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

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Abstract

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

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

Introduction

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

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

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

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

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

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

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

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

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

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

Acoustic analysis of stimuli

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

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

Personality test

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

Empathy test

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

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

Attitudes towards animals:

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

Statistical analysis

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

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

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

Results

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

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

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

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

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

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

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

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 ($p < 0.05$).

Discussion

Effect of acoustic characteristics on perception of stimuli

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

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

Stimuli features and intensity rating

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

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

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

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

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

Situation recognition through perceived intensity

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

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

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

Castration vocalizations different from other situations

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

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

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

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

Table 1

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	-

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

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

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

* p < 0.05; ** p < 0.01; *** p < 0.001); ¹ proportion of vocalized sound; ² intercall interval; ³ harmonic-to-noise ratio; ⁴ subharmonics

Figures

Figure 1. Hypotheses examined in the study.

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.

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680