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Gilts are motivated to exit a stall

Thomas Ede✉ & Thomas D. Parsons

Stalls (or crates) are still a common type of housing in the swine industry, despite public concern and regional legislation restricting their use. In this study, we examined the motivation of gilts to exit a stall. Sixteen stall-naïve gilts (Large White x Landrace) were locked for 60 min in a gestation crate that had been mounted with a novel apparatus allowing continuous monitoring (2 Hz measuring frequency) of the force applied to its back gate by the animal. Raw force measurements were low-pass filtered and discrete pushing events identified via local maxima. All gilts displayed some level of motivation to exit the crate, ranging from 41 to 173 in the number of pushing events, as well as exerting a maximum force applied from 124 to 645 N. A hierarchical cluster analysis applied to the median and interquartile range (IQR) of force generated during individual pushing events yielded two behavioural profiles. One group of eight animals was more active than the other. This group exhibited a greater number of pushes, recorded a higher maximum, median force and its IQR, as well as a shorter time interval between two pushes (all t-tests with a $P < 0.05$). While all these naïve animals worked to leave the stall, gilts displayed different motivation profiles in trying to exit the stall consistent with a reactive/proactive framework. Taken together these findings provide further evidence to support stall confinement as aversive to swine but highlight the complexities in understanding and improving pig welfare.

Crates or stalls are prevalent in pig farming and while facilitating animal management they can be highly restrictive to pigs. Crates used in breeding and gestation are usually 60 to 70 cm in width and prevent even simple movements like turning around. Changes in legislations and marketing initiatives aiming to refine or move away from this practice altogether have been gaining momentum in Europe, North America, Australia and New Zealand (for a review see Plush et al.[1]), but crating – even if only temporary – remains common in the industry.

With instances of public opinion rejecting crate confinement[2], there is a need for animal-based data to assess its impact on animal welfare. Scientific interest for crate confinement is not new, but previous efforts have mainly focused on physiology, oral-nasal-facial behaviors, productivity or reproductive performance, which have yielded mixed results on the welfare effects of stalls[3,4]. In the past several years, the literature has integrated affective states[5,6] (i.e. the emotional component of responses characterized by valence and arousal) with attempts to include animals' perspectives in assessments of animal welfare. Recently, gilts were reported to display a clear preference for an open area over crates[7], but this study provided a free-access system where animals could go in and out of crates as they pleased. Unfortunately, a free-access system is not representative of the conditions in which most stalled pigs are housed, where they are confined to their enclosure. Gilts spend less time in a stall when they can exit it, but what is their response to inescapable confinement?

To answer this question, motivation paradigms provide a valuable complement to preference studies[8,9]. Operant responses, or the amount of work an animal is willing to do in order to obtain or avoid a resource has been implemented in many contexts. For example, previous research has studied the number of button presses or levers lifts produced by pigs to measure their motivation for food[10–12], environmental enrichment[13], nest-building materials[14] or exercise opportunity[15,16]. In other species, push-gates (or doors) have been applied to measure the work-rate or maximum price paid for resources such as food[17,18], a nest-box[19], a social partner[20], a bedded area[21] or pasture access[22]. To our knowledge, the measurement of force has seldom been used in the study of pig motivation.

In addition to the growing interest in affective states, an emphasis on individual differences, personalities and coping styles has developed[23–25], shifting from a sole focus on population-based measures. Individual differences have been reported in gilts in their preference between short and long confinement[26], and in their preference between crates and an open area[7], but little is known about pig's motivational differences.

The objectives of this study are two-fold. First, we aim to evaluate the motivation of naïve gilts to escape a stall during short-term confinement via a novel measuring apparatus allowing continuous monitoring of escape attempts. Our second objective is to assess inter-subjects variability in response to confinement and characterize—if applicable—the different motivation profiles.

Department of Clinical Studies, University of Pennsylvania School of Veterinary Medicine, 505 Byrd Road, Kennett Square, PA, USA. ✉email: tede@vet.upenn.edu

Methods
Animals and apparatus
This study was conducted at the Penn Vet Swine and Research Center in Kennett Square, Pennsylvania, USA. Routine practice followed Global Animal Partnership's Animal Welfare standards[27]. All experimental animal procedures were approved by the University of Pennsylvania's Institutional Animal Care and Use Committee (Protocol #804656) and were performed in accordance with our IACUC guidelines and regulations. Reporting was done in accordance with ARRIVE guidelines.

Sixteen Large White x Landrace (T70 sow line, Norsvin/Topigs) gilts naive to stalls were enrolled at 268 ± 44 d old. Gilts were housed in a 164 m^2 open pen with other gilts at ~ 2.7 m^2/head and fed via an electronic automatic feeder (Schauer Compident Electronic Sow Feeding system, Prambachkirchen, Austria). Water was available *ad libitum*. At approximately 11 am (SD ± 2 h), gilts were brought individually to a 1.9 × 0.6 m a free-access stall and led inside the stall with grain sprinkled on the floor (Kalmbach P200NGM 12% protein Natural Sow Gestation Meal, Chambersburg, Pennsylvania, USA). The rear gate of the stall was closed once the gilt was fully in, and she was left in the stall for a 60 min study period. Only one animal was tested at a time. The testing crate was located in the main barn, enabling olfactory, auditory and partial visual contact with other pigs.

The free access stall (Schauer Self-Catching Gestation Stall, Prambachkirchen, Austria) was designed to allow animals to enter and exit the stall on their own. However, this stall was modified to allow electronic control of the animals' exit once they had entered the stall (Fig. 1A). An electromagnetic lock (V2M1200 Maglocks, Securitron, Phoenix, Arizona, USA) was used to hold the stall closed when activated. A load cell (RAS1 S-Beam, LoadStar Sensors, Fremont, California, USA) was placed in line with the electromagnetic lock to measure the forces generated by the gilt as she was trying to leave the stall. The opening threshold was set at 4000 N to prevent gilts from exiting the stall. No animal reached this ceiling, and no positive feedback was provided (i.e. the electromagnetic lock did not allow the gate to move). A custom designed steel assembly (72 × 44 × 36 cm) was bolted to the crate that housed both the electromagnet and the load cell as well as controlling electronics (NextFab, Philadelphia, PA; Fig. 1B). Force data from the load cell was sampled at a 2 Hz rate via a digital interface module (DI-100U, Loadstar sensors, Fremont, California, USA) and stored on a laptop computer (Dell Latitude 5430 Rugged laptop, Round Rock, Texas, USA) using the ControlVUE data recording software (LoadStar Sensors, Fremont, California, USA).

Data processing and analysis
Raw data was composed of the forces generated by the animals as well as higher frequency technical noise (i.e. small contaminant random variations) arising from the recording electronics (Fig. 2A). To facilitate the analysis of the animal components of the data, the spectral density of force data was estimated with an autoregressive model[28] to determine the optimal cut-off for low pass filtering in order to remove high frequency noise. The frequency threshold was taken to be 0.1 Hz by visual inspection. Data was transformed using a digital Butterworth low-pass filter[29] and filtered data was used in all subsequent data analysis and presentations (Fig. 2B).

To quantify gilts' escape behaviors, discrete pushing events were identified using local force maxima as a proxy. A local maximum was defined as a measure superior to the previous 6 and subsequent next 6 measures (with a sampling rate of 2 Hz, this approximates to 3 s before and after a given time point), with a difference of at least 10 N for at least one measure before and after (Fig. 2C). To avoid the non-detection of 'slow rise' or 'slow release' pushes, a local maximum was considered a pushing event if its apex was clearly above noise (266 N [60 lbf]).

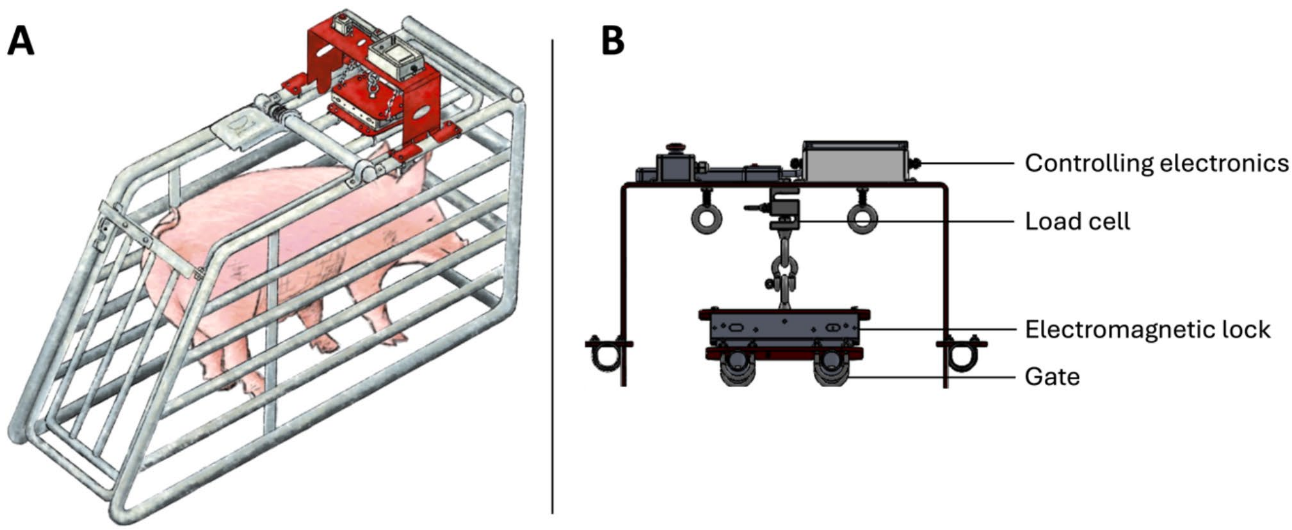

Fig. 1. Overview of the experimental apparatus (**A**) and rendering of the force meter (**B**). Drawing by Sophi Ali (independent illustrator).

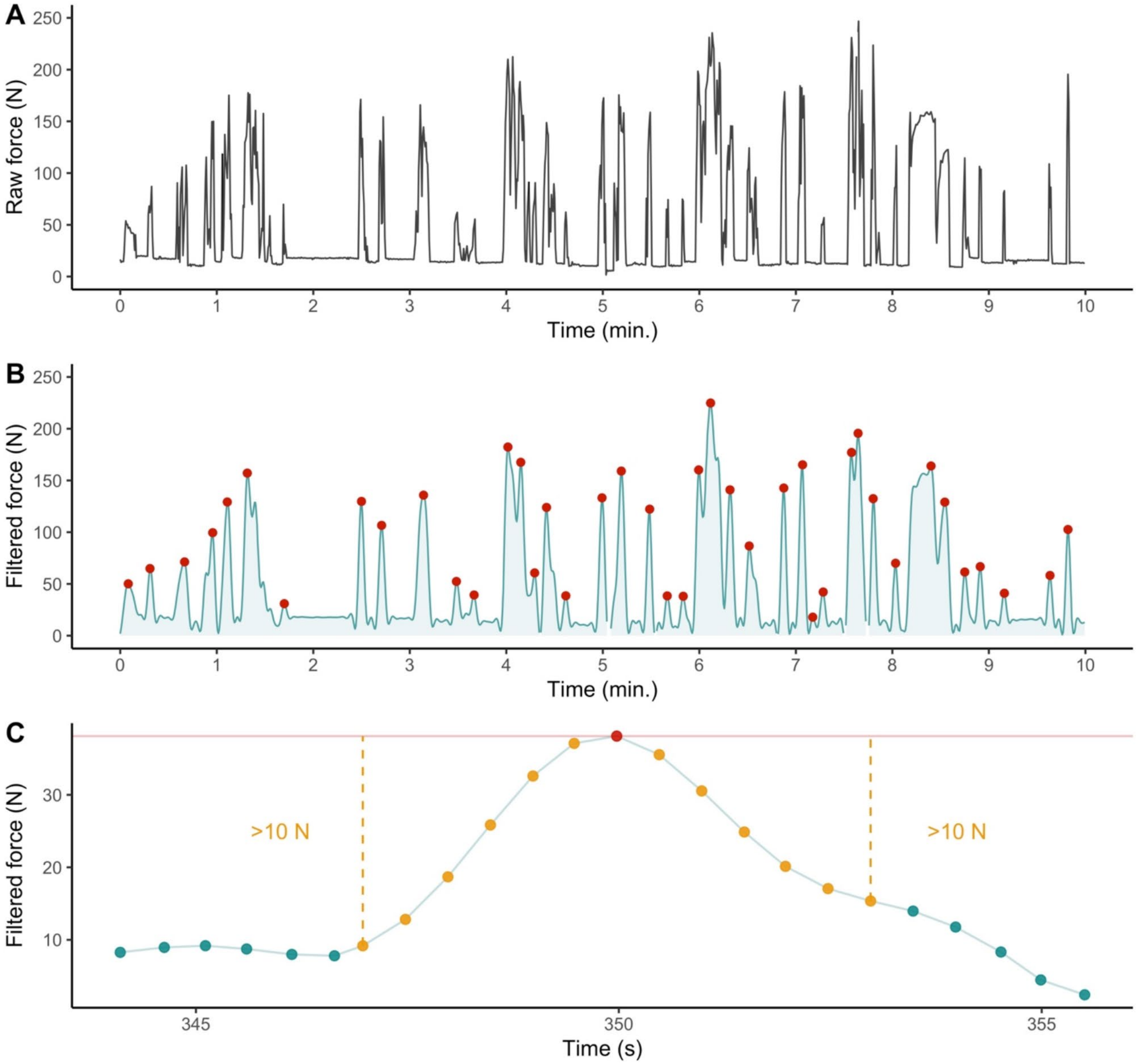

Fig. 2. Example of raw force data collected (without removal of high frequency technical noise) (**A**), its transformation by Butterworth low-pass filter (**B**) and an example of a pushing event (**C**). Data is extracted from the first 10 min for gilt 5454. The blue shaded area in (**B**) represents the Area Under the Curve. Red dots in (**B**) and (**C**) represent pushing events. In (**C**), the pushing event is defined by a superior value to its 6 preceding and following force measures (orange dots), with at least one measure before and after above a 10 N difference.

Reliability between visual and algorithm-based identifications of pushing events was conducted on 20 pseudo-randomly selected 100 s data epochs (one section from each gilt, with at least one pushing event detected) totaling in 2000 s of observations. Pushing events were identified manually, then accordance with algorithm-based detection was calculated. The sensitivity [True positive/(True positive + False negative)] of the algorithm was 94.0%, and its specificity [True negative/(True negative + False positive)] 99.7%.

For each gilt, the median and interquartile range (IQR) of the force applied during a pushing event was calculated. A hierarchical cluster analysis was conducted on these values to investigate groupings in gilts' behavioural profiles in response to confinement without a pre-defined number of outcomes. The optimal number of k-means clusters was determined to be 2 using the *fviz_nbclust* function from the *factoextra* R package[30]. Two main clusters of 8 gilts each were yielded by dendrogram. Differences between the two clusters on other summary measures (total number of pushes, maximum force applied, area under the curve (force integrated over time: impulse), average time between two pushes, time of first push and time of last push) were tested with t-tests.

Results

All gilts exerted some level of force on the stall. Descriptive results are detailed for all gilts in Table 1 (median, IQR and maximum force applied, number of pushes, AUC, times of first, last and between pushes). Ranges highlight that even the least active gilts still pushed a minimum median of 53.8 N and made at least 41 attempts (reaching a minimum peak force of 124 N). All gilts were quick to produce their first push (all under 4 min.) and kept pushing until at least 28 min. The high coefficients of variation and ranges for all measures indicate gilts displayed different profiles in their force applied on the stall over time (Fig. 3).

Cluster analysis on median forces applied during pushing events and their IQR yielded two clusters of 8 animals each (clusters "*Low*" and "*High*"), with distinct force distributions (Fig. 4). Although all gilts applied some level of force on the stall, gilts from the *High* cluster had a higher median force (*Low* = 66.1 N, *High* = 136.6 N, t = 5.4, P < 0.001, CI = 45.6, 95.3 N) and IQR during pushing events (*Low* = 43.2 N, *High* = 106.8 N, t = 5.4, P < 0.001, CI = 36.3, 90.8 N), as well as a higher number of pushes (*Low* = 61.3, *High* = 104.4, t = 2.7, P = 0.03, CI = 6.5, 79.8), maximum force applied (*Low* = 201.3 N, *High* = 394.6 N, t = 3.4, P = 0.005, CI = 70.6, 316.1 N), area under the curve (*Low* = 72974, *High* = 129182, t = 3.1, P = 0.01, CI = 15221, 97194) and a lower time interval between pushes (*Low* = 53.0 s, *High* = 34.8 s, t = -2.4, P = 0.03, CI = -34.1, -2.1 s). Gilts from the *High* cluster tended to have a lower time to apply their first push (*Low* = 61.3 s, *High* = 11.3 s, t = -2.0, P = 0.08, CI = -108.8, 8.6 s) (Fig. 5). No differences between the two clusters were found in the time of the last push (*Low* = 51.5 min, *High* = 53.1 min, t = 0.3, P = 0.7, CI = -8.6, 11.9 min).

Discussion

All gilts applied force against the back gate of the stall during a 60-minute period of confinement. These animals produced at least 41 pushing events, all had their first push within 4 min of confinement, the maximum amount of force generated during a single push was 645 N, and most animals were still attempting to escape at the end of the trial.

Our results are consistent with other reports that sows display some level of motivation to exit their stall for a 3-min exercise opportunity[15], and that gilts prefer an open area over a stall when free-access is available[7]. However, as previously noted, preferences are relative and might reflect a weak but consistent inclination (like "grapes over cherries" as put by Fraser and Matthews[8]). With our results indicating gilts will work strongly and persistently to exit a stall, it suggests that gilt's preference to avoid stalls is not weak, but that confinement – even for a short period – is most likely an unwanted experience for naïve gilts.

The second finding from this study is that short-term confinement elicits different escape strategies from gilts. Although all individuals were motivated to exit the stall, their motivation profiles appeared to split evenly between two clusters: very active (*High*) which produced harder, faster, and more frequent pushes compared to a less active group (*Low*). This is consistent with a previous report of sows being classified as high or low resistance in the first 2 h of being tethered[31]. This two-way split is also in accordance with the common separation between proactive vs. reactive coping styles[32], a framework that has been applied to pigs[24]. Within this framework, individuals are characterized by their strategic approach to challenges. Proactive individuals are associated with active strategies (e.g. rodents burying an electric prod to avoid shock), whereas reactive individuals adopt a more passive style (e.g. hiding from the electric prod) (see Koolhaas et al.[32]). In pigs, coping style is usually evaluated by holding the animal on its back and noting the amount of resistance[24]. However, limitations of the reactive/proactive hypothesis in predicting pig's coping responses has been noted[24,33,34]. Specifically, Jensen et al.[35] commented that when discussing active/passive coping styles in piglets, grouping in 2 clusters might be an oversimplification. We hoped to avoid misrepresenting the potential complexity of behavioural profiles by using hierarchical clustering without an a priori assumption about the number of outcomes. While this unbiased approach still yielded two clusters, the gilts' responses were not purely dichotomous (Figs. 3 and 4), and perhaps reflect a spread along a bimodal continuum. Furthermore, our limited sample size may have constrained the number of clusters extracted. We do not consider our division in two clusters as definitive, but rather an appropriate starting point in considering the diversity of motivation profiles in pigs.

The gilts' motivation to exit the stall reported here suggests a negative affective state associated with confinement, consistent with previous research noting that gilts will choose to be confined for 30 min instead of 4 h[26]. However, we cannot conclude from these findings whether the welfare of animals from one cluster was more impacted than the other despite the observed differences in their behaviors. Intuitively, we could speculate

Measure	Mean ± SD	CV (%)	Range
Median force (N)	101.3 ± 42.1	41.5	53.8–183.6
IQR force (N)	75.0 ± 39.9	53.2	32.3–165.4
Number of pushes	82.8 ± 38.5	46.5	41–173
Max. force (N)	298.0 ± 147.5	49.5	124.0–645.3
AUC (Ns)	101,078 ± 45,386	44.9	41,648–190,469
Time between pushes (s)	43.9 ± 17.2	39.2	20.0–79.7
Time first push (s)	36.3 ± 54.7	150.8	5.0–217.0
Time last push (min)	52.3 ± 9.2	17.6	28.0–59.7

Table 1. Descriptive results of force applied on a stall over a 60 min period for gilts ($n = 16$). SD: standard deviation, CV: coefficient of variation (SD/Mean), AUC: area under the curve.

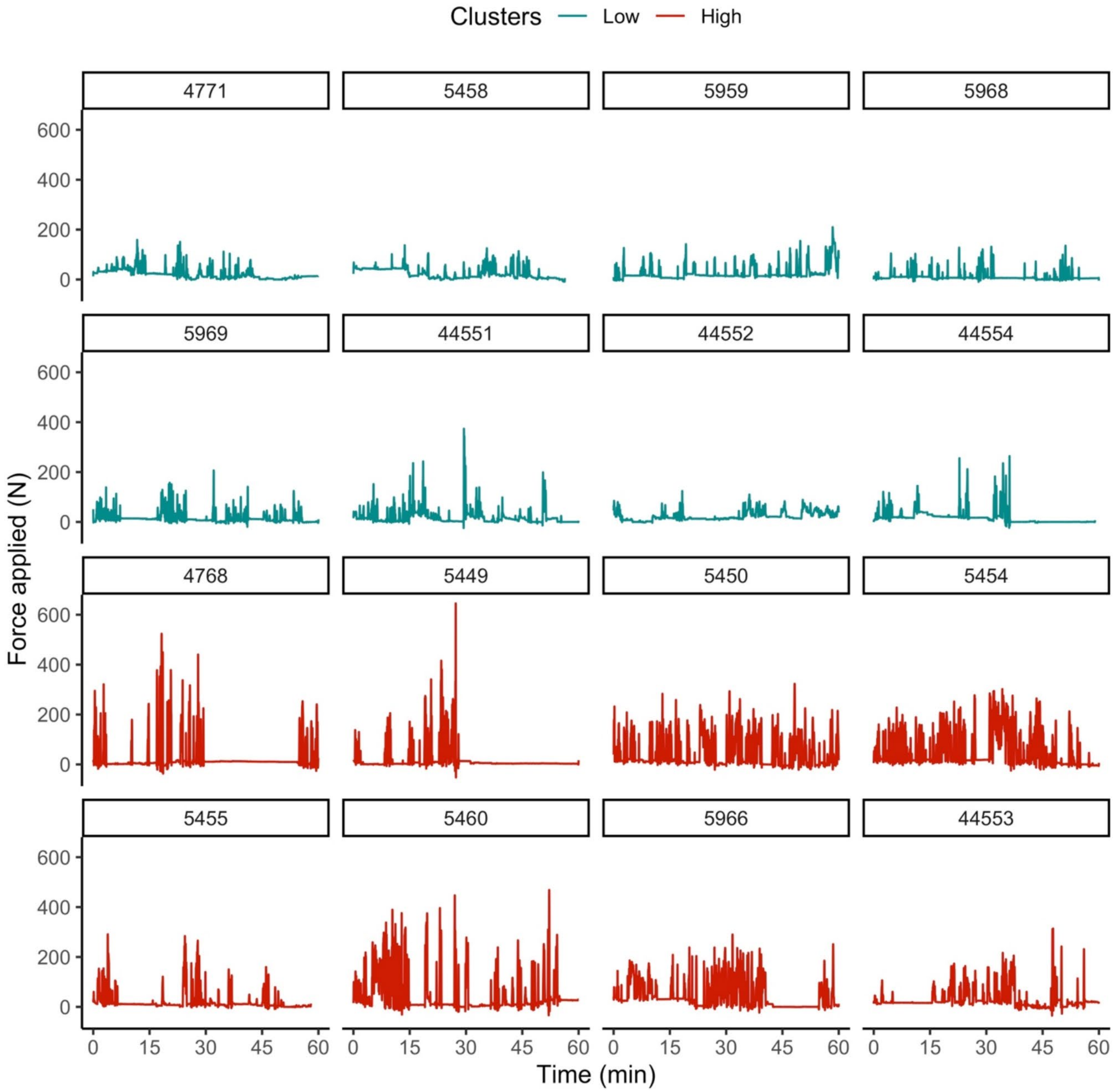

Fig. 3. Force applied on the crate by each gilt over 60 min after confinement. Presented data was processed with a low-pass Butterworth filter.

that gilts from the *High* cluster (more active, producing more force) were more motivated to exit the stall, hence had worse welfare in response to confinement. However, pigs classified as reactive have been observed to be more impacted by their environment than proactive pigs, and more generally, the interaction between housing and personality or coping style is still unclear (see review by O'Malley et al.[24]). Furthermore, as noted by Franks[36] when discussing safety-maintenance behaviours in rats, an observed lack (or in our case, lower) motivation to engage in a behaviour could reflect dysfunction and poorer welfare rather than an absence of interest in the behaviour. For example, animals with highly compromised welfare can exhibit anhedonia (i.e. a decreased sensitivity to pleasurable rewards)[37] or learned helplessness (i.e. "giving up" escape attempts from unavoidable negative experiences)[38]. One would expect that such states might develop from prolonged poor welfare and thus it is interesting to ponder how to interpret the two gilts in this study that stopped their exit attempts after only 30 min of confinement (ID #5449, #44554, in Fig. 4).

The scope of this study was limited to gilts' first experience with stalls and restricted to a short-term 60-minutes of confinement. However, pigs on farms using crates likely will be exposed to much longer bouts of confinement such as days, weeks or months. Prior stall experience has been observed to influence motivation for feed (but surprisingly, not for an exercise opportunity)[16], and gilts' aversion to stalls decreased with time of exposure when free-access to an open area was available[7]. It remains unclear whether previous experience with

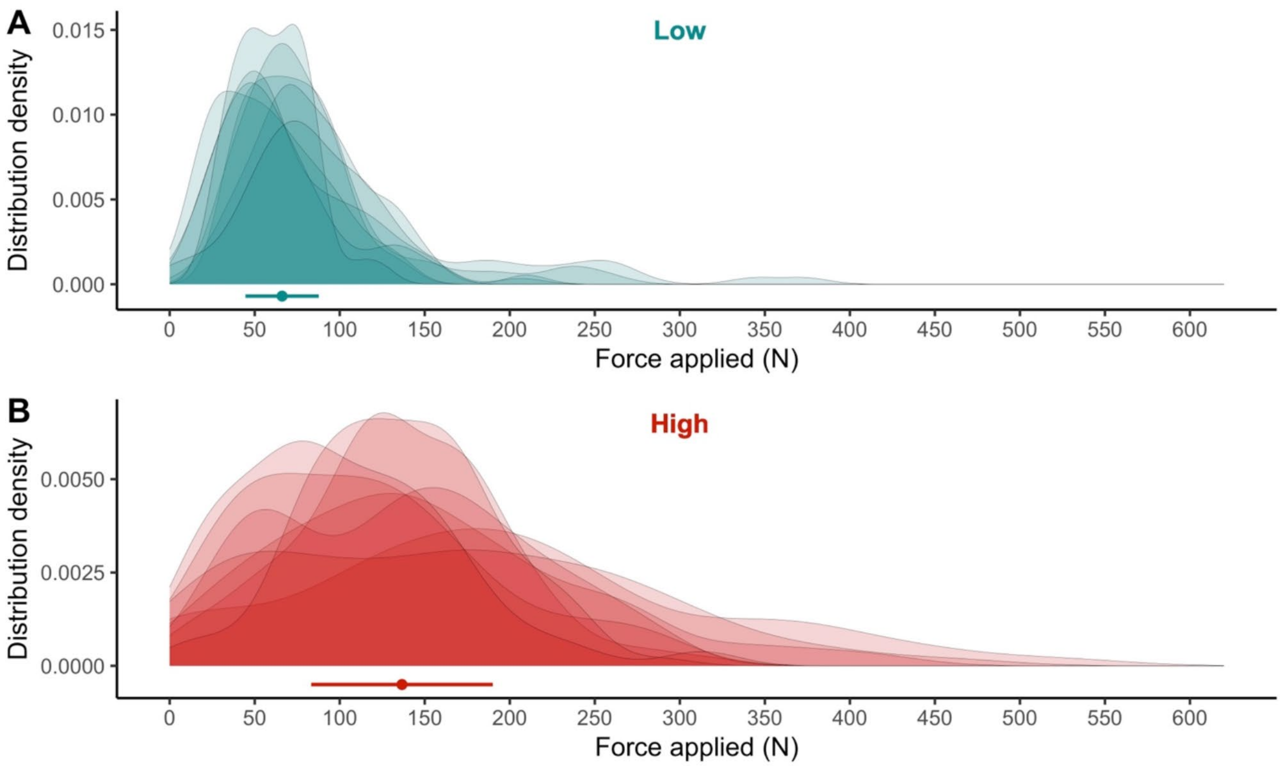

Fig. 4. Distribution of force applied on the crate by each gilt over 60 min after confinement. Gilts were divided in two clusters (Low: **A**, High: **B**) based on the median force of pushing events and their IQR (point and range under distribution densities).

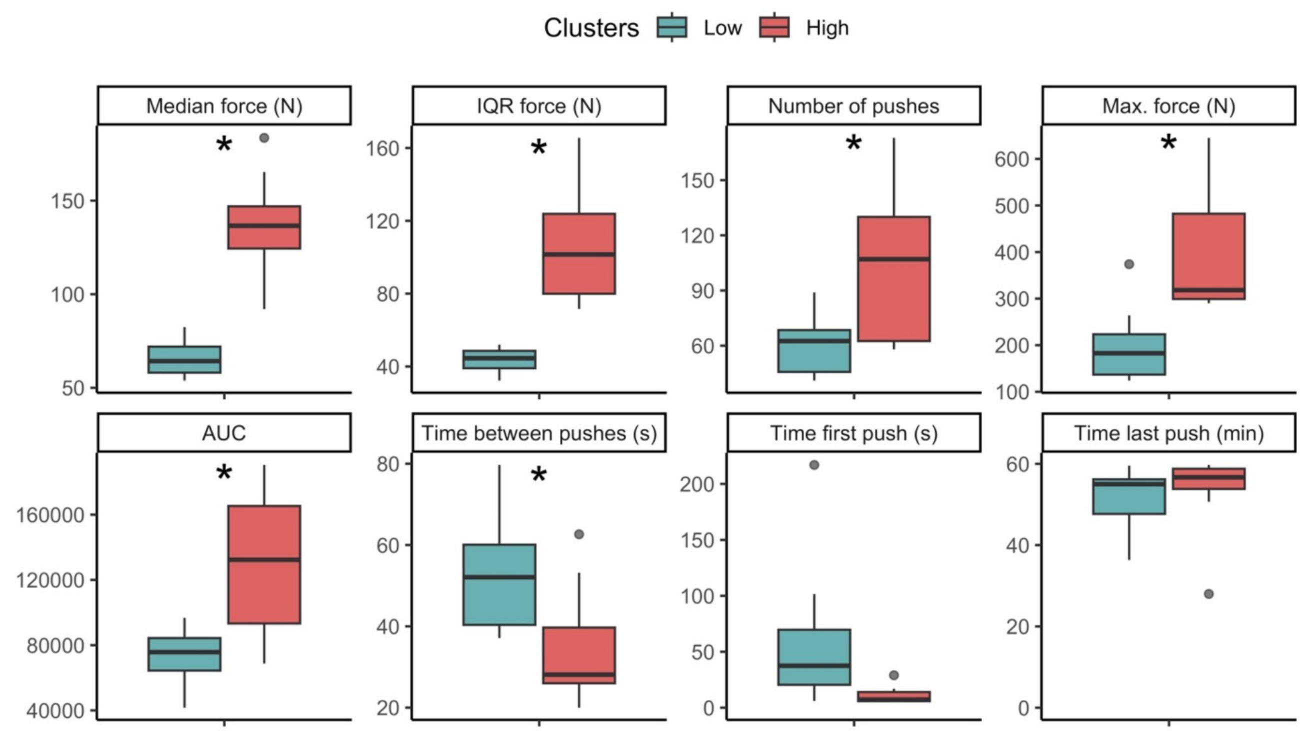

Fig. 5. Differences between the two clusters (Low and High) in summary measures of pushing events. Variables marked with an asterisk represent a significant difference between the two clusters (t-test, $p < 0.05$).

confinement will affect pigs' motivation to exit a stall, or if their motivation profile is similar (or related) to a personality trait, showing consistency through time and experiences[39,40].

The 60 min. duration of our study did not allow us to observe the full range in persistence across all animals. Thus, it is unknown whether "giving up" was simply due to a physical process like exhaustion or a psychological process – potentially influenced by individual temperament – where animals accept the impossibility of opening the crate. Our results suggest gilts separate in two behavioural clusters during short-term confinement and highlight the utility in characterizing individual animal differences in the interpretation of animal welfare studies. While we do not know whether this divide translates into similar responses to long-term restraint, it does raise questions about the role of individual animal needs in the refinement of housing systems for food animals[41,42]. Finally, our design did not allow us to explore physical confinement without some partial social isolation. Further research thus is needed to investigate the importance of social dynamics during stressful events and the potential of conspecifics to mitigate (or worsen) stress responses[43,44].

Conclusion

We measured gilts' motivation to exit a stall during short-term confinement using a novel apparatus that allowed continuous monitoring of force applied to the exit gate of a crate. All gilts displayed some level of motivation to exit the stall. Cluster analysis characterized two behavioral profiles, one characterized by more frequent and harder attempts to exit the stall. These results further support previous evidence that stall confinement is an unwanted experience for gilts.

Data availability

Data and R code are available in supplemental materials (SM1 and SM2 respectively).

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Author contributions

TE and TDP conceived the experiment. TE collected the data. TE and TDP analyzed the data. TE wrote the initial draft. TE and TDP reviewed and approved the submitted version.

Declarations

Competing interests

The authors declare no competing interests.

Additional information

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Correspondence and requests for materials should be addressed to T.E.