

The impact of farrowing room noise on sows' reactivity to piglets

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ABSTRACT: Despite much interest in sow welfare, the impact of the acoustic environment on sow reactivity to her piglets is rarely considered. The objective of this study was to understand the impact of noise produced by mechanical ventilation and other sows on a sow's reactivity to her piglets. Sows were farrowed in one of three environments: 1) with eight other sows exposed to constant fan noise (GROUP-FAN; $n = 10$), 2) alone with fan noise present (ISO-FAN; $n = 10$), and 3) alone without fans running (ISO-QUIET; $n = 10$). Sows were subjected for 5 min to a piglet removal event (REMOVAL) by an unknown handler twice, at 24 and 48 h postfarrowing. During a REMOVAL, sows were observed via video recording for changes in posture, eating and drinking behavior, and head orientation. Audio was recorded to quantify vocalizations by the sow. Once piglets were returned, sows underwent further behavior observations for 10 min (RETURN), resulting in approximately 15 min of total video observation. Sows were classified as young (second and third parity) and old (fifth parity and older). The YOUNG sows tended to be more Alert (looking toward the handler or their piglets) during REMOVE than OLD sows ($P = 0.07$; 2.01 and 1.33, respectively). The ISO-FAN sows vocalized

the loudest during REMOVAL ($P < 0.001$) with ISO-QUIET sows performing the quietest vocalizations (GROUP-FAN: 72.22 ± 1.06 dB; ISO-FAN: 73.61 ± 1.07 dB; ISO-QUIET: 67.41 ± 0.99 dB). During RETURN, YOUNG sows spent more time sitting than OLD sows ($P < 0.01$; $7.48 \pm 1.6\%$ and $0.91 \pm 1.8\%$, respectively). The ISO-QUIET sows tended to have more posture changes during the RETURN with ISO-FAN having the least changes ($P = 0.06$; GROUP-FAN: 1.23 ± 0.4 ; ISO-FAN: 0.44 ± 0.3 ; ISO-QUIET: 1.61 ± 0.4). Finally, sows decreased the amount of time Alert in the second RETURN ($P = 0.03$; first: $3.9 \pm 0.6\%$; second: $2.5 \pm 0.6\%$). Overall, sows acclimated to the removal and return events with decreased vocalizations and decreased Alert behaviors in the second REMOVAL and RETURN. Additionally, YOUNG sows performed more active behaviors than OLD sows, indicating that sows may become less interested in or cannot hear their piglets as they age. Finally, there is some indication that ventilation presence has an effect on sow-piglet communication with ISO-FAN sows having the loudest vocalizations when compared with sows without ventilation noise, indicating that ventilation noise may be a possible competitor with a sow's ability to communicate with her piglets.

Key words: auditory environment, farrowing, piglet crushing, sow welfare

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INTRODUCTION

Almost half of all preweaning deaths in swine are due to sows crushing their piglets (USDA, 2012); however, the exact cause of crushing is not fully understood. A potential factor may be that sows struggle to identify their own newborns as identification can take 1 d to develop (Horrell and Hodgson, 1992). Piglet identification requires multiple senses such as olfactory and auditory cues (Horrell and Hodgson, 1992; Illmann et al., 2002). Swine have a wide hearing range (Heffner and Heffner, 1990) with high specificity at levels in which piglets call (Marchant-Forde et al., 2009). Therefore, hearing may be influential on sow behavior towards her piglet and the auditory environment of sows should be considered.

Mechanically ventilated swine farms often average constant noise levels above 80 decibels (dB; Zurbrigg, Accessed 2015). Sows have been reported to respond to piglet calls when calls have been played louder than normal piglet calling (84–86 dB) levels (Hutson et al., 1993). Also, noisy environments can interfere with the nursing pattern between sows and piglets (Agers and Jensen, 1985). Loud living conditions and levels at which a sow reacts to a piglet suggest that the lack of sow responsiveness to piglets is due to environmental conditions. As sows frequently live in large facilities, call distinction from sow and neighbor offspring may be masked by background noise or by calls from neighbors. No data are available demonstrating if multisow rooms or ventilation noise is a factor on sow–piglet communication. However, facilities containing a high level of noise interference may contribute to the difficulty of sows to react to piglets, leading to the high levels of piglet mortality exhibited in today's swine industry.

The objectives of this study are to understand the impact of several sources of noise in a typical production setting on sow reactivity to removal of her piglets and to determine if parity influences the sow's reactions. It was hypothesized that sows in a quiet environment void of other sows and ventilation noise would be more reactive to piglets than sows in an environment with mechanical noise or in the presence of other sows and piglets whose calls may mask sow–piglet communication.

MATERIALS AND METHODS

Animals and Housing

All procedures were approved by the Purdue Animal Care and Use Committee (#1604001396).

Thirty, second parity and older Landrace x Yorkshire sows were enrolled in this study. Sows were assigned to one of three treatments on day 112 of gestation: 1) housed with eight other sows under constant fan noise (GROUP-FAN; $n = 10$), 2) housed alone with fan noise present (ISO-FAN; $n = 10$), and 3) housed alone without fans running (ISO-QUIET; $n = 10$). Sows in ISO-QUIET were housed at the USDA-ARS LBRU Farm Animal Behavior Laboratory in West Lafayette, IN, and ISO-FAN and GROUP-FAN sows were housed at the Purdue University Animal Science Research and Education Center swine farm in West Lafayette, IN. Both facilities are located on the same farm. The ventilation system in GROUP-FAN and ISO-FAN utilized five 14" Turbo Fans (Chore-Time Hog, PigTek Pig Equipment Group, Milford, IN).

All sows were maintained in standard farrowing crates of the same size (0.61×2.29 m) with finger bars. All sows were fed the same controlled diet of total mixed ration in the morning at approximately the same time each day. Piglets were not processed until after the study was complete (3 d of age), and therefore, processing did not interfere with the results. Heat sources were the same between all treatments. Sows farrowed in each environment during the same months to prevent any seasonal effects. Sows did not receive any assistance during farrowing and the first time piglets were physically handled was during the steal events.

Behavior Tests

Behavior testing occurred the day after (at least 24 h later) and 2 d after farrowing (approximately 48 h postfarrowing). On average, the first test occurred 27.7 h after farrowing with a range of 24 to 34 h after completion of farrowing. The second test occurred 24 h after the first test. Tests occurred as follows: an unfamiliar caretaker entered and removed all of the test sow's piglets from the room. Utilizing an unfamiliar caretaker ensured an equal degree of disturbance to all sows, as older sows are familiar with more caretakers on farm. The sow was left without her piglets for 5 min. Observation of removal behavior (REMOVAL) occurred once the first piglet was removed from the farrowing crate until the first piglet was returned to the farrowing crate. During piglet removal, at least one piglet was encouraged to vocalize by holding the piglet on its side while the handler was still near the farrowing crate. Sow behaviors were categorized as described in detail in Table 1, and the duration of

Table 1. Ethogram of sow behaviors observed during REMOVAL and RETURN of piglets

Behavior	Description
Posture	
Standing	All four legs are in contact with the ground and no portion of the abdomen is in contact with the floor
Sitting	Front two legs are in contact with the ground while the hindquarters of the sow maintain contact with the floor
Lying	Ventral or lateral aspect of torso is in contact with the floor and no legs are actively weight bearing
Consuming	
Eating	Head is in feeder
Drinking	Mouth is in contact with nipple waterer
Not consuming	Head is not in contact with feed or water source
Head orientation	
Alert*	Oriented towards handler during REMOVAL or toward the direction the piglets had been removed (i.e., oriented towards door)
Rooting/nosing*	Sow is actively using nose to contact piglet body or using nose to explore the ground of the crate upon piglet removal
Not moving	Maintained in a neutral position
Other	Sow is performing a behavior other than the ones provided here
Initiation of nursing [†]	Time until the sow presented her teats and at least half of the piglets are suckling or massaging the teats

All REMOVAL behaviors were recorded during a 5-min duration starting when the first piglet was removed from the farrowing crate by an unknown handler until the first piglet was returned to the farrowing crate. The RETURN behavior observation was performed for 10 min after the first piglet was returned.

*Behaviors were also calculated as the number of times sows performed each behavior. Rooting/nosing was calculated based on the entire duration of a bout. A bout began when the snout was in contact with either the piglet or the ground and ended when the contact was no longer maintained. Alert behaviors began each time a sow turned her head in the direction of the handler and ended when the animal turned its head in a different direction.

[†]Behavior only observed during RETURN.

each behavior pattern was used to calculate total percentage of time performing each behavior within each category (sum of percentages within each category totaled 100%). Behaviors within each category (posture, consuming, and head orientation) were considered mutually exclusive. Rooting/nosing and Alert behaviors were described in two ways. The number of times sows performed each behavior was calculated, and the percent of time each behavior was performed based on the entire duration of a bout was calculated. A bout began when the snout was in contact with either the piglet or the ground, and ended when the contact was no longer maintained. Alert behaviors began each time a sow turned her head in the direction of the handler and ended when the animal turned her head in a different direction. Video recordings were performed using cameras (Nuvico CB-HD65N-L Bullet camera; Nuvico; Englewood, NJ) which were placed above and directly behind the sow prior to farrowing to maximize viewing area and maintained until the completion of the tests. Once the first piglet was returned to the sow, RETURN behavior observation started and sow behavior was recorded for 10 min. Behavioral observations were the same for RETURN as for REMOVAL (Table 1) with the addition of latency until the sow initiated nursing following the return of her first piglet. All behavioral observations were performed using continuous sampling and analyzed

using a behavioral analysis program (Observer XT, Noldus, Leesburg, VA).

A microphone (SM3, Wildlife Acoustics, Maynard, MA) was placed along the top of each farrowing crate. Audio was collected to evaluate sow vocalization during REMOVAL behavior tests and used to gather the amplitude of the ambient environment audio every 15 min throughout the 48-h sampling period. All sow vocalization variables are outlined in Table 2. Ambient environmental audio was calculated using free software (PRAAT, University of Amsterdam, Amsterdam, The Netherlands) by gathering the overall average dB level across frequencies. Vocalizations were analyzed using audio analysis software (Avisoft-SASLab Pro, Avisoft Bioacoustics, Glienicke, Germany). Number, duration, and interval were measured on all vocalizations produced by the sow, regardless of background noise. However, GROUP-FAN sows were in the presence of other sows during REMOVALS, so only calls which were clearly discernable without other sow or piglet vocalizations were used to calculate mean frequency (Hz), amplitude (dB), and bandwidth (Hz). Calls containing unwanted background noise were determined based on visual and auditory inspection of each call. A total of 30.3% of calls were rejected for further analysis. Bandwidth measures were calculated based on the maximum and minimum frequency for each vocalization. Audio variables

Table 2. Vocalization variables gathered during the REMOVAL of piglets from a sow

Variable	Description
Properties*	
Number, #	Total number of calls performed by a single sow
Duration, s	Amount of time that a call was performed
Interval, s	Time between the beginning of each call
Variables†	
Frequency, Hz	Highest frequency produced above 30 dB averaged across entire call
Amplitude, dB	Loudness at the peak frequency averaged across entire call
Bandwidth, Hz	Difference between the maximum frequency (referred to here as “Frequency”) and minimum frequency averaged across the call

The REMOVAL period was recorded during a 5-min duration starting when the first piglet was removed from the farrowing crate by an unknown handler until the first piglet was returned to the farrowing crate.

*Completed on all recorded calls, regardless of background noise level.

†Mean of call variables were performed only on calls recorded without disrupting background noise (other sows, piglets, or metallic noise from crates) and were analyzed taking an average for each call.

were calculated based on the average across the entire call for a given value. Frequency variables were calculated for frequencies presented above 30 dB. Finally, production variables were collected to include the number of still-born, born alive, and total piglets crushed by the sow within the first 48 h following farrowing.

Statistics

Sows were classified as either YOUNG (second and third parity sows) or OLD (fifth, sixth, and seventh parity sows). Piglets born alive and stillborn piglets were analyzed using the Wilcoxon–Mann–Whitney test statistic. Total piglets crushed were analyzed with a Spearman correlation. All other data were analyzed using a mixed model ANOVA with treatment, REMOVAL/RETURN number (for example, first REMOVAL or second REMOVAL per sow), and parity treated as fixed effects, and the interaction of treatment by parity included in the model. Sow and replicate were random effects. Repeated measures were utilized for vocalizations and behavior observations with sow nested in treatment. Assumptions were checked to ensure a normal distribution, homogeneity of variance, and linearity of the data. Differences between means were measured using Tukey–Kramer honest significant difference and significance was defined when the $P < 0.05$ with tendencies at $0.05 < P < 0.10$.

RESULTS

Production Variables

The environment of the ISO-QUIET sows had the lowest overall dB level compared with the environment of the GROUP-FAN and ISO-FAN ($P < 0.001$) throughout the 48-h time period; however, GROUP-FAN and ISO-FAN environments did not differ from each other (GROUP-FAN: 65.62 ± 1.85 dB; ISO-FAN: 64.26 ± 1.46 dB; ISO-QUIET: 48.90 ± 1.31 dB). A total of 13 sows were OLD and 17 sows were YOUNG. The number of piglets born alive ranged from 3 to 16 with an average of 10.0 ± 0.7 piglets per sow and did not differ with parity or treatment ($P > 0.80$; Table 3). Although treatment did not influence stillborn piglets ($P > 0.10$; Table 3), OLD sows ($P = 0.01$; 1.86 ± 0.29 piglets/sow) had more stillborn piglets than YOUNG sows (0.70 ± 0.29 piglets/sow). In the first 48 h after farrowing, six piglets were crushed by a total of five sows, with no treatment effect ($P = 0.51$, $r = -0.12$) but a tendency ($P = 0.07$, $r = 0.34$) for OLD sows (0.39 ± 0.13 piglets/sow) to crush more piglets than YOUNG sows (0.05 ± 0.11 piglets/sow). On a percentage basis, GROUP-FAN, ISO-FAN, and ISO-QUIET crushed $2.4 \pm 1.6\%$, $1.4 \pm 0.9\%$, and $0.7 \pm 0.6\%$ piglets, respectively ($P = 0.44$, $r = -0.15$).

REMOVAL Behavior

During the REMOVAL, sows spent time lying ($73.72 \pm 4.30\%$), standing ($15.18 \pm 3.82\%$), and sitting ($10.71 \pm 2.30\%$) with no effect of treatment ($P > 0.10$; Table 4), REMOVAL order, litter size, or parity ($P > 0.10$). On average, sows changed posture 1.41 ± 0.23 times per REMOVAL ($P > 0.10$; GROUP-FAN: 1.64 ± 0.47 ; ISO-FAN: 1.28 ± 0.43 ; ISO-QUIET: 1.53 ± 0.45). Overall, sows spent the majority of the time during REMOVAL not consuming feed or water ($92.44 \pm 2.72\%$), without regard to REMOVAL order ($P = 0.43$), treatment ($P = 0.14$; Table 4), or parity ($P = 0.38$). None of the measured variables influenced sow eating or drinking behavior ($P > 0.10$; Table 4).

Most of the time during REMOVAL, sows' head remained not moving ($58.05 \pm 4.66\%$), and this was not affected by treatment ($P = 0.90$; Table 4). The percentage of time and the number of times sows performed Rooting/nosing were not influenced by treatment ($P = 0.17$, 0.25 , respectively; Table 4), parity, or REMOVAL order ($P > 0.10$). There was a tendency for a treatment by parity interaction on the total amount of time sows

performed the Alert behavior, with YOUNG ISO-QUIET sows performing the behavior the most ($P = 0.09$; Figure 1). The YOUNG sows tended to perform Alert behavior more frequently than OLD

sows ($P = 0.07$; Figure 2). There was no influence of treatment on total time spent performing Other behaviors ($P > 0.10$; Table 4).

Table 3. Farrowing production variables

Variable	Treatment*			P value
	GROUP-FAN	ISO-FAN	ISO-QUIET	
Born alive (#)	10.20 ± 3.33	11.20 ± 3.94	9.90 ± 3.48	0.70
Stillborn (#)	1.30 ± 1.34	1.20 ± 1.23	1.10 ± 1.37	0.83
Crushed (#)	0.30 ± 0.67	0.20 ± 0.42	0.10 ± 0.32	0.55

*Sow treatments were assigned as follows: 1) housed with eight other sows under constant fan noise (GROUP-FAN; $n = 10$), 2) housed alone with fan noise present (ISO-FAN; $n = 10$), and 3) housed alone without fans running (ISO-QUIET; $n = 10$).

REMOVAL Audio Response

All vocalization data are presented in Table 5. The number of vocalizations performed tended to be higher in the first REMOVAL ($P = 0.06$; 51.64 ± 8.95 vocalizations) than the second REMOVAL (39.56 ± 9.43 vocalizations) regardless of treatment or parity ($P > 0.10$). Duration of each vocalization and intervals between vocalizations did not change with treatment, REMOVAL order, or parity ($P > 0.10$). Frequency also did not

Table 4. Behavior results during REMOVAL and RETURN of piglets

Variable	Treatment*			P value
	GROUP-FAN	ISO-FAN	ISO-QUIET	
REMOVAL				
Posture				
Standing, %	17.9 ± 8.2	16.4 ± 7.8	12.5 ± 8.4	0.89
Sitting, %	12.0 ± 4.7	9.8 ± 4.5	11.1 ± 4.9	0.95
Lying, %	68.4 ± 8.8	73.5 ± 8.1	79.9 ± 8.7	0.77
Consuming				
Eating, %	3.2 ± 5.0	11.8 ± 4.3	1.1 ± 4.4	0.14
Drinking, %	3.8 ± 1.8	2.0 ± 1.6	0.6 ± 1.6	0.33
Not consuming, %	92.9 ± 5.9	85.3 ± 5.2	98.8 ± 5.3	0.14
Head orientation				
Alert, %	10.2 ± 3.8	16.6 ± 3.6	21.4 ± 3.9	0.13
Alert, #	3.7 ± 0.9	3.5 ± 0.8	5.6 ± 0.9	0.18
Rooting/nosing, %	6.5 ± 1.7	2.6 ± 1.6	3.5 ± 1.8	0.25
Rooting/nosing, #	2.4 ± 0.6	0.9 ± 0.5	1.7 ± 0.6	0.17
Not moving, %	57.2 ± 8.8	55.1 ± 8.4	60.8 ± 9.0	0.90
Other, %	26.9 ± 7.0	26.3 ± 6.4	13.8 ± 6.7	0.27
RETURN				
Posture				
Standing, %	15.2 ± 7.5	21.6 ± 6.7	11.3 ± 6.8	0.51
Sitting, %	2.9 ± 2.1	2.1 ± 2.0	7.6 ± 2.1	0.15
Lying, %	80.8 ± 7.4	76.4 ± 6.7	80.8 ± 6.9	0.87
Consuming				
Eating, %	7.6 ± 5.4	13.6 ± 4.9	4.4 ± 5.0	0.39
Drinking, %	2.1 ± 0.8	1.0 ± 0.8	1.0 ± 0.8	0.51
Not consuming, %	89.8 ± 5.5	85.6 ± 5.0	94.7 ± 5.2	0.42
Head orientation				
Alert, %	2.6 ± 0.9	2.9 ± 0.8	4.1 ± 0.8	0.34
Alert, #	1.6 ± 0.5	2.0 ± 0.4	2.5 ± 0.4	0.31
Rooting/nosing, %	10.8 ± 3.0	17.3 ± 2.9	16.0 ± 3.1	0.29
Rooting/nosing, #	7.8 ± 1.5	10.2 ± 1.4	9.6 ± 1.5	0.48
Not moving, %	55.4 ± 8.9	43.5 ± 8.2	50.6 ± 8.5	0.61
Other, %	31.7 ± 7.1	36.5 ± 6.7	28.9 ± 6.9	0.72
Initiation of nursing, s	311.6 ± 61.7	355.2 ± 59.7	216.6 ± 63.2	0.29

All REMOVAL behaviors were recorded during a 5-min duration starting when the first piglet was removed from the farrowing crate until the first piglet was returned to the farrowing crate. The RETURN behavior observation was performed for 10 min after the first piglet was returned.

*Sow treatments were assigned as follows: 1) housed with eight other sows under constant fan noise (GROUP-FAN; $n = 10$), 2) housed alone with fan noise present (ISO-FAN; $n = 10$), and 3) housed alone without fans running (ISO-QUIET; $n = 10$).

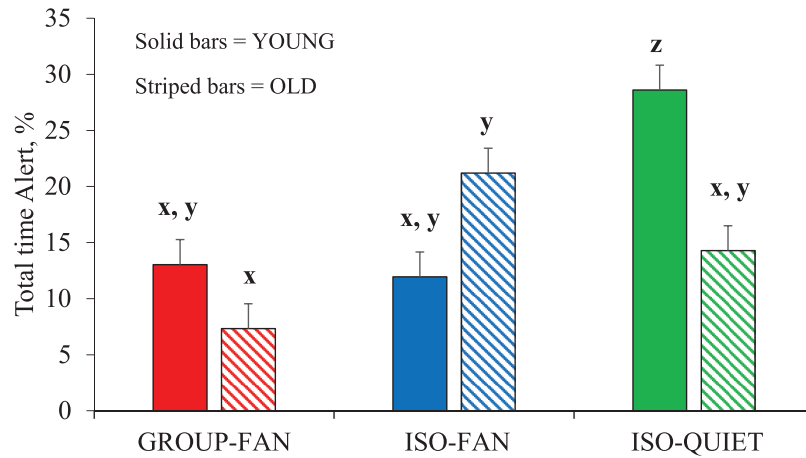


Figure 1. Total time Alert (head oriented towards handler during REMOVAL or toward the direction the piglets had been removed) during the REMOVAL in the parity by treatment interaction. The REMOVAL period was recorded during 5 min starting when the first piglet was removed from the farrowing crate until it was returned to the farrowing crate. Sows farrowed: 1) housed with eight other sows under constant fan noise (GROUP-FAN), 2) housed alone with fan noise present (ISO-FAN), or 3) housed alone without fans running (ISO-QUIET). Parities were characterized as either YOUNG sows (second and third parity) or OLD sows (fifth, sixth, and seventh parity). Bars with different superscripts indicate a tendency ($P = 0.09$).

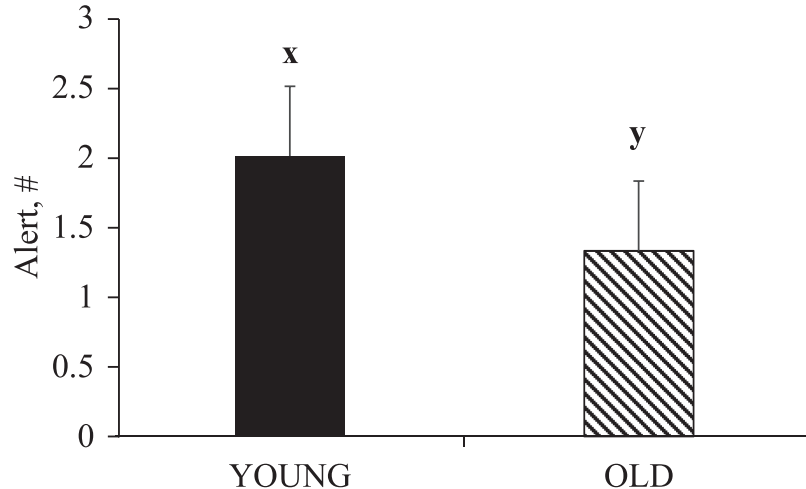


Figure 2. Total number of Alert (head oriented towards handler during REMOVAL or toward the direction the piglets had been removed) during the REMOVAL by parity of sow. Parities were characterized as either YOUNG sows (second and third parity) or OLD sows (fifth, sixth, and seventh parity). The REMOVAL period was recorded during a 5-min duration starting when the first piglet was removed from the farrowing crate by an unknown handler until the first piglet was returned to the farrowing crate. Bars with different superscripts indicate a tendency ($P = 0.07$).

differ with treatment, REMOVAL order, or parity ($P > 0.10$). A 1-dB difference in amplitude could be observed between the first and second REMOVAL ($P < 0.001$; 70.49 ± 0.60 and 71.67 ± 0.62 dB, respectively). Additionally, QUIET sows vocalized the quietest, compared with ISO-FAN and GROUP-FAN sows ($P < 0.01$; Table 5). A treatment by parity interaction occurred with OLD ISO-QUIET sows vocalizing quieter than OLD ISO-FAN and YOUNG GROUP-FAN, with OLD GROUP-FAN, YOUNG ISO-FAN, and YOUNG ISO-QUIET as intermediaries ($P = 0.04$; Figure 3). Finally, the bandwidths for vocalizations were wider by 263.58 Hz in the first REMOVAL ($1,815.56 \pm 167.13$ Hz) than in the second REMOVAL ($1,551.98 \pm 168.84$ Hz;

$P < 0.01$), irrespective of treatment ($P = 0.14$; Table 5) or parity ($P = 0.71$).

RETURN Behavior

Sitting behavior was only different by parity ($P = 0.01$), with YOUNG sows ($7.48 \pm 1.61\%$) spending more time sitting than OLD sows ($0.91 \pm 1.77\%$). Standing and lying behaviors were not affected by treatment ($P > 0.10$; Table 4); however, treatment ($P = 0.06$) tended to affect the number of posture changes. The ISO-QUIET sows had the most posture changes (1.61 ± 0.35), ISO-FAN sows had the least (0.44 ± 0.34), and GROUP-FAN sows performed intermediary (1.23 ± 0.38). Standing, lying, and posture changes were not

Table 5. Call properties measured per call by the sow during the REMOVAL of piglets

Call property	Treatment*			P value
	GROUP-FAN	ISO-FAN	ISO-QUIET	
Number, #	32.82 ± 14.83	39.81 ± 15.60	64.16 ± 14.62	0.31
Duration, s	0.28 ± 0.02	0.24 ± 0.02	0.26 ± 0.02	0.37
Interval, s	13.30 ± 3.70	14.46 ± 3.73	7.46 ± 3.37	0.33
Frequency, Hz	306.92 ± 69.30	454.70 ± 70.28	362.26 ± 65.30	0.34
Amplitude, dB	72.22 ± 1.06 ^a	73.61 ± 1.07 ^a	67.41 ± 0.99 ^b	0.001
Bandwidth, Hz	2,151.02 ± 290.14	1,553.10 ± 296.67	1,347.19 ± 277.67	0.14

The REMOVAL period was recorded during a 5-min duration starting when the first piglet was removed from the farrowing crate until the first piglet was returned to the farrowing crate.

*Sow treatments were assigned as follows: 1) housed with eight other sows under constant fan noise (GROUP-FAN; $n = 10$), 2) housed alone with fan noise present (ISO-FAN; $n = 10$), and 3) housed alone without fans running (ISO-QUIET; $n = 10$).

^{a,b}Superscripts in the same row differ.

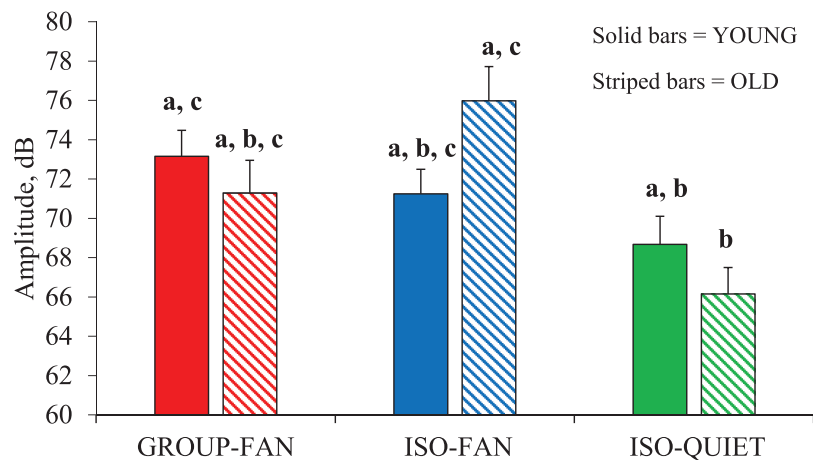


Figure 3. Amplitude (dB) of vocalizations by sows during piglet REMOVAL with the treatment by parity interaction. The REMOVAL period was recorded during a 5 min starting when the first piglet was removed from the farrowing crate by an unknown handler until it was returned to the farrowing crate. Sows farrowed: 1) housed with eight other sows under constant fan noise (GROUP-FAN), 2) housed alone with fan noise present (ISO-FAN), or 3) housed alone without fans running (ISO-QUIET). Parities were characterized as either YOUNG sows (second and third parity) or OLD sows (fifth, sixth, and seventh parity) in each treatment. Bars with different superscripts indicate a difference ($P < 0.05$).

affected by age of sows or order of RETURNS ($P > 0.10$). Time spent eating, drinking, or time until nursing did not vary with parity ($P > 0.10$), RETURN order ($P > 0.10$), or treatment ($P > 0.10$; Table 4).

During RETURN of piglets, the number of times sows performed Alert behavior did not differ across treatments ($P > 0.10$; Table 4), whereas the percent of time Alert was higher in the first RETURN ($3.86 \pm 0.60\%$) than in the second RETURN ($2.55 \pm 0.60\%$; $P = 0.03$). Additionally, there was a tendency for parity to affect time performing Alert behavior ($P = 0.06$), with OLD sows ($2.34 \pm 0.70\%$) spending almost half of the time spent by YOUNG sows ($4.07 \pm 0.67\%$). No differences were observed for percent time Rooting/nosing or the number of Rooting/nosing attempts, percent time performing Other behaviors, or Not moving regardless of treatment, parity, or RETURN order ($P > 0.10$; Table 4).

DISCUSSION

During this study, older sows crushed more piglets than younger sows, regardless of treatment. Others (Jarvis et al., 2005; Li et al., 2010) have reported increased piglet mortality and crushing with increasing age of sows. Sows above fourth parity may physically struggle to react appropriately as older sows are larger in size and have greater difficulty in changing posture from standing to lying and back to standing (Marchant and Broom, 1996; Marchant et al., 2000).

The current study tested the sows' reactivity to their piglets being removed and then returned by an unknown handler. Piglet-directed behavior by the sow during a single removal of piglets reflects the sows' reactivity to a piglet in danger and can be used as an indicator of sow maternal ability throughout an entire lactation (Andersen et al., 2005; Grimberg-Henrici et al. 2017). Indeed, sows will react consistently in different sow-piglet

reaction tests throughout lactation (Pitts et al., 2002). In the current study, sow Alertness, Rooting/nosing, and vocalizations were measured during REMOVAL and RETURN with the hopes of assessing the influence of the auditory environment on a sow's response to a piglet in danger, such as a crushing event.

Sows in the ISO-QUIET treatment tended to have more posture changes during the RETURN than sows in other treatments. Sows who are more reactive to small and disadvantaged piglets (Weary et al., 1996) and who do not crush their offspring were shown to be more restless when their piglets are removed or disturbed (Andersen et al., 2005). It is possible that by placing sows in a quieter environment, without other sows or ventilation noise, they are more aware of the general location of their piglets. Increasing sow awareness to piglets has the potential to increase piglet liveliness, as sows performing a greater number of posture changes during early lactation has been associated with less piglet crushing events (Valros et al., 2003).

Searching behavior in sows can also provide valuable insight into a sow's maternal ability as amount of time alert and nosing attempts demonstrate a stress response to piglet removal (Grimberg-Henrici et al., 2017). The YOUNG ISO-QUIET sows performed more Alert behaviors than sows from any other treatments during the REMOVAL of piglets. Overall, YOUNG sows performed more Alert behaviors than OLD sows during the RETURN, showing greater interest in piglets care. Others have also found a decrease in reactivity to piglets with an increase in sow parity (Held et al., 2006). The fact that during both RETURN observations, YOUNG sows spent more time sitting than OLD sows could be beneficial because sows which are reactive to a piglet distress call are quicker to sit or stand up (Hutson et al., 1993). Younger sows appeared to be more aware of their piglets' presence in the farrowing pen and may therefore further benefit from being in a quiet environment without sow or ventilation noises.

Latency to initiate a nursing during the RETURN was not affected by sow environment. Increased attempts by the sow to begin nursing is another strong indicator of maternal care (Grimberg-Henrici et al., 2017) and interfering with this process may lead to decreased liveliness of piglets. Fan noise was shown to interfere with sow grunting patterns, milk letdown, and teat stimulation during the first 3 d after farrowing (Agers and Jensen, 1985; Agers and Jensen, 1991). Grunting is associated with the initiation of milking by the sow

(Agers and Jensen, 1985); therefore, it stands to reason that minimizing any interference with this signal would improve the sow-piglet relationship. However, Johnson and others (2001) have previously demonstrated that sows which farrow outside in a hut do not differ in nursing interval from those which are farrowed inside surrounded by other sows. Other studies have also reported that sows initiate a nursing about 3 to 5 min after the return of their piglets regardless of any treatment (Andersen et al., 2005). It may be that the variability in individual sow nursing behavior could make it difficult to detect any differences due to treatment and that a larger sample size would have been required.

Sows which farrowed with other sows and background fans or with just background fans vocalized louder than sows which farrowed in the quietest environment. Sows in the ISO-QUIET treatment were given an opportunity to bond with their piglets without interference from the mechanical noise or noise produced by other sow-piglet pairs. It was expected that sows which had the opportunity to develop a bond with their piglets in the quiet environment would experience greater distress during the piglet REMOVAL and would attempt to communicate louder. However, it also stands to reason that sows will vocalize in an optimal way in their environment, as was the case in our study for amplitude. The ISO-FAN and GROUP-FAN sows vocalized louder than ISO-QUIET sows. This could indicate that sows in both treatments were competing against mechanical ventilation or other sow piglet noise when attempting to vocalize, as overall ISO-FAN and GROUP-FAN treatments were similar for overall ambient environmental amplitude. However, the difference between ISO-QUIET and ISO-FAN or GROUP-FAN was small (about a 6-dB difference) and possibly does not contain great biological significance, as the relationship between piglet crushing and sow vocalization has been met with mixed results (Melišová et al., 2011; Grimberg-Henrici et al., 2016).

Overall, vocalization properties were different between the first and second REMOVAL. Sows called more frequently and calls contained a wider bandwidth in the first REMOVAL. In piglets, a common property of alarm calls is a wider bandwidth (Iacobucci et al., 2015). The change in bandwidth and call number observed in this study could demonstrate a decrease in sow reactivity to piglet REMOVAL and RETURN in the second test. Tests were performed 2 d in a row because sows can require up to a full day to readily identify their own piglets (Horrell and Hodgson, 1992).

Pigs do not differentiate well between humans (Hemsworth et al., 1996); therefore, it is possible the negative interaction with a human during a removal is complemented with positive interactions with a human during feedings. And, overtime, the changes in vocalization variables in this study suggest that sows may have become more accustomed to having humans near her piglets from the first to second REMOVAL.

Finally, individual sows can vary greatly in maternal care, making predicting maternal ability quite difficult. Andersen et al. (2005) found strong individual behavioral differences between sows which are crushers from noncrushers of piglets during a separation and reunion test. Individuals varied in distress call response, nosing and rooting behavior, and activity. These individual differences in maternal responsiveness behavior likely play a large influence in piglet crushing and piglet care.

CONCLUSION

As sows reside constantly in noisy facilities, it is likely that current noise levels have a negative impact on sow communication. However, in which ways remain somewhat inconclusive. Sows will vocalize louder in the presence of background noise and may benefit from environments designed to minimize the amount of background noise which interferes with communication between sows and piglets. Younger sows specifically may benefit from a quieter environment immediately following farrowing. Further research should be focused in minimizing noise produced by mechanical ventilation. Decreased interference between a sow and her piglets may result in better communication, which has the potential to result in less piglet crushing.

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