & Miklósi, 2011) but can be to some extent improved by experience (Linnankoski et
478 al., 1994; Tallet et al., 2010). Our listeners had very limited experience with pigs and we hypothesized
479 that in "naïve" humans, other psychological differences between individuals might influence their
480 assessment of emotions in the piglet voices and/or their ability to discern the situation from the calls.
481 However, neither the emotional empathy nor the cognitive empathy nor the attitudes toward
482 animals had any effect on the judgements. This was not due to the masking effect of the very
483 negative castration calls as no effect was found in the dataset after the exclusion of the castration
484 vocalisations. As this is the first study investigating this connection, the results need to be checked

485 with further investigations, perhaps using a more detailed, less verbally based empathy tests, such as
486 the Multifaceted Empathy Test (Dziobek et al., 2008).

487 To summarize, we provide the evidence that human decoding of the emotional content of
488 animal vocalisation may be based on very simple acoustic criteria. Also, recognition of the situation
489 of the calling animal could be based on the perceived emotional intensity of the calls. Surprisingly,
490 listeners' psychological profiles neither significantly affected the emotional intensity and valence
491 decoding nor it affected accuracy of contexts recognition.

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497

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650 **Tables**

651 Table 1

652 *Simple correlations between emotional intensity, valence and acoustic variables*

variable	1	2	3	4	5	6	7	8	9
1. intensity	-	-0.39*	0.32	0.24	-0.08	0.22	-0.06	0.07	-0.05
2. valence	-0.86***	-	-0.32	-0.70***	-0.33*	-0.44**	0.22	-0.40*	-0.10
3. vocprop ¹	0.70***	-0.71***	-	0.56***	-0.34*	-0.14	0.00	-0.03	0.08
4. duration	0.70***	-0.79***	0.72***	-	0.30	0.16	-0.27	0.42*	0.21
5. callint ²	-0.14	-0.04	-0.32*	0.16	-	0.25	-0.10	0.27	0.16
6. pitch	0.81***	-0.87***	0.58***	0.63***	-0.08	-	-0.08	0.64***	0.15
7. jitter	0.00	0.08	0.03	-0.03	-0.07	-0.03	-	-0.37*	0.11
8. HNR ³	0.01	-0.16	-0.05	0.11	0.21	0.25	-0.41**	-	0.17
9. SH ⁴	0.47***	-0.54***	0.44**	0.40**	-0.03	0.62***	0.02	0.16	-

653

654 *Note.* Correlations for dataset excluding castration situation are presented above diagonal (n = 36)

655 and correlations for dataset including castration situation are presented bellow diagonal (n = 48).

656 Pearson's r and point-biserial correlation coefficeints in case of subharmonics are shown.

657 * p < 0.05; ** p < 0.01; *** p < 0.001); ¹ proportion of vocalized sound; ² intercall interval; ³ harmonic-

658 to-noise ratio; ⁴ subharmonics

659

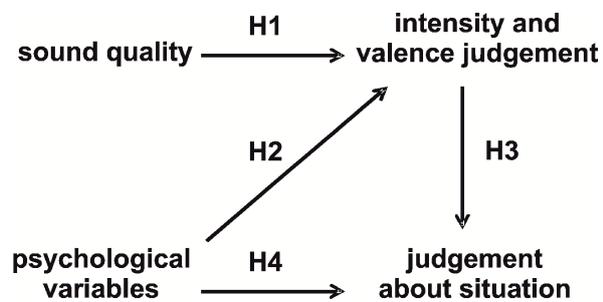
660

661

662 **Figures**

663

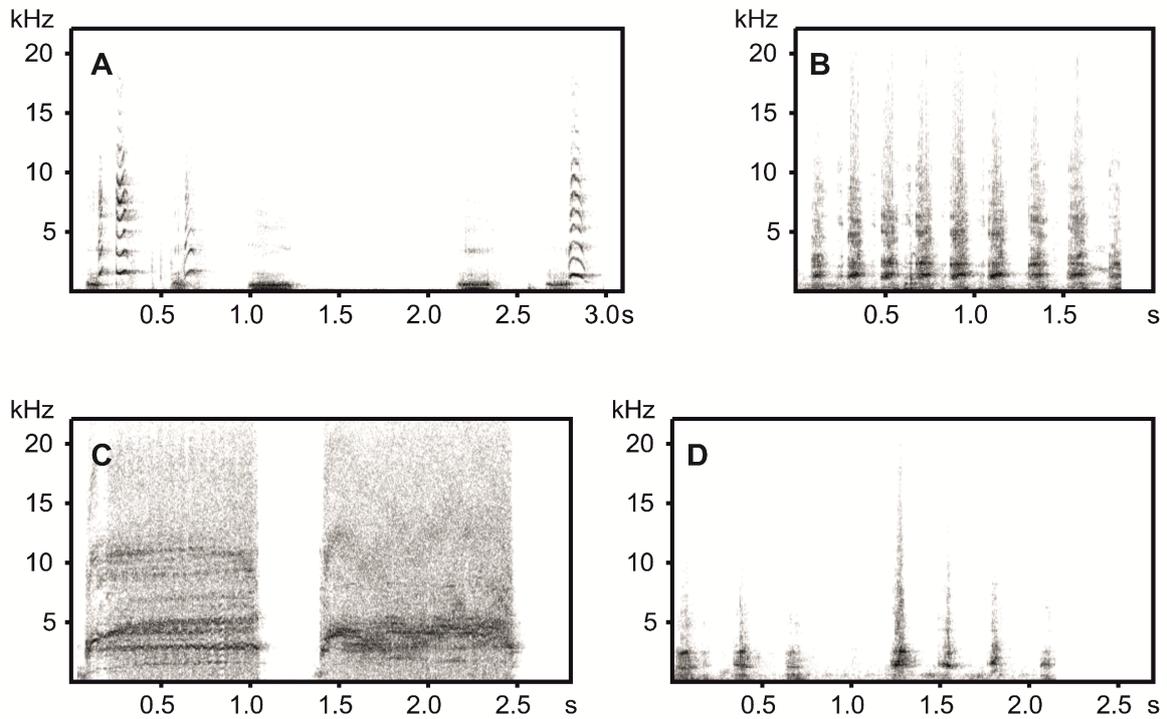
664 *Figure 1.* Hypotheses examined in the study.



665

666

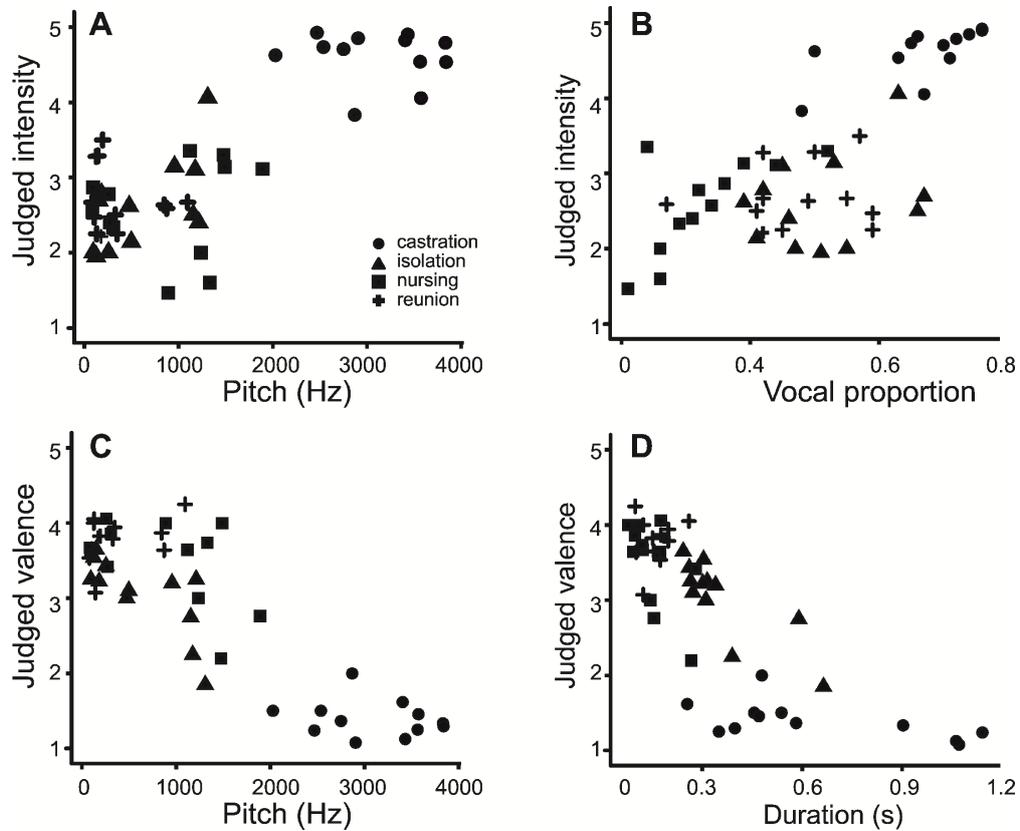
667 *Figure 2. Spectrograms of typical piglets' calls in the 4 situations: isolation (A); reunion with mother*
668 *(B); castration (C); nursing (D).*



669

670

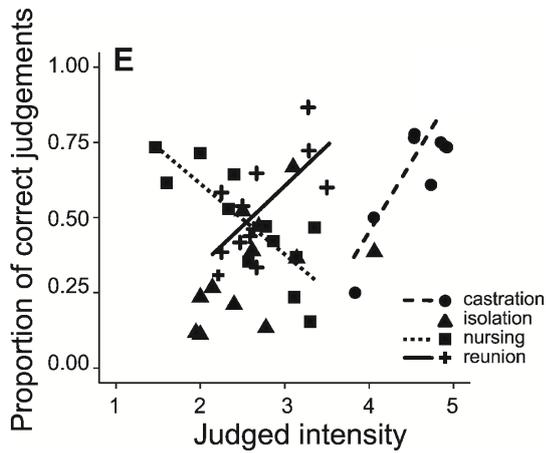
671 *Figure 3.* Influence of the acoustic variables on emotional intensity and valence judgements of calls
672 from the four situations.



673

674

675 Figure 4. Influence of judged emotion intensity on the proportion of correct identifications of the
676 situation. For illustration, linear regression lines are depicted for nursing (dotted line), reunion (full
677 line) and castration (dashed line). There was no significant relationship between proportion of
678 correct judgements and judged emotional intensity for isolation calls.



679

680