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A note on the effect of gestation housing environment on approach test measures in gilts

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Abstract

Systems' welfare evaluation, including behavioural testing, is becoming increasingly popular in farm animal assurance schemes. The aims of this study were to investigate whether fairly short-term exposure to gestation housing systems, which varied in physical, environmental and human-input factors, influenced behavioural and physiological measures during a human approach test—often used to identify problems in human–animal interactions. Twenty-four Large White × Landrace gilts were initially subjected to identical human contact and daily husbandry. Forty-two days after service, the gilts were randomly assigned to either an indoor housing system ($n = 16$) or an outdoor housing system ($n = 8$), which differed physically and in the amount of human contact and daily husbandry. The indoor system used an electronic sow feeder (ESF), was more space-limited and thermally-controlled and had human contact centered on cleaning out. The outdoor system was more extensive, had much greater space accessible, was not thermally-controlled and had human contact that centered around feeding. The human approach test was carried out on all gilts 30–44 days after entry to the gestation system. At testing, each individual was fitted with heart rate monitor and then moved into a test arena. After 2 min an unfamiliar human entered the pen and stood motionless for 3 min against one wall and then approached the gilt and touched her snout. Throughout the experimental period, behaviour and sound within the test arena were recorded continuously. During the 2 min familiarisation period, outdoor gilts had lower heart rates (108.2 bpm versus 123.7 bpm, $P < 0.05$) and tended to perform fewer short vocalisations (0.5 calls per min versus 3.4 calls per min, $P < 0.1$). Outdoor-housed gilts also carried out less locomotor behaviour (2.2 sections crossed versus 4.0 sections crossed, $P < 0.05$) and tended to perform fewer short (1.4 calls per min versus 5.0 calls per min, $P < 0.1$) and long vocalisations (0.2 calls per min versus 1.8 calls per min, $P < 0.1$) over the

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3 min test period. Outdoor gilts tended to be slower to approach within 0.5 m of the human (69.9 s versus 19.3 s, $P < 0.1$) but they then took less extra time to make physical contact (3.3 s versus 52.7 s, $P < 0.1$). Mean heart rate was significantly lower in outdoor sows over the whole 3 min period (99.5 bpm versus 115.5 bpm, $P < 0.05$). The results demonstrate that short-term exposure to different housing systems did influence behavioural and physiological measures during a standard human approach test and thus, systems differences should be taken into account before making judgements about the human–animal relationship on any commercial farm, based on results of behavioural tests of this type.

Keywords: Pigs-housing; Gestation; Environment; Approach test; Behaviour; Heart rate

1. Introduction

Over recent years, there has been a large increase in the number of assurance schemes that have been established to address consumer concerns about the animal welfare and food safety issues surrounding meat products, and to confer marketing advantages (Main et al., 2001). A major feature of these schemes is the need to quantitatively assess welfare of animals on-farm, using a combination of assessment of the physical environment, the husbandry regime and the animals' health and behaviour (Sørensen et al., 2001). It is the latter part that perhaps presents the greatest challenge, especially in terms of devising a standard test that can be used on different farms and the results of which can provide an objective welfare measure under varying conditions. One such area that has received attention is that of the human–animal relationship and specifically the quantification of an animal's fear of humans (Bonde et al., 1999; Rousing et al., 2001).

Historically, the human approach test was proposed as a test of fear of humans in pigs by Hemsworth et al. (1981) and it is with this assumption that this type of test is being examined as an on-farm assessment tool, essentially trying to quantify the quality of human handling, with slow approach or avoidance perhaps highlighting a poor human–animal relationship and the use of adverse techniques. However recently, there have been doubts raised as to whether the interpretation of the test as a measurement of fear is valid (Pedersen, 1997; Marchant-Forde, 2002). The approach behaviour of the pig is likely to be greatly influenced by its familiarity with the test environment (Pedersen, 1997) and the test may simply reflect the pig's level of motivation to explore the arena rather than provide a measure of the specific fear response to a human who is behaving in an atypical fashion (Lawrence et al., 1991; Pearce and Patterson, 1993; Marchant et al., 1997a). It may therefore be expected that the approach behaviour of the pig will vary in relation to the relative difference between the test arena and its usual home environment and the relative quantity and quality of human contact within that home environment. Animals coming from an enriched system into a barren test arena may be behaviourally inhibited due to fear of novelty (Korte, 2001) or conversely, may show increased activity (Beattie et al., 2000). Likewise, animals that receive regular contact with humans (Jones and Waddington, 1993) or that have learnt to associate humans with food delivery (Pajor et al., 2000) may either be quick to approach the human or may avoid a human behaving atypically (Miura et al., 1996). Differences in results obtained between farms may therefore simply reflect differences in environmental experience rather than real differences in quality of handling.

In order that the results of a human approach test can be interpreted with confidence and applied within more general welfare assessment, it is important to increase our current knowledge of how different housing systems can affect the results obtained. The aims of this study were therefore to investigate whether fairly short-term exposure to two different gestation housing systems, which varied in factors such as physical environment, thermal environment, ability to exercise and quantity and quality of human contact, influenced behavioural and physiological measures during a standard human approach test.

2. Materials and methods

2.1. Animals and housing

The subjects were 24 Large White × Landrace gilts from the same source (Cotswold Pig Development Company, Rothwell, UK), housed in two different gestation systems. Initially, all gilts were subject to identical human contact and daily husbandry. They had arrived on the farm at point-of-serve from the same place and were housed together in six groups of four, in the same service area, which consisted of covered lying areas (2.5 m × 2.5 m) and concrete-floored outdoor runs (2.5 m × 3.5 m). They were fed once daily at 07:30 h by hand into a non-partitioned trough in each pen. Forty-two days after natural service, which occurred on the second detectable oestrus, the gilts were randomly assigned, over the same time period, to existing multiparous sow groups in either an indoor housing system ($n = 16$) or an outdoor housing system ($n = 8$). The numbers assigned were unequal because the existing systems needed unequal numbers of gilts to replace sows being culled. The eight gilts entering the outdoor system were made up of pairs from four of the six groups. The 16 gilts entering the indoor system were made up of pairs from four groups and all the remaining two groups. Both systems contained large dynamic groups of 25 animals at any one time.

The indoor-housed group had access to a straw-covered lying area (7.5 m × 5.5 m) and a dunging area (9.0 m × 5.5 m), all part of one large room. Part of the dunging area was occupied by an electronic sow feeder (ESF) (crate by Quality Equipment, Bury St. Edmunds, UK and electronics by Nedap Poiesz, Hengelo, Netherlands), in which the sows were fed one at a time from 05:00 h and without human presence. Each sow wore a collar with transponder, which identified it to the ESF computer and ensured that each sows received the appropriate food ration (2.2–2.5 kg—Ultrabreed 16, Dalgety, Bury St. Edmunds, UK). Water was available ad libitum from nipple drinkers and a water trough situated in the dunging area. The room was ventilated by two thermostatically-controlled 900 rpm, 45 cm fans and supplementary heating was provided in cold weather. The room was lit both by natural daylight and artificial lighting with lights switched on at 06:00 h and off at 22:00 h. The dunging area was cleaned once daily in the morning, by hand, by a stockperson, during which the gilts were shut into the lying area by means of two gates—although at this time of day, the animals were usually resting in the strawed lying area and did therefore not generally interact with the stockperson or require handling. Fresh straw was added to the lying areas, daily. After mucking out, the stockperson spent approximately 5 min moving through the pigs to ensure that there were no health problems. This whole process would take about 15 min. On a weekly basis, three or four animals would be removed to the farrowing accommodation and three or four animals would be reintroduced from the service area.

The outdoor-housed group had access to a covered, strawed lying area (10 m × 6 m) adjacent to a covered, concrete-floored feeding area (10 m × 6 m). They also had access to an uncovered, concrete-floored dunging area and two large areas of pasture (each ca. 150 m × 25 m). Gilts were fed daily in individual stalls in the feeding area at 08:00 h. At feeding time, the stockperson entered the pen and opened a gate to allow the animals access to the feeding area. The animals entered the feeding stalls and were then shut in manually by the stockperson who walked down the passageway in front of the stalls. The stockperson then walked back down the passageway and fed all the sows the appropriate amount of feed (2.2–2.5 kg—Ultrabreed 16, Dalgety, Bury St. Edmunds, UK) sequentially and inspected them for signs of ill-health. After all the sows had finished eating, they were released from the stalls and herded back into the main lying area, with the aid of a solid, hand-held board. The area around the feeders was cleaned daily by hand and fresh straw added to the lying areas, daily. This whole process would take up to 1 h. On a weekly basis, three or four animals would be removed to the farrowing accommodation and three or four animals would be reintroduced from the service area.

Thus, the two systems varied both in physical and thermal environment and in the degree of human contact received on a daily basis. In the indoor system, gilts had exposure to a limited range of environmental stimuli whilst human contact was maintained over a relatively short time period, unassociated with delivery of food. In the outdoor system, the gilts had exposure to a wide range of environmental stimuli and human contact was maintained over a longer time period each day and was associated with the daily delivery of food.

2.2. Experimental procedures

The human approach test was carried out on all 24 gilts between 72 and 86 days after service, so that stage of gestation had no confounding effect on the heart rate data (Marchant and Broom, 1995), and this was 30–44 days after entry to the gestation system. At testing, a group of four gilts from the same housing system was moved to a handling area, approximately 60 m away from the home pen. Here, each individual was separated in turn from its pen-mates and fitted with a Polar Vantage NV (Polar Electro Oy, Kempele, Finland) heart rate monitor (see methodology in Marchant et al., 1995), which was set to record and store successive inter-beat intervals. Each gilt was then moved a further 10 m and introduced individually into a 2.4 m × 3.4 m test arena.

The test arena was solid-sided, with the floor marked into six squares and a semicircle of 0.5 m diameter around the point at which the human stood. All gilts were equally unfamiliar with the handling area, the test arena and wearing a heart rate monitor. After a 2 min familiarisation period, an unfamiliar human entered the pen and stood motionless for 3 min against one wall, without responding to any contact by the pig. At the end of this 3 min period, the human approached the gilt from the front and reached out and touched her on the snout. The gilt was then moved back to the handling area, where the heart rate monitor was removed and she was reintroduced to her pen-mates. Throughout the experimental period, behaviour and sound within the test arena were recorded continuously using a camcorder with built-in microphone (Panasonic NV-G3B, Matsushita Electric Industrial Co. Ltd., Japan). The clocks on all the Polar Vantage receivers and the camcorder were synchronised to allow co-ordination of behavioural and physiological events.

The behaviour of all gilts was analysed on video playback to determine:

1. the amount of locomotor behaviour, in terms of the number of squares crossed by the front feet per 30 s, during the familiarisation period and during the test period;
2. time taken for the pig to approach within 0.5 m of the human;
3. time taken for the pig to make physical contact with the human;
4. total number of physical contacts with the human, such as biting, licking and nosing;
5. the number of short and long vocalisations, as categorised in Marchant et al. (2001) during the familiarisation period and during the test period.

When the whole group had been tested, they were moved back to their home pen in the dry sow house. The heart rate data were downloaded from the receivers by 'wire-free' contact via a Polar Interface (Polar Electro Oy, Finland) onto a PC. The data were displayed in graphical and numerical form using Polar Heart Rate Analysis Software (Version 4.00, Polar Electro Oy, Finland) and analysed to determine:

1. mean heart rate over the familiarisation period in beats per min (bpm);
2. mean heart rate over the test period in bpm;
3. mean heart rate per 30 s time block over all 5 min;
4. heart rate change when the human entered the pen at the end of familiarisation, in terms of bpm and percentage change;
5. heart rate change when the human approached and touched the pig, in terms of bpm and percentage change.

2.3. Statistical analysis

For the mean heart rate values during familiarisation and testing, the heart rate data were averaged over the whole 2 or 3 min period by counting the number of inter-beat intervals and dividing by the time to give the mean heart rate in bpm. For the changes in heart rate in response to the human, a mean inter-beat interval was calculated from the 10 consecutive inter-beat intervals preceding the event and this value (in ms) was then converted into bpm by dividing it into 60,000. The same procedure was carried out for the 10 consecutive inter-beat intervals following the event. The change in heart rate was calculated as the difference between the two bpm values. The percentage change was also calculated.

During the approach test, some animals did not approach within 0.5 m ($n = 4$) or make physical contact with the human ($n = 12$), within the 180 s assigned to the test. Where this occurred, these gilts were given an arbitrary score of 180 s and between-systems comparisons were carried out using non-parametric Mann–Whitney tests which compares medians, as to give this arbitrary score and then use a parametric test which compares means may have given misleading statistical results.

Comparisons between housing systems of vocalisation rates, behaviour and changes in heart rate were carried out using unpaired Student's *t*-tests. As heart rate is correlated with activity, mean heart rate data were compared using a General Linear Model, with housing system as the between-subjects factor and locomotor activity included as a covariate. Data were log-transformed as appropriate when the assumption of normality was not fulfilled (Sokal and Rohlf, 1981).

3. Results

During the 2 min familiarisation period, there were no differences between treatments in locomotor behaviour or rates of performance of long vocalisations (see Fig. 1 and Table 1). However, outdoor gilts tended to perform fewer short vocalisations. Mean heart rate was significantly lower in outdoor sows (see Fig. 2), over the whole 2 min period and within each 30 s time block, with locomotor behaviour included as a covariate in the GLM.

There was no difference between treatments in heart rate response to the human entering the pen, but human presence did affect behaviour (see Table 1). Outdoor-housed gilts carried out significantly less locomotor behaviour and tended to perform fewer short and long vocalisations over the 3 min test period. Outdoor gilts also tended to be slower to approach within 0.5 m of the human but conversely, once they had approached within 0.5 m, they then took significantly less extra time to make physical contact. Two out of 16 indoor gilts and 2 out of 8 outdoor gilts did not approach to within 0.5 m of or make contact with the human during the 3 min period. A further six indoor gilts and two outdoor gilts did approach to within 0.5 m but then did not make contact. Thus, only half the gilts in both treatments approached and made contact with the human in the 3 min.

Mean heart rate was significantly lower in outdoor sows (see Fig. 2) over the whole 3 min period. It was still lower, within each 30 s time block, with locomotor behaviour included as a covariate in the GLM. However, there was no difference between treatments in heart rate response when the human approached and touched the pig at the end of the 3 min period.

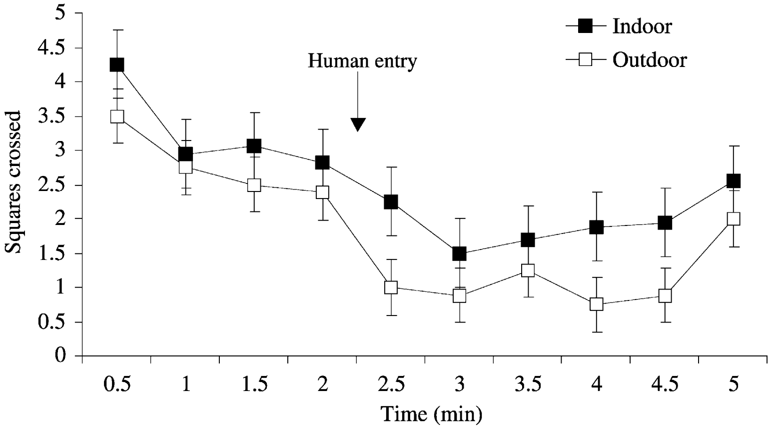

Fig. 1. Mean ± S.E. locomotor behaviour, measured in terms of sections crossed per min, of gilts from two different gestation systems during a standard human approach test.

Table 1
Mean (95% confidence limits) and median (inter-quartile ranges) behavioural and heart rate parameters of gilts from two gestation housing systems during a standard human approach test

Student's *t*-test	Indoor gilts	Outdoor gilts	*t*-value	Significance
Familiarisation period				
Total number of sections crossed per min	6.4 (4.7–8.1)	5.6 (2.6–8.6)	0.37	ns[a]
Short vocalisation rate (calls per min)	3.4 (0.1–6.7)	0.5 (0.1–0.8)	1.91	†
Long vocalisation rate (calls per min)	1.1 (0.0–3.0)	0.1 (0.0–0.3)	1.20	ns
Change in HR when human enters the pen (bpm)	8.6 (4.4–12.8)	6.4 (0.4–12.4)	0.57	ns
Change in HR when human enters the pen (%)	7.8 (4.0–11.6)	6.7 (0.0–13.4)	0.35	ns
Approach test period				
Total number of sections crossed per min	4.0 (2.7–5.2)	2.2 (1.6–2.8)	2.42	*
Short vocalisation rate (calls per min)	5.0 (1.0–9.0)	1.4 (0.0–2.7)	1.85	†
Long vocalisation rate (calls per min)	1.8 (0.0–4.1)	0.2 (0.0–0.6)	1.72	†
Mean number of interactions with human	1.3 (0.5–2.2)	1.1 (0.0–2.3)	0.19	ns
Change in HR when human approaches the pig (bpm)	6.4 (2.2–10.5)	7.0 (3.1–10.9)	−0.74	ns
Change in HR when human approaches the pig (%)	6.0 (2.1–9.9)	7.9 (2.9–12.9)	−1.01	ns
General linear model	**Indoor gilts**	**Outdoor gilts**	**$F_{1,21}$-value**	**Significance**
Mean HR (bpm) over the 3 min period	115.5 (106.7–124.3)	99.5 (89.0–109.9)	4.66	*
Mean HR (bpm) over the 2 min period	123.7 (114.4–133.1)	108.2 (98.3–118.2)	4.77	*
Mann–Whitney *U*-test	**Indoor gilts**	**Outdoor gilts**	***Z*-value**	**Significance**
Time taken to approach to within 0.5 m (s)	19.3 (10.6–76.9)	69.9 (29.5–164.3)	−1.68	†
Time taken to interact (s)	144.2 (37.7–180.0)	121.9 (34.2–180.0)	0.15	ns
Time between approach to within 0.5 m and contact (s)	52.7 (2.6–144.5)	3.3 (0.3–48.7)	1.68	†

Data for Student's *t*-test and GLM analyses were transformed by taking natural logarithms. Reported means and 95% confidence limits are back-transformed. Data for Mann–Whitney *U*-test analysis were not transformed. Values reported are medians and inter-quartile ranges.

[a] ns: not significant.

† $P < 0.1$.

* $P < 0.05$.

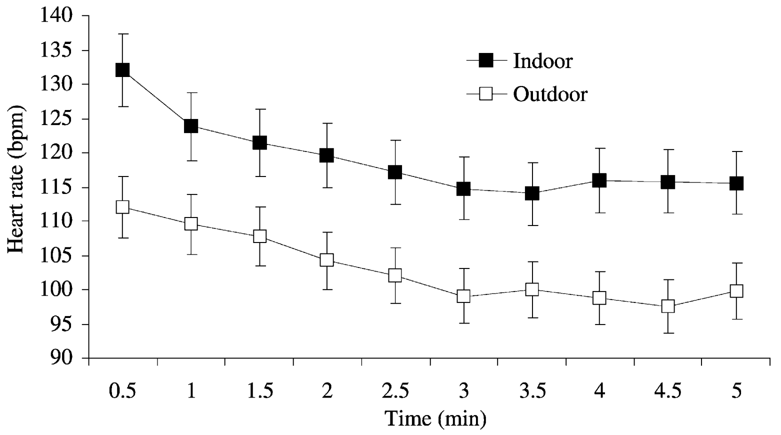

Fig. 2. Mean ± S.E. heart rate, measured in terms of beats per min, of gilts from two different gestation systems during a standard human approach test.

4. Discussion

The results demonstrate that gilts kept in different housing systems, even over the relatively short time period of 30–42 days prior to testing, did differ in behavioural and heart rate measures in this human approach test. Before assignment to the different systems, the gilts had been housed and treated identically.

During the familiarisation and approach test periods, gilts from the outdoor system had significantly lower heart rates. Gilts from the two housing systems were at a similar stage of gestation, a variable that is known to have a large effect on HR (Marchant and Broom, 1995), but had been subjected to quite different thermal and physical environments. Although data elsewhere suggests that indoor and outdoor sows do not differ greatly in the proportion of time spent active (Dailey and McGlone, 1997), sows with access to outdoor areas do probably differ in the intensity of that activity—walking greater distances whilst foraging. It has already been demonstrated that the amount of exercise that a housing system permits affects cardiovascular fitness (Marchant et al., 1997b) and thus heart rates of outdoor-housed sows could be lower than the indoor sows due to their ability to perform more higher intensity exercise.

Also during both periods, there was a consistent tendency for outdoor gilts to be less vocal than indoor gilts. Short vocalisations are thought to be associated with investigatory behaviour (Marchant et al., 2001) and long calls are thought to function as contact calls (Marchant et al., 2001). The outdoor gilts appear to be showing reduced investigatory behaviour and lower vocal and heart rate responses to social isolation in the novel surroundings. Korte (2001) discusses behavioural inhibition due to fear of novelty. However, the general effect of increased complexity during rearing is reduced fear of novelty (Broom, 1969). It may be that animals with a more diverse experience, such as experience gained in the outdoor system that is relevant to the situations that they might encounter later are hesitant in certain novel situations because of better ability to recognise and evaluate potentially risky situations. Locomotor behaviour was lower in outdoor pigs when the human was present during the approach test period, perhaps indicating either a fear-related reduction in exploration.

However, the actual approach behaviour towards the human shows interesting differences and apparent discrepancies. It might be predicted that outdoor gilts, exposed to greater handling and human contact than the indoor gilts, would be less fearful of humans and thus approach quicker (Tanida et al., 1994; Hemsworth et al., 1996a,b). Alternatively, outdoor gilts might be better at recognising an anomalous situation and hence be more cautious. Those outdoor gilts that did approach and make contact took significantly longer to approach the human than the indoor gilts that approached and made contact. This might indicate that the outdoor gilts showed greater fear of humans (e.g. Hemsworth et al., 1981, Hemsworth et al., 1986). However, the outdoor gilts then tended to go from 0.5 m to contacting the human quicker than the indoor gilts, so showed less fear of humans by this measure. The heart rate data, recorded when the human first entered the pen and then approached and touched the pig showed no differences between treatments. Hence it appears that that the difference in approach behaviour is not related to fear of humans. It could be that initially, the outdoor gilts showed behavioural inhibition due to a greater appreciation of the unusual aspects of the situation and were thus slower to approach the human. However, once they had overcome this apparent unwillingness to approach, the positive association between the human and food, which has been shown to influence approach behaviour (Hemsworth et al., 1996b), meant that physical contact occurred quicker.

In conclusion, short-term exposure to different housing systems that varied in many factors such as physical environment, thermal environment, exposure to pathogens, ability to exercise, quantity and quality of human contact, did indeed influence behavioural and physiological measures during a standard human approach test. If this type of test was being used as an on-farm assessment tool, these results might infer that the human–animal relationship was poorer in the outdoor system and that these gilts were being subjected to adverse handling techniques. However, this inference would be misleading and the study clearly demonstrates system level differences that should be taken into account before making any judgements on stockperson care.

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References

Beattie, V.E., O'Connell, N.E., Kilpatrick, D.J., Moss, B.W., 2000. Influence of environmental enrichment on welfare-related behavioural and physiological parameters in growing pigs. Anim. Sci. 70, 443–450.

Bonde, M., Rousing, T., Sørensen, J.T., 1999. Repeatability and inter-rater agreement of behaviour tests on piglets on commercial farms. In: Bøe, K.E., Bakken, M., Braastad, B.O. (Eds.), Proceedings of the 33rd International Congress of the International Society for Applied Ethology. Agricultural University of Norway, Ås, Norway, p. 124.

Broom, D.M., 1969. Effects of visual complexity during rearing on chicks' reactions to environmental change. Anim. Behav. 17, 773–780.

Dailey, J.W., McGlone, J.J., 1997. Oral/nasal/facial and other behaviours of sows kept individually outdoors on pasture, soil or indoors in gestation crates. Appl. Anim. Behav. Sci. 52, 25–43.

Hemsworth, P.H., Barnett, J.L., Hansen, C., 1981. The influence of handling by humans on the behaviour, growth, and corticosteroids in the juvenile female pig. Hormone Behav. 15, 396–403.

Hemsworth, P.H., Barnett, J.L., Hansen, C., 1986. The influence of handling by humans on the behaviour, reproduction and corticosteroids of male and female pigs. Appl. Anim. Behav. Sci. 15, 303–314.

Hemsworth, P.H., Price, E.O., Borgwardt, R., 1996a. Behavioural responses of domestic pigs and cattle to humans and novel stimuli. Appl. Anim. Behav. Sci. 50, 43–56.

Hemsworth, P.H., Verge, J., Coleman, G.J., 1996b. Conditioned approach-avoidance responses to humans: the ability of pigs to associate feeding and aversive social experiences in the presence of humans with humans. Appl. Anim. Behav. Sci. 50, 71–82.

Jones, R.B., Waddington, D., 1993. Attenuation of the domestic chicks' fear of human-beings via regular handling—in search of a sensitive period. Appl. Anim. Behav. Sci. 36, 185–195.

Korte, S.M., 2001. Corticosteroids in relation to fear, anxiety and psychopathology. Neurosci. Biobehav. Rev. 25, 117–142.

Lawrence, A.B., Terlouw, E.M.C., Illius, A.W., 1991. Individual-differences in behavioral-responses of pigs exposed to nonsocial and social challenges. Appl. Anim. Behav. Sci. 30, 73–86.

Main, D.C.J., Webster, A.J.F., Green, L.E., 2001. Animal welfare assessment in farm assurance schemes. Acta Agric. Scand. Sect. A Anim. Sci. Suppl. 30, 108–113.

Marchant-Forde, J.N., 2002. Piglet- and stockperson-directed sow aggression after farrowing and the relationship with a pre-farrowing, human approach test. Appl. Anim. Behav. Sci. 75, 115–132.

Marchant, J.N., Broom, D.M., 1995. Basal heart rate of group-housed sows in relation to stage of gestation. In: Rutter, S.M., Rushen, J., Randle, H.D., Eddison, J. (Eds.), Proceedings of the 29th International Congress of the International Society for Applied Ethology. UFAW, Potter's Bar, London, pp. 77–78.

Marchant, J.N., Mendl, M.T., Rudd, A.R., Broom, D.M., 1995. The effect of agonistic interactions on the heart rate of group-housed sows. Appl. Anim. Behav. Sci. 46, 49–56.

Marchant, J.N., Burfoot, A., Corning, S., Broom, D.M., 1997a. The Human Approach Test—a test of fearfulness or investigatory behaviour? In: Hemsworth, P.H., Spinka, M., Kostal, L'. (Eds.), Proceedings of the 31st International Congress of the International Society for Applied Ethology. Research Institute of Animal Production, Uhrineves, Czech Republic, p. 182.

Marchant, J.N., Rudd, A.R., Broom, D.M., 1997b. The effects of housing on heart rate of gestating sows during specific behaviours. Appl. Anim. Behav. Sci. 55, 67–78.

Marchant, J.N., Whittaker, X., Broom, D.M., 2001. Vocalisations of the adult female domestic pig during a standard human approach test and their relationships with behavioural and physiological measures. Appl. Anim. Behav. Sci. 72, 23–39.

Miura, A., Tanida, H., Tanaka, T., Yoshimoto, T., 1996. The influence of human posture and movement on the approach and escape behaviour of weanling pigs. Appl. Anim. Behav. Sci. 49, 247–256.

Pajor, E.A., Rushen, J., de Passille, A.M.B., 2000. Aversion learning techniques to evaluate dairy cattle handling practices. Appl. Anim. Behav. Sci. 69, 89–102.

Pearce, G.P., Patterson, A.M., 1993. The effect of space restriction and provision of toys during rearing on the behaviour, productivity and physiology of male pigs. Appl. Anim. Behav. Sci. 36, 11–28.

Pedersen, L.J., 1997. Socialisation to humans of pigs at different ages. In: Hemsworth, P.H., Spinka, M., Kostal, L'. (Eds.), Proceedings of the 31st International Congress of the International Society for Applied Ethology. Research Institute of Animal Production, Uhrineves, Czech Republic, p. 208.

Rousing, T., Bonde, M., Sorensen, J.T., 2001. Aggregating welfare indicators into an operational welfare assessment system: a bottom-up approach. Acta Agric. Scand., Sect. A, Anim. Sci. Suppl. 30, 11–18.

Sokal, R.R., Rohlf, F.J., 1981. Biometry. Freeman, San Francisco.

Sørensen, J.T., Sandøe, P., Halberg, N., 2001. Animal welfare as one among several values to be considered at farm level: the idea of an ethical account for livestock farming. Acta Agric. Scand., Sect. A, Anim. Sci. Suppl. 30, 11–18.

Tanida, H., Miura, A., Tanaka, T., Yoshimoto, T., 1994. The role of handling in communication between humans and weanling pigs. Appl. Anim. Behav. Sci. 40, 219–228.