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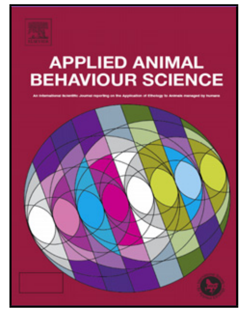
Accepted Manuscript



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PII: S0168-1591(18)30148-5
DOI: https://doi.org/10.1016/j.applanim.2018.10.009
Reference: APPLAN 4722

To appear in: *APPLAN*

Received date: 9-4-2018
Revised date: 5-10-2018
Accepted date: 9-10-2018

Domestic piglets (*Sus scrofa domestica*) are attentive to human voice and able to discriminate some prosodic features

Sandy Bensoussan [a], Raphaëlle Tigeot [a], Alban Lemasson [b], Marie-Christine Meunier-Salaün [a], Céline Tallet [a] *

[a] PEGASE, Agrocampus Ouest, INRA, 35590 Saint-Gilles, France

[b] Université de Rennes, Ethologie animale et humaine – C.N.R.S. – Université Caen Normandie, Paimpont, France

* Corresponding author

Telephone No: +332 23 48 50 53, Fax No: +332 23 48 50 80, e-mail address:

celine.tallet-saighi@inra.fr

Highlights

- Pig-human relationship may rely on human voice
- Piglets are attentive to human voice.
- Piglets spontaneously use rhythm and pitch to discriminate two voices
- Piglets do not spontaneously discriminate human emotions and intentions

Abstract

Vocal communication is of major social importance in pigs. Their auditory sensitivity goes beyond the intraspecific level; studies have shown that domestic pigs are sensitive to and can learn to recognise human voices. The question of which prosodic features (intonation, accentuation, rhythm) of human speech may matter (to what, their receptiveness/learning time?), however, remains open. A total of 42 piglets were allocated to three experimental groups. Each piglet was submitted to three choice tests, during which different pairs of sounds were broadcast. Each group was first offered a choice between an unmodified (neutral) human voice and a background noise, in order to verify the attractiveness of human voice. We found that piglets could distinguish human voice; they gazed more rapidly ($P < 0.05$) and for longer ($P < 0.05$) in the direction of the human voice than in the direction of the background noise. Group 1 was then submitted to artificially modified voices: low *vs* high-pitched, and then slow *vs* rapid rhythm. Group 2 was submitted to artificially modified voices with a combination of these features: rapid and high-pitched *vs* slow and low-pitched, and then slow and high-pitched *vs* rapid and low-pitched. Group 3 was submitted to naturally recorded voices coding for different emotions (happiness *vs* anger) and then different intonations (interrogation *vs* command). We found that piglets approached the loudspeaker broadcasting the rapid rhythm (6 s (2 - 32)) more rapidly than the loudspeaker broadcasting the slow rhythm (33 s (15 - 70); $p < 0.05$). They also spent more time near the loudspeaker broadcasting the “high-pitched and slow” voice (86 s (52 - 110)) than near the one broadcasting the “low-pitched and rapid” voice (29 s (9 -73); $W = 86$, $P < 0.05$). In sum, the sensitivity of piglets for human prosody was moderate but not inexistent. Our results suggest that piglets base their responses to human voice on a combination of prosodic features.

Keywords

human-animal relationship, piglets, voice prosody, auditory preferences, choice test

1. Introduction

Any inter-individual relationship develops through a series of interactions in time (Hinde, 1976; Estep and Hetts, 1992). In human-animal relationships, the quality of the interactions - pleasant, neutral or unpleasant – has impact on the long-term response developed by domestic animals toward humans (Hemsworth and Coleman, 2011). It is therefore crucial to investigate the factors that influence the quality of a given interaction (Appleby and Hughes, 1993; Tanida et al., 1994).

Several studies have already shown that domestic animals base their response to human interaction on different human characteristics (Seabrook and Bartle, 1992). Animal responses are usually interpreted as either fear or attractiveness (Seabrook and Bartle, 1992; Hemsworth and Coleman, 2011). This plays an important role for developing human-animal relationship as positive interactions are appeasing for animals, e.g. dogs (Kostarczyk, 1992) and horses (Lynch et al., 1974). In farm animals, positive interactions typically increase productivity and facilitate handling (Hemsworth and Coleman, 2011; Tallet et al., 2018). For example, type of visual interaction modulates animal behaviour; whether human experimenters are standing still or slowly approaching them in or near their pen affects the avoidance responses of laying hens and chicks (Jones, 1993; Barnett et al., 1994), cows (Hemsworth et al., 1987) and wolves (*Canis lupus*) (Woolpy and Ginsburg, 1967). Human posture can also have an effect, as pigs exhibit fear to those who are standing more erect when approaching them (Miura et al., 1996). Adding gentle tactile interactions such as brushing or petting also increased approaches of humans by lambs (Markowitz et al., 1998), poultry (Jones, 1993) and cattle (Hemsworth et al., 1996). Non-visual and non-tactile sensory modalities have been far less studied, most notably olfactory and auditory characteristics (Hemsworth and Coleman, 2011; Tallet et al., 2018).

Some animals have been shown to discriminate between familiar and unfamiliar humans (horses: Proops and McComb, 2012; carrion crows: Wascher et al., 2012; cats: Saito and Shinozuka, 2013) or between women and men (elephants: McComb et al., 2014; dogs:

Ratcliffe et al., 2014), which requires them to be able to detect very subtle differences in human voice. Additionally, aversion to shouts has been found in cattle (Waynert et al., 1999; Pajor et al., 2000), and singing is used to help Scandinavian herdswomen to move their flocks (Ivarsdotter, 2002). Loudness of human voice did not however seem to affect the approach responses of pigs (Hemsworth et al., 1986). The prosodic characteristics of the human voice may also be an indicator of the quality of the relationship between farmers and their animals. Seabrook and Bartle (1992) reported that dairy units where cows were talked "with", had better milk yields than dairy units where stockpeople talked "to" them, i.e. issuing comments or commands. Further research is necessary to assess the degree of sensitivity of animals to prosodic features of human speech.

Domestic pigs are ideal models for this research; they are gregarious animals who develop social relationships with both conspecifics and humans (Graves, 1984). They have a broad hearing range (42 Hz to 40.5 kHz (Heffner and Heffner, 1990) and high sensitivity for frequencies below 1.5 kHz, which falls into the pitch of human voice (Signoret et al., 1975). They also have a large vocal repertoire, varied in acoustic structure and context of use (Tallet et al., 2013). In presence of a human, pigs were not found to be more attracted by the broadcast of a harsh and loud voice than by the broadcast of a quiet and soft voice (Hemsworth et al., 1986). However, it has recently been demonstrated that piglets are able to discriminate and recognise different human voices (Tallet et al., 2016). Moreover, the postnatal reactions of piglets to a human voice were influenced by whether the pregnant sow had heard it when she was experiencing positive or negative emotional stimulation. Some pigs can even learn to use human voice in referential communication (Nawroth and von Borell, 2015), which previously has not been thought possible without training (Bensoussan et al., 2016). More research is necessary in order to understand the responses of pigs to human voice, and their sensibility and acoustic basis.

This study is the first to examine the sensitivity of piglets to prosodic features in the human voice. The attentiveness of piglets to a human voice broadcast was first checked. Piglets were then submitted to choice tests during which two different voices were systematically broadcast, varying in one or more prosodic features. The acoustics of mammal calls vary strongly with the valence and arousal state of the caller (Briefer, 2012). As such, this study tested prosodic features typically involved in emotion coding (i.e. pitch, speed, rhythm).Human voices are typically acoustically complex, and so the interactions between prosodic features and different speaking intonations were also investigated, with human voices both artificially and naturally modified. We hypothesised that certain characteristics would affect the attractiveness of a voice according to their possible valence for animals, such as speaking slowly rather than rapidly or speaking with a 'happy' rather than an 'angry' tone.

2. Material and Methods

This study was granted ethical approval on 10 August 2015 by the local ethics committee (CR2EA – 07 Comité Rennais d'éthique en expérimentation animale, number 201503270953906).

2.1. Animals and rearing conditions

Forty-two female domestic piglets (*Sus scrofa domestica*) were used, born at the experimental unit of Saint-Gilles (INRA, France) from 11 Large White x Landrace sows inseminated by Pietrain semen. Piglets were submitted to tail docking and iron injection on the second day of life. They were weaned at 28 days of age (Day 1 of the experiment, Table 1) and transferred to the experimental pens (1.30 x 1.20 m). Animals were housed in groups of three siblings, and equipped with coloured ear tags for individual identification. The piglets were allocated to three experimental groups of 14 each, according to their weight, in order to homogenise the mean weight at weaning between groups. In each pen one piglet belonged to experimental group 1, another to experimental group 2 and the last to experimental group 3.

Pens were equipped with chains as enrichment material, a feeder (0.6 x 0.2 m), a drinking bowl, and had slatted floors. Animals had *ad libitum* access to water and commercial feed pellets. Three weeks post-weaning they were vaccinated against *Haemophilus parasuis.* Ambient temperature during the experiment was on average 25.5°C, decreasing from 28°C to 23°C in the post-weaning period (40 days). Artificial light was provided from 08:00 h to 16:00 h.

2.2. Sounds

2.2.1. Recordings and selection

As piglets were reared by male caretakers, we chose to test only responses to female human voices. The voices of twenty-eight female volunteers blind to the precise aims of the project were recorded. The recordings were made with a microphone (MKH 50 P 48 Sennheiser, Germany) and a microphone module with an acoustic foam windscreen (K6/ME66 Sennheiser, Germany). The microphone was connected to an audio digital portable recorder (PMD661 Marantz Professional, The Netherlands; amplitude resolution: 16 bits; sampling rate: 44.1 kHz; WAV format).

To evaluate the perception of emotion in human voice by the piglets, we asked volunteers to record the following sentence with three respective emotional intentions (neutral, happy and angry): “De ce côté, cochon. Allez. Par ici. Viens là.” (translation: “On this side, pig. Come on. This way. Come here.”). We obtained two recordings per emotional intention for each volunteer. The recordings were then evaluated by 25 listeners to verify the reliability with which the correct emotional intention was perceived, and in each case the most reliable of the two was selected. For evaluation each sentence was played twice, and the listener was asked to choose the emotion coded from a list of six possible answers: surprise, anger, happiness, fear, neutral and “I don’t know”. The same prosodic feature (neutral, happiness…) was not broadcast more than twice consecutively as well as the same volunteer's voice. We used the recordings from the volunteers whose emotions were most reliably perceived. We kept recordings from 14 women; one per piglet per group (tests 1A, 1B, 1C, 2A, 2B, 2C; Table 1). The background noise of the recording room (with no biological sound) was also recorded for 5 s and used as a control in tests 1A, 2A and 3A.

As we also intended to evaluate how well piglets perceive the tone of human voice (tests 3B and 3C), the volunteers were asked to record a list of expressions often used in breeding facilities (e.g. come on, stop, move…) in a commanding tone and in an interrogative tone. The delivery of the correct tone in the recordings was assessed separately by three experimenters. The recordings from the 14 women (one for each piglet in group 3) with the best delivery of the expected tone were kept. We then also selected the neutral sentences recorded previously from the 14 corresponding women. The chosen recordings were edited with the Audacity software (2.0.6, www.audacityteam.org) to obtain sentences of five syllables pronounced in a commanding tone and in an interrogative tone. Vowels and consonants were balanced between the edited sentences.

2.2.2. Analysis and modifications

Acoustic measurements were analysed with ANA software (Richard, 1991). Neutral voice recordings were characterised by a mean fundamental frequency of 223 ± 23 Hz and a resonance frequency of maximal intensity of 269 ± 63 Hz in the entire sentence. The neutral sentences were then acoustically modified to make them higher-/lower-pitched and faster/slower in rhythm using automatic options from Audacity software. For pitch modification (tests 2B and 2C), a scale of ± 15% frequency switch was chosen. This was chosen so that it remains in the female natural frequency range (Titze, 2000; Assmann et al., 2006). For rhythm modifications, a switch of ± 1/3 speed rhythm was chosen and rapid sentences were played twice, in order to standardise the duration of recordings.

2.3. Familiarisation of piglets to transport by cart and to the test arena

Familiarisation trainings and tests (Table 1) were carried out in a room separated from the home pens room but located in the same building. The test arena was T-shaped, and made of opaque plastic walls and concrete flooring (Fig 1). It was divided into two parts: a starting area where the piglet was introduced to the arena prior to testing, and a test area in the form of a corridor where the test occurred. One loudspeaker (MA-100su Mipro Electronics, Taiwan) was placed at each end of the test area through a hole in the wall to broadcast the recordings.

From day 5, all piglets were familiarised to the transport to the testing arena by cart (Table 1). The two loudspeakers alternated every 5 s between broadcasting livestock noises at 65 ± 1 dB and the material used for the voice recordings. Livestock noises were recorded in the rearing room and consisted mainly of ventilation sound and metallic noise from the manipulation of metallic bars or feed troughs by pigs. Each rearing group of piglets was moved in an opaque cart to the test arena three times over two days (day 5 and 6) and allowed to explore the test area for 10 min. On Days 7 and 8, they were moved one by one and allowed to explore the test arena for 5 min once per day. To ensure familiarisation, on the two days prior to their first test each piglet was individually moved to the test area for 5 min.

2.4. Playback setup

Piglets from each experimental group were submitted to three consecutive two-choice tests (Table 1). The first choice test assessed the perception of the broadcast, and the two next ones the discrimination of acoustic features. For a given test, a single piglet was moved by cart from its pen to the starting area of the test arena. Playbacks were broadcast once on each side of the test area before opening its access and then continuously until the end of a test which lasted 5 min. If a piglet did not enter the test area after 30 s, it was gently pushed by the experimenter. For each piglet the type of recording (neutral, background, high-pitched, low-pitched…) was always broadcast on the from the same direction (left or right), and direction was balanced among the piglets. The two loudspeakers played their sound alternated with livestock noises for the duration of the test. The sound level was fixed at 65 ± 2 dB max at 1 m from the source.

2.5. Behavioural observations

The behaviours of the piglets during the tests were video recorded with a camera (Panasonic France P2C5-2230P33, France) fixed above the test area , and connected to a computer equipped with a video acquisition card Mpeg Noldus 2.1 and the Mpeg Recorder software (Noldus, The Netherlands). Experimenters were not visible to the animals. Experimenter 1 counted the calls and recorded spatial occupation (Table 2) via a portable computer (Dell precision M4400) equipped with The Observer XT 11.0 software (Noldus, The Netherlands). Experimenter 2 recorded the gazes of piglets via a Psion portable system (Workabout Pro3, Psion Teklogix, The United Kingdom) with Pocket Observer 3.0 software (Noldus, The Netherlands). The Observer was used to extract the frequency of each behaviour occurring, and the duration and latency of their first occurrence.

One video is missed from group 2 due to a saving failure. The corresponding data were removed from the analysis thus we ended with a sample of 14 piglets in experimental groups 1 and 3, and 13 in experimental group 2.

2.6. Statistical analyses

All statistical analyses performed with R software (3.1.1, r-project.org (R Core Team, 2014)). Before analysis, we controlled for laterality biases (number of piglets entering the test area on the left (L) side versus number of piglets entering on the right (R) side) with binomial tests. In no cases did piglets present any laterality bias (test 1A: 7 L vs 6 R, test 1B: 9 L vs 4 R, test 1C: 10 L vs 3 R; test 2A: 5 L vs 9 R, test 2B: 8 L vs 6 R, test 2C: 6 L vs 8 R; test 3A: 10 L vs 3 R, test 3B: 5 L vs 8 R, test 3C: 8 L vs 5 R; binomial bilateral tests $p > 0.05$).

For choice tests, paired Wilcoxon comparisons (W) were used to determine the impact of the sound broadcast type on the observed behavioural measures. Results were considered as significant when the probability of the null hypothesis was less than or equal to 0.05. Values are presented as medians and interquartile range (Q25-Q75). Fisher tests were used to compare the number of piglets emitting high-pitched calls.

3. Results

We found significant effects of the speed of speech, and of combinations of speed and pitch on pig behaviour. They are reported below.

3.1. Analysis of tests 1A, 2A, 3A: attention paid to human voice *versus* background noise

Piglets were attentive to human voice; they gazed more rapidly towards the side with the human voice than the side with the background noise in experimental groups 1 and 2 (1: W = 73, P = 0.009; 2: W = 86, P = 0.005; 3: W = 23, P = 0.22, Fig. 2). Piglets from all experimental groups also gazed longer in the direction of the human voice than in the direction of the background noise (1: W = 77, P = 0.003; 2: W = 90, P = 0.002; 3: W = 62, P = 0.011; Fig. 3). However physical attraction did not differ between the sounds. Piglets went near the loudspeakers after 45 s (19 – 92) (1: W = 50, P = 0.78; 2: W = 38, P = 0.38; 3: W = 60, P = 0.33; Fig. 4). They stood near them for a total of 52 s (32 – 90) (1: W = 43, P = 0.89; 2: W = 36, P = 0.32; 3: W = 45, P = 1; Fig. 5). Piglets expressed as many low-pitched calls near each type of sound (median frequency of 0.2 (0.1-0.4); group 1: W = 53, p = 0.29, group 2: W = 40.5, p = 0.47, group 3: W = 23, p = 0.68). Ten piglets did emit high-pitched calls, and four vocalised more near the human voice than near the background noise.

3.2. Analysis of 1B test: influence of variations in pitch (high *versus* low pitch)

Pitch did not influence piglet behaviour during the test. Piglets took 104 s before gazing at the loudspeakers (31 - 249) (W = 40, P = 0.97, Fig. 2), and looked for 0.7 s (0.4 – 2.2) (W = 51, P = 0.37, Fig. 3). They went near the loudspeakers 21 s (10 - 34) (W = 41, P = 0.78, Fig. 4) after the start of the test, for 49 s (29 – 88) (W = 37, P = 0.58, Fig. 5). They emitted 0.4 (0.2 - 0.5) low-pitched calls per minute (W = 43, P = 0.81). Among the 13 piglets that entered the loudspeaker zones, six emitted high-pitched calls in the zone of the high-pitched voice and six in the zone of the low-pitched voice (Fisher's exact test, P = 1).

3.3. Analysis of 1C test: influence of variations in rhythm (rapid *versus* slow)

Piglets moved towards the loudspeaker broadcasting the rapid rhythm six times sooner (median values) than to the loudspeaker broadcasting the slow rhythm (W = 78, P = 0.03, Fig. 4). There was no significant difference for the other behaviours. Piglets first gazed at the loudspeakers 97 s (48 - 159) after the start of the test (W = 40, P = 0.97, Fig. 2), and for 0.7 s (0.4 – 2.2) (W = 44, P = 0.72, Fig. 3). They stood near the loudspeakers for 61 s (36 – 85) (W = 50, P = 0.78, Fig. 5). They emitted 0.3 (0.2 - 0.4) low-pitched calls per minute (W = 37, P = 0.88). Among the 13 piglets which entered the loudspeaker zones, six emitted high-pitched calls in the zone of the slow rhythm voice and none in the zone of the rapid rhythm voice (Fisher's exact test, P = 0.005).

3.4. Analysis of 2B and 2C tests: influence of combinations of variations in pitch (high *versus* low pitch) and rhythm (slow *versus* rapid)

Crossing pitch and rhythm of the voice did not influence piglet behaviour in test 2B, but did in test 2C. In test 2B (high-pitched and rapid vs low-pitched and slow), piglets first gazed at the loudspeakers 173 s (82 - 301) after the start of the test (W = 50, P = 0.78, Fig. 2), and for 1.6

s (0.0 – 2.9) (W = 54, P = 0.58, Fig. 3). They went near the loudspeakers in 26 s (11 - 55) (W = 36, P = 0.31, Fig. 4), and for 52 s (32 – 90) (W = 74, P = 0.19, Fig. 5). They emitted 0.2 (0.1 - 0.3) low-pitched calls per minute (W = 38, P = 0.69). All piglets entered the loudspeaker zones, and none emitted high-pitched calls.

In test 2C (high-pitched and slow vs low-pitched and rapid), piglets spent about three times the amount of time (median values) near the loudspeaker broadcasting the "high-pitched and slow" voice than near the one broadcasting the "low-pitched and rapid" voice (W = 86, P = 0.04, Fig. 5). There was no difference for the other behaviours. Piglets gazed at the loudspeakers 163 s (66 - 259) after the start of the test (W = 52, P = 1, Fig. 2), and for 2.4 s (0.5 – 6.1) (W = 42, P = 0.53, Fig. 3). They went near the loudspeakers in 21 s (13 - 68) (W = 51, P = 0.73, Fig. 4). They emitted 0.2 (0.2 - 0.3) low-pitched calls per minute (W = 30, P = 0.29). All piglets entered the loudspeaker zones, 4 emitted high-pitched call in the zone of the high-pitched and slow voice and none in the zone of the low-pitched and rapid voice (Fisher's exact test, P = 1).

3.5. Analysis of 3B and 3C tests: Influence of prosodic variations: emotion (happiness vs anger) and intonation (question vs command))

In both tests, there was no difference in observed piglet behaviour between the two broadcast voices. In test 3B, piglets first gazed at the loudspeakers after 173 s (61 - 301; W = 63, P = 0.24, Fig. 2), for 1.1 s (0.0 – 3.0) (W = 40, P = 0.73, Fig 3.). Piglets entered the loudspeaker zones in 17 s (11 – 27) (W = 58, P = 0.40, Fig. 4), and for an average duration of 66 s (37 – 103) (W = 61, P = 0.29, Fig. 5). Piglets emitted 0.1 (0.1 - 0.2) low-pitched calls per minute (W = 55, P = 0.06), and only 2 piglets emitted high-pitched calls toward the choleric voice and 3 toward the happy voice.

In test 3C, piglets first gazed at the loudspeakers after 111 s (33 – 272) (W = 42, P = 0.45, Fig. 2),for 1.2 s (0.1 – 3.8) (W = 41, P = 0.50, Fig. 3). Piglets entered the loudspeaker zones in 21 s (10 - 34) (W = 65, P = 0.18, Fig. 4), and for a total duration of 70 s (38 - 107) (W = 41, P = 0.78, Fig. 5). Piglets emitted 0.2 (0.1 - 0.2) low-pitched calls per minute (W = 20, P = 0.77), and only 1 piglets emitted high-pitched calls toward the choleric voice) and 3 toward the happy voice.

4. Discussion

In this study, piglets were able to discriminate natural and modified human voices. They were also more attentive to a human voice than a background noise. They more rapidly approached a voice with a more rapid rhythm than a slower one, and spent more time near a high-pitched and slow voice than a low-pitched and rapid voice. They did not however show any discrimination between either of the two emotions, or the two intentions/intonations.

In the first choice test, piglets gazed more rapidly and longer in the direction of the recorded human voice than in the direction of the recorded background noise. Piglets were thus attentive to and able to perceive human voice broadcast. Human voice may be a signal for the arrival of the human in the barn, announcing upcoming positive events (food provision, cleaning) or more stressful ones (moving to another room), and thus this attention might have adaptive value. Our testing situation thus validated acoustic discriminative capacities in piglets. The specificity of the attention to human voice compared to any kind of other sound should be tested further, for instance by comparing human voice recordings to other sounds similar in their acoustic characteristics.

Piglets spent the same amount of time in the zone of the loudspeaker broadcasting the neutral voice as in the zone of the loudspeaker broadcasting the background noise. This shows that they were not physically attracted by human voice, just simply attentive. This could be explained by the absence of familiarity of the broadcast voices for the piglets, even if they did not seem frightening due to the absence of high-pitched calls, which are a sign of neophobia in choice tests (Tallet et al., 2016). Piglets may have located the source of the sound (Heffner and Heffner, 1989) as they turned their head in its direction, but they did not approach, suggesting that the prosody of the voice (text was read in a neutral tone) was not attractive for them.

In the following choice tests, piglets were able to discriminate prosodic features of human voice. Their behaviour was influenced by the rhythm and by the pitch in combination with the rhythm. In many species including pigs, rhythm and pitch are notably used to encode the identity of individuals (e.g. pig: Špinka et al., 2002; sheep: Searby and Jouventin, 2003; Australian sea lion: Charrier and Harcourt, 2006; Campbell monkey: Lemasson et al., 2010; cattle: Padilla de la Torre et al., 2015) and their emotional state (mammals: Briefer, 2012). There is a universal link between the internal states of animals and the acoustic structure of their vocalisations, described in the Motivation-Structural Rule of Mortons (1977). Due to this link animals can perceive information from calls of another species. In this study pigs were sensitive to rhythm and pitch in human voice, as they are with intra-specific vocalisations. The capacities of pigs to discriminate human voices after learning has been already shown in younger animals (Tallet et al., 2016), but to our knowledge this is the first time that spontaneous fine discrimination of acoustic features of human voice have been reported.

The rapid rhythm and pitch of voice may have had direct impact on the piglets' arousal, which then affected their behaviour. This would be in agreement with the theory of Owren and Rendall (2001) in non-human primates,who proposed that some acoustic features are "attention-and-arousal-inducing ", i.e. they attract the attention and modify the arousal state of receivers. This is the case of upward frequency sweeps, rapid amplitude fluctuations or any rapid/large variation in acoustic features. The increase in rhythm used here not only shortened the words, but also made the intrinsic modulations more abrupt, which likely caused an increase in the attention of the piglets.

The rapid rhythm (1/3 faster than normal rhythm) tested induced more attraction (latency to approach reduced) than the slow rhythm (1/3 slower than normal rhythm) and the latter induced significantly more high-pitched calls. This is in agreement with the potential attention-inducing properties of increasing the rhythm of a sentence. The difference observed in the approach behaviour toward the two sounds may result either from an attraction for the rapid rhythm, or a repulsion for the slow rhythm. Piglets spent 61 s near the loudspeakers, whatever the sound rhythm (52 s near the neutral sound in A tests). This suggests that the rapid rhythm was attractive but did not elicit any specific emotional state, and that the slow rhythm was not repulsive, but still induced stress/fear reactions expressed by high-pitched calls (Tallet et al., 2016). This rapid-rhythm voice shortened the pronunciation of the words which could be interpreted as shorter sounds. This result is in correspondence with the fact that at intra-specific level, short calls are associated to non-aggressive social context (Briefer, 2012) and to situations that are less negative (reunion with the sow, after nursing) than longer calls (castration or crushing) (Tallet et al., 2013). The acoustic cue that influenced piglets behaviour remains to be determined, because by modifying the rhythm of the sentence we both modified the duration of the words and the intervals between the words. In vocal expression in mammals, increasing the duration of the calls is associated with negative valence, and would be a sign of high arousal in pigs (Briefer, 2012). Increasing the interval between the calls is also associated with negative valence in mammals (Briefer, 2012) but results in pigs are not always consistent on this association (Leliveld et al., 2017). If the decoding of human calls by pigs follows their intra-specific encoding rules, further investigation is needed to assess the perception of rhythm in human voice by pigs.

The combination of a high pitch with a slow rhythm (versus low pitch and rapid rhythm) resulted in an increase in the time spent near the loudspeakers by the piglets. The time spent near a sound in a choice test characterises the preference of the subject; the sound near which piglets spend the longer time is considered the preferred one (Parfet and Gonyou, 1991). A slow rhythm is a characteristic of positive states, but by itself did not attract the piglets in our study. The combination of slow rhythm and high pitch may have taken a positive value for the piglets, or at least have had an attractive value, due to curiosity and alert reactions. The high pitch could have increased the arousal of the piglets, which would be in accordance with Owren and Rendall (2001). High-pitched pig calls have often been demonstrated to induce alert responses from the receivers (Talling et al., 1996; Illmann et al., 2008; Düpjan et al., 2011). The mechanism underlying this effect should be investigated further.

Piglets discriminated simple acoustic features of human voice, but choice tests between angry and happy intonations, and between commanding and questioning voices did not induce any such behavioural differences. The absence of discrimination of human voice compared to background noise in group 3 may explain that piglets did not discriminate the sounds broadcast in the other tests. It could be that this population of piglets is somehow less sensitive to sounds, for an as yet unkown reason. However the absence of spontaneous discrimination between emotions by piglets agrees with the findings of Hemsworth et al. (1986), who compared reactions to a loud and harsh voice and a soft and quiet voice broadcast in the presence of a motionless human. Piglets in our experiment may have been too young to recognise human functional prosodies. Indeed, in Owren and Rendall (1997), some sounds directly influence behaviour, while others necessitate a conditioning via experience with the context of emission. The encoding of emotion and intention in human voice is complicated (Laukka et al., 2005), likely more so than in pig calls. In our experiment, piglets had a limited experience of human voice, and possibilities to learn the encoding of human emotional states in their voices were almost inexistent. Piglets may therefore need more experience with human sounds expressing emotions and intentions, and with the consequences of these expressions to adapt their responses. Piglets may also need other signals, for example visual cues, to discriminate emotions and intentions as they are not solely expressed verbally (Juslin and Laukka, 2003). This is indeed the case for dogs, even if they have extended contact with humans (Scheider et al., 2011). Testing the impact of a preliminary extended experience with human voice in relation to human emotional states would likely help us to better understand the mechanisms underlying the perception of human voice by pigs.

5. Conclusion

This study showed that pigs are attentive to human voice. They are able to discriminate some simple features of human voice, namely rhythm and combinations of rhythm and pitch. The function of these discriminative capabilities, and the potential existence of others should be investigated further.

More complex prosodic features, which encode the emotional state or the intention encoded in a voice were not spontaneously discriminated by the piglets in this study, likely due to a lack of experience with humans and human voice prosody. The possibility that pigs use the emotional and intentional content of human voice to adapt their behaviour therefore remains to be answered.

Declarations of interest: none

6. Acknowledgment and additional information

The authors would like to thank Michel Lefebvre for building the testing apparatus. We would like to acknowledge Patrick Touanel, Henri Renoult, Fabien Guérin and all the staff from the experimental farm, as well as Carole Guérin. We are also very grateful to all the volunteers who accepted we record their voice, and all the respondents who evaluated the records. We also thank the reviewers for their helpful comments to improve the content of the article, and are grateful to Eva Read who edited the English spelling.

This work received a grant from the INRA institute and the Brittany regional council n°30000937 SB. The experiment was funded by a grant from the INRA-PHASE “Crédits incitatifs” and from the GDR2822 Éthologie. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

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Figure captions

Figure 1. Schematic representation of the test arena. Numbers indicate the virtual cutting of the test area to analyse locomotion.

Figure 2. Median (and IQ) latency (s) to gaze in the direction of the loudspeaker according to the sound broadcasted in the choice tests for each group of piglets.

**: $p < 0.01$. BN: background noise, Voice: neutral tone, High-P: high-pitch, Low-P: low-pitched, Angr: angry tone, Com: commanding tone, Ques: questioning tone.

Figure 3 Median (and IQ) duration (s) of gazing in the direction of the loudspeaker according to the sound broadcasted in the choice tests for each group of piglets.

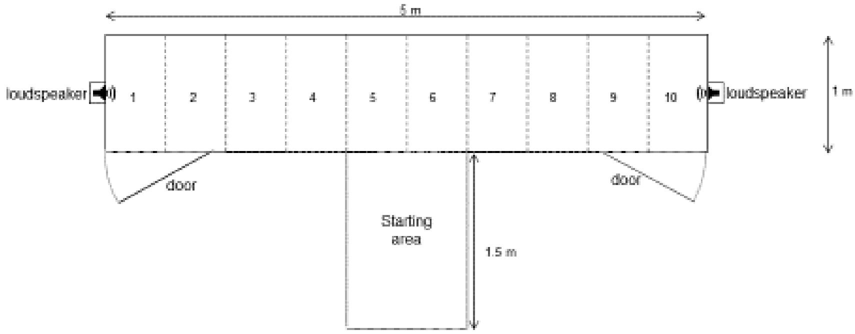
**: $p < 0.01$. BN: background noise, Voice: neutral tone, High-P: high-pitch, Low-P: low-pitched, Angr: angry tone, Com: commanding tone, Ques: questioning tone.

Figure 4. Median (and IQ) latency (s) to approach the loudspeaker according to the sound broadcasted in the choice tests for each group of piglets.

**: $p < 0.01$. BN: background noise, Voice: neutral tone, High-P: high-pitch, Low-P: low-pitched, Angr: angry tone, Com: commanding tone, Ques: questioning tone.

Figure 5. Median (and IQ) time (s) spent near the loudspeaker according to the sound broadcasted in the choice tests for each group of piglets.

**: $p < 0.01$. BN: background noise, Voice: neutral tone, High-P: high-pitch, Low-P: low-pitched, Angr: angry tone, Com: commanding tone, Ques: questioning tone.


5 m
loudspeaker
1
2
3
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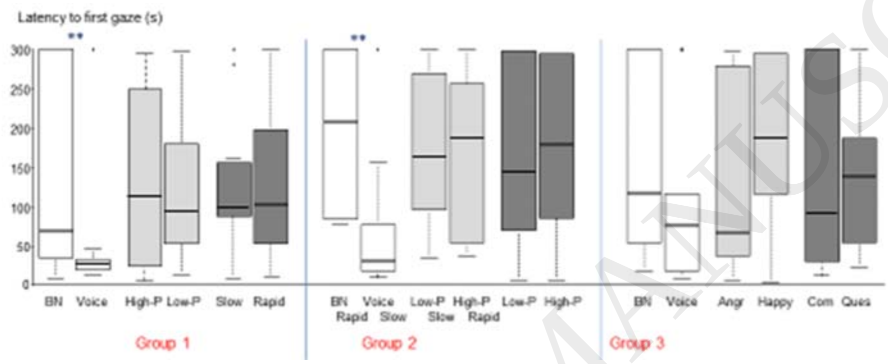
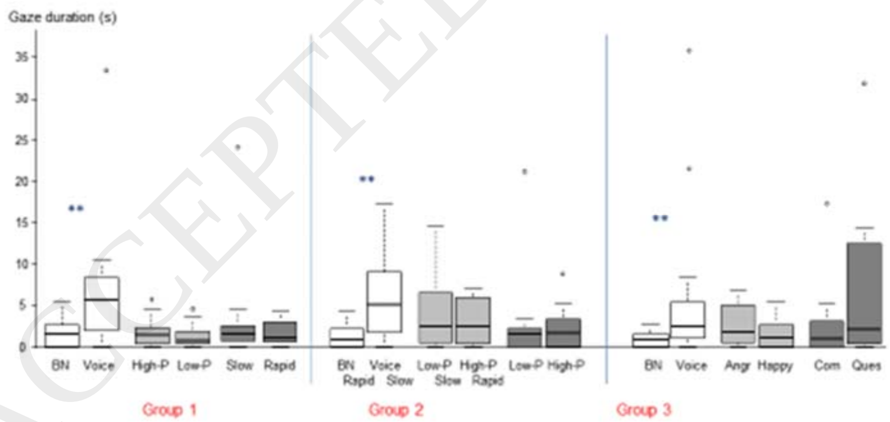
5
6
7
8
9
10
loudspeaker
1 m
door
door
Starting area
1.5 m


Latency to first gaze (s)
300
250
200
150
100
50
0
**
**
BN
Voice
High-P
Low-P
Slow
Rapid
BN Rapid
Voice Slow
Low-P Slow
High-P Rapid
Low-P
High-P
BN
Voice
Angr
Happy
Com
Ques
Group 1
Group 2
Group 3


Gaze duration (s)
35
30
25
20
15
10
5
0
**
**
**
BN
Voice
High-P
Low-P
Slow
Rapid
BN Rapid
Voice Slow
Low-P Slow
High-P Rapid
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High-P
BN
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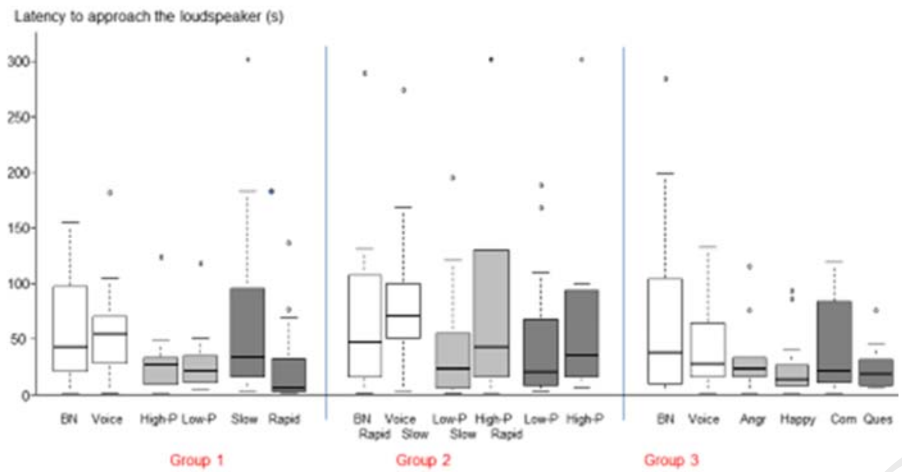
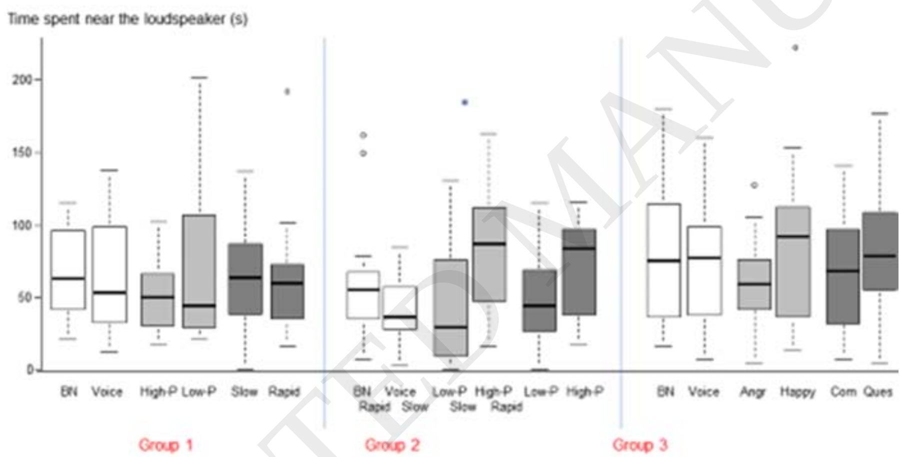
Com
Ques
Group 1
Group 2
Group 3



Latency to approach the loudspeaker (s)
300
250
200
150
100
50
0
BN
Voice
High-P
Low-P
Slow
Rapid
BN Rapid
Voice Slow
Low-P Slow
High-P Rapid
Low-P
High-P
BN
Voice
Angr
Happy
Com
Ques
Group 1
Group 2
Group 3



Time spent near the loudspeaker (s)
200
150
100
50
0
BN
Voice
High-P
Low-P
Slow
Rapid
BN Rapid
Voice Slow
Low-P Slow
High-P Rapid
Low-P
High-P
BN
Voice
Angr
Happy
Com
Ques
Group 1
Group 2
Group 3

Table 1. Timeline of the experiment.

Day	Experimental group	Step	Test label	Duration and frequency
1	All (n = 42)	Weaning and transfer to experimental home pen		1 h
5 & 6		Group familiarisation to cart transport and test arena		10 min, 3 times/ 2 days
7 & 8		Individual familiarisation to cart transport and test arena		5 min, once/ day
9 & 12	Group 1 (n = 14)	Individual familiarisation to cart transport and test arena		5 min, once/ day
13		Individual choice test human voice *versus* background noise	Test 1A	1 test/ piglet/ day
14		Individual choice test low-pitched voice *versus* high-pitched voice	Test 1B	1 test/ piglet/ day
15		Individual choice test rapid voice *versus* slow voice	Test 1C	1 test/ piglet/ day
16 & 19	Group 2 (n = 14)	Individual familiarisation to cart transport and test arena		5 min, once/ day
20		Individual choice test human voice *versus* background noise	Test 2A	1 test/ piglet/ day
21		Individual choice test low-pitched and rapid voice *versus* high-pitched and slow voice	Test 2B	1 test/ piglet/ day
22		Individual choice test low-pitched and slow voice *versus* high-pitched and rapid voice	Test 2C	1 test/ piglet/ day
23 & 26	Group 3 (n = 14)	Individual familiarisation to cart transport and test arena		5 min, once/ day
27		Individual choice test human voice *versus* background noise	Test 3A	1 test/ piglet/ day
28		Individual choice test angry *versus* happy tone	Test 3B	1 test/ piglet/ day
29		Individual choice test interrogative *versus* commanding tone	Test 3C	1 test/ piglet/ day

Table 2. Behavioural activities observed during the tests.

Behaviour	Description
Gaze	Animal with the head directed to one loudspeaker
Low-pitched call[a]	Low-pitched vocalisation emitted with a closed mouth: grunts
High-pitched call[a]	High-pitched vocalisation ending with an open mouth: scream, squeal or grunt-squeal
Entrance zone	First zone entered by the piglet: left or right side
Near the loudspeaker	Animal with two forelegs in the zone near the loudspeaker (zones 1+2, zones 9+10, Fig.1), i.e. less than 1m from one loudspeaker

[a]: Reimert et al. (2013)