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1 **Vocal expression of emotional valence in pigs across** 2 **multiple call types and contexts**

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23 Introduction

24 Emotions, unlike mood, are short-lived reactions associated with specific events. They can be characterized
25 by two main dimensions; their arousal (bodily activation) and valence (negative versus positive) (Mendl et al.
26 2010). Knowledge of the valence of emotions experienced by domestic and captive animals is crucial for
27 assessing and improving their welfare, as it enables us to minimize the negative emotions that they might
28 experience and to promote positive ones. Emotions can affect vocalizations directly or indirectly through the
29 brain, lungs, larynx or vocal tract. As a result, vocal expression of emotions has been observed across
30 species (Briefer 2012), and could serve as a non-invasive and potentially very reliable tool to assess animal
31 emotions. In pigs (*Sus scrofa*), vocal expression of emotions has been relatively well studied (e.g. Leliveld et
32 al. 2016; Briefer et al. 2019). However, it is not known if the vocal indicators revealed in previous studies are
33 valid across call types and contexts. To find this out, we conducted an analysis of the effect of emotional
34 valence on a large database of pig vocalizations, including calls recorded in the most common emotional
35 situations encountered by pigs throughout their lives, from birth to slaughter.
36

37 Materials & Methods

38 Recordings

39 Pigs of various ages (piglets to finishing pigs) were recorded in 22 contexts triggering both negative emotions
40 (e.g. crushing, missed nursing, castration, fear conditioning, isolation, restraint, barren environment, and
41 slaughter), and positive emotions (e.g. nursing, huddling, social reunion, exposition to an enriched arena,
42 and running) (for more details see Tallet et al. 2013; Linhart et al. 2015; Leliveld et al. 2016; Leliveld et al.
43 2017; Briefer et al. 2019). The putative valence of the various contexts was based on the function of
44 emotions to trigger avoidance (negative emotions) or approach (positive emotions) and the behavior of the
45 pigs (Mendl et al. 2010). Experiments included in this analysis were approved by the respective authorities
46 for each country (Germany: Federal State of Mecklenburg-Western Pomerania (AZ:7221.3-2-045/13);
47 Switzerland: Swiss Cantonal Veterinary Office (TG02/2014); Czechia: Institutional Animal Care and Use
48 Committee of the Institute of Animal Science and the Czech Central Committee for Protection of Animals,
49 Ministry of Agriculture (dMZe 1244 and 44248/2007–17210); Norway: National animal research authority
50 (FOTS id 12021)).
51

52 Vocal analyses

53 In order to exclude very short sounds, in which parameters might not be accurately measured, only high
54 quality calls with a duration > 0.05 s were selected for the acoustic analysis ($n = 7392$ calls). We used the
55 acoustic features of the calls to classify them as low-frequency stable, modulated or tonal calls, high-
56 frequency stable or modulated calls, or mixed calls (6 types), based on Tallet et al. (2013). Then, depending
57 on the call type, we extracted 11 to 18 vocal parameters using a custom-built script in Praat, which batch-
58 processed the analyses and the exporting of output data. The measured parameters belonged to the six
59 following categories: source-related (fundamental frequency, “F0”), energy spectrum distribution, duration,
60 amplitude modulation (“AM”), noise, filter-related (vocal tract resonances).
61

62 Statistical analyses

63 To eliminate redundancy, we used a principal component analysis to select one vocal parameter within each
64 category, which explained most of the variance in the data across all call types, for further analyses. Since
65 the minimum formant dispersion (“DFmin”), originally categorized along with the linear predictive coding
66 (“LPC”) coefficients never associated (i.e. loaded highly ($r \geq 0.5$) on the same PC) with these parameters,
67 it was analyzed separately. These selected seven parameters (i.e. one for each of the six categories and
68 DFmin; Table 1) were then used as outcome variables in linear mixed-effects models (lmer function in R
69 software), to assess if they were affected by the valence of the contexts (positive or negative; fixed factor).
70 The models included as control factors the age category and the call type. The context of production nested
71 within the identity of the pig, nested within the experiment number, nested within the team who performed the
72 recording was added as a random factor to control for repeated measurements and dependencies. The p-
73 values were calculated with parametric bootstrap tests.
74

75 Results and Discussion

76 Five of the seven tested vocal parameters were affected by the valence of the context (Table 1). After
77 controlling for the type of call and the age category (control factors), our analyses revealed that pigs

78 produced calls characterized by a higher center of gravity, a shorter duration, less noise (lower Wiener
79 entropy), lower formants (measured using the formant dispersion) and LPC coefficients in positive compared
80 to negative contexts.

81 **Table 1.** Model estimates, lower (lo.ci) and upper (up.ci) 95% confidence intervals for the vocal parameters
82 included in the linear mixed-effect models, as a function of the valence of the contexts (* $p < 0.05$; ** $p < 0.01$;
83 "NS" Non significant).
84
85

Parameter	Valence	estim	lo.ci	up.ci	P value
Mean F0 (Hz)	Pos	132.91	124.81	141.13	NS
	Neg	138.19	130.49	146.26	
Spectral centre of gravity (Hz)	Pos	967.70	877.57	1084.53	*
	Neg	895.54	806.46	996.58	
Duration (s)	Pos	0.17	0.14	0.21	**
	Neg	0.42	0.34	0.51	
AM extent (dB)	Pos	5.77	4.60	7.30	NS
	Neg	5.67	4.50	7.24	
Wiener entropy	Pos	-1.63	-1.84	-1.44	**
	Neg	-1.52	-1.71	-1.33	
DFmin (Hz)	Pos	846.64	778.01	921.82	**
	Neg	964.72	899.40	1035.78	
4th LPC coefficient (Hz)	Pos	3913.22	3742.58	4069.90	**
	Neg	4185.93	4020.41	4334.90	

86 Some of these changes are in line with previous findings (e.g. spectral center of gravity, Leliveld et al. 2016;
87 duration, Briefer et al. 2019). In particular, shorter durations in positive contexts have been observed across
88 multiple species and could be a feature conserved throughout evolution (Briefer 2012). Overall, our results
89 suggest that some parameters change with the valence experienced by pigs in a similar way across call
90 types. These vocal parameters could be very useful for developing automated methods to monitor pig
91 welfare on-farm.
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