Environmental enrichment induces optimistic cognitive biases in pigs

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ARTICLE INFO

ABSTRACT

The objective assessment of affective (emotional) state in farm livestock, especially positive states, poses a significant challenge. In human psychology, there is evidence that affective state can alter cognition, with more positive states being associated with an increased likelihood of judging ambiguous information postively (a phenomenon described as optimistic cognitive bias). The aim of this study was to investigate whether judgement biases could be used to assess affective states in pigs housed in environments with different levels of enrichment. Two groups of five gilts were housed in either enriched (E) or barren (B) environments for the first five weeks of the experiment. The enriched group had more space, straw and objects to manipulate. The pigs were trained on a go/no-go task to discriminate two auditory cues, a positive cue that predicted a food reward if the pig approached a hatch, and a negative cue that predicted a mildly aversive experience if the pig approached the same hatch. The quality of the pigs' environment was then changed over time in a balanced, cross-over design (either EBE or BEB). Tests of cognitive bias were made on individual pigs before and after each change in environment using an unreinforced, ambiguous, auditory cue different from either the positive or the negative cue. In test sessions, positive, negative and amibiguous cues were presented in a randomised sequence, and the pigs' responses (whether they approached the hatch and latency to approach) were recorded. Both groups were more likely to approach the hatch and were faster to approach the hatch in response to the ambiguous cue when currently housed in the enriched environment. There was also an interaction between current and past environment, whereby pigs that started in the enriched environment were subsequently less likely and slower to approach the hatch when moved to a barren environment than pigs intially housed in the barren environment. These results show that pigs have more optimistic judgement biases in enriched environments indicative of a more positive affective state. Also, pigs that have spent time in an enriched environment react more negatively to being subsequently housed in a barren environment. We conclude that cognitive bias has potential to provide additional information about the effect of various management regimes on farmed animals' welfare. This will be increasingly important for identifying practices to promote positive affective states in our food producing animals.

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1. Introduction

The development of objective methods for assessing the affective (or emotional) states of non-human animals is a crucial step in improving animal welfare (e.g. Dawkins, 2008). In human psychology, there is an extensive body of literature showing that affective state can influence cognitive processes (Bar-Haim et al., 2007; Eysenck et al., 1991; Williams et al., 1997). Typically, negative affective states are accompanied by greater attention to threatening stimuli and an increased likelihood that ambiguous information will be interpreted pessimistically, whereas more postive states are accompanied by more optimistic judgements. The term 'cognitive bias' is used as a general label for these effects of affective state on cognitive processes (Mendl et al., 2009). The existence of affectively induced cognitive biases in humans has lead to the suggestion that measures of cognitive bias might provide a novel method for objectively assessing both positive and negative affective states in non-human animals (Mendl et al., 2009; Paul et al., 2005). In animal studies, 'optimism' and 'pessimsim' are defined operationally as respectively, an increased expectation of reward in the face of ambigous information and an increased expectation of punishment in the face of ambiguous information. No assumption is made about whether these objective biases in decision-making are accompanied by subjective emotional states. The cognitive bias approach has a number of attractive features compared with exisiting methods for welfare assessment, including: clear a priori predictions about the types of biases expected, greater selectivity for the valence of an emotional state as opposed to the level of arousal involved, the ability to assess postive as well as negative emotional states, and finally, the non-invasive nature of the techniques involved (Mendl et al., 2009; Paul et al., 2005). In support of the hypothesis that cognitive bias could be a useful welfare assessment tool, there is evidence from a range of species including rats (Brydges et al., 2011; Burman et al., 2008a; Enkel et al., 2010; Harding et al., 2004), European starlings (Bateson and Matheson, 2007; Brilot et al., 2010; Matheson et al., 2008), sheep (Doyle et al., 2010a,b, 2011), dogs (Mendl et al., 2010a) domestic chicks (Salmeto et al., 2011) and even honeybees (Bateson et al., 2011) that animals hypothesised to be in more negative affective states are typically more pessimistic, whereas animals hypothesised to be in more postive states are more optimistic.

There is mounting evidence that animals housed in enriched conditions have better welfare, and hence by assumption more positive affective states, compared to those housed in more barren environments (e.g. Balcombe, 2006). This belief is supported by the cognitive bias assessments, that report more optimistic cognitive biases in both laboratory rats and European starlings currently housed in more enriched or more stable cages (Bateson and Matheson, 2007; Brydges et al., 2011; Harding et al., 2004; Matheson et al., 2008). There is also a suggestion that the recent history of an animal can be important in determining its affective state. For example, Bateson and Matheson (2007) found that starlings only exhibited a pessimistic cognitive bias in barren cages when they had recently been moved from enriched cages. Together these studies suggest that cognitive bias could be a useful tool for measuring the impact of an animal's environment on its affective state and hence its welfare.

In the current study we focus on assessing the impact of different housing practices on pig welfare. A range of different housing and rearing practices are used for pigs, some of which involve substantial changes in environment, for example outdoor reared pigs being finished inside. There are 5 million pigs on UK farms (DEFRA, 2010), so numerically, pig welfare is important. The recent European Commission funded Welfare Quality research project's "Assessment Protocols for pigs" (2009), as well as those for cattle and poultry, emphasise the importance attributed to assessing positive emotional states in welfare assessment of our food producing animals. Currently such affective states are captured by Qualitative Behaviour Assessment terms (e.g. depressed, happy, content, frustrated, active, relaxed), (e.g. Wemelsfelder, 2007) which are scored subjectively by an independent auditor and the results entered into a weighted formula to produce a score (Welfare Quality, 2009). Tests of cognitive bias would offer a complementary, objective measure to support these subjective assessments.

The aim of our study was to investigate whether a cognitive bias methodology could be used to assess the effects of environmental enrichment on affective state in pigs. Provision of various types of environmental enrichment has been found to improve traditional welfare indicators (e.g. health and production parameters, tail biting, aggression, fear of humans, exploratory behaviour and play) in a number of other studies with pigs (for reviews see: Bracke et al., 2006; van de Weerd and Day, 2009) and our hypothesis was therefore that pigs currently housed in enriched pens would display more optimistic cognitive biases than pigs currently housed in barren pens. We also sought to investigate the extent to which the affective state of pigs is influenced by their previous environmental experiences. Based on a number of studies showing that animals, including pigs, are particularly sensitive to a decrement in environmental quality (e.g. Bateson and Matheson, 2007; Burman et al., 2008b; Melotti et al., 2011; Oostindjer et al., 2011a,b), we hypothesised that we would see greater pessimism in pigs currently housed in a barren environment if they had previously experienced an enriched environment. We assessed the cognitive bias of individual pigs using a go/no-go judgement bias task based on a learnt discrimination of two auditory cues one of which predicted a positive and one a negative outcome (i.e. similar to the the task used by Harding et al., 2004). We defined optimism operationally as a higher proportion of responses to an amibiguous cue as if it were the cue predicting the positive outcome, and pessimism as a higher proportion of responses to an ambiguous cue as if it were the cue predicting the negative outcome.

2. Materials and methods

2.1. Animals and housing environment

Two groups, each of five Large White × Landrace gilts, approximately 12 weeks of age and weighing 35 kg at

Table 1
Summary of experimental design.

	Training (5 weeks total)	Test environment 1 (7 days total)	Test environment 2 (7 days total)
Group EBE (n = 5):	Enriched	Barren	Enriched
Group BEB (n = 5):	Barren	Enriched	Barren
Cognitive bias tests:	Test 1	Test 2	Test 4
		Test 3	Test 5

entry to the experiment, were assigned randomly to be housed in either an enriched or barren environment. The barren environment (in accordance with the minimum legal provision for pigs housed intensively under EC Directive 2008/120/EC) provided 1.2 m² of space per pig, had partially slatted concrete flooring and enrichment was provided only in the form of a wood log on the floor. The enriched environment incorporated a solid floor, 1.9 m² of space per pig, clean straw which was replenished daily, suspended metal chains and logs, sticks and cardboard boxes were added each day. The choice of these enrichments was based on previous research investigating the effects of ennvironmental enrichment on welfare indicators in pigs (e.g. Beattie et al., 2000; Bolhuis et al., 2005; Scott et al., 2007). The pens were in the same controlled-environment room, with automatically controlled fan ventilation set to maintain a room temperature of 20 °C and controlled lighting which was on from 0700–1800. Both pens were ration fed once daily in the morning on a commercial pelleted grower diet distributed on the solid floor at the front of the pen, with water freely available from two adjacent bite drinkers positioned 0.5 m above the slatted floor.

The pigs were health checked daily and there were no health issues during the study. The study adhered to the Association for the Study of Animal Behaviour's guidelines for the use of animals in research, and was approved by the Newcastle University animal ethics committee.

2.2. Overview of the experimental design

For the first five weeks of the experiment, the training phase, pigs were housed in either the enriched (Group EBE) or the barren (Group BEB) environment. The pigs were trained individually in a single test arena (2 m × 4 m) on a go/no-go discrimination task analogous to that used in previous cognitive bias experiments with starlings, rats and honeybees (Bateson et al., 2011; Bateson and Matheson, 2007; Harding et al., 2004). The animals had to learn to discriminate two auditory cues, one positive and one negative. The positive cue, a note on a glockenspiel, predicted reinforcement with a food reward (apple) if the pig approached the hatch in the training arena (the "go" response). The negative cue, a click of a dog-training clicker, predicted punishment with a mildly aversive experience (a plastic bag waved in the face) if the pig approached the hatch. In the original protocol, notes on a glockespiel an octave apart had been proposed as the positive and negative cues, with intermediate ambiguous notes used as the ambiguous test cues (like Harding et al., 2004). However, within the available time scale the pigs did not learn to discriminate notes of different frequency, so the unrelated auditory cues were adopted. Once the animals had learnt the go/no-go

discrimination, cognitive bias was tested by recording the pigs' response to a novel auditory cue unlike either of the trained cues, the squeak from a dog toy. We hypothesised that since this auditory cue was untrained, but would be presented in the same location as the positive and negative cues and inserted within a sequence of reinforced positive and negative cues, that it would be ambiguous to the pigs in this context, rather than merely novel, and that it could therefore be used to assess their judgement biases. Our test differs from a conventional novel object test (e.g. Feenders et al., 2011) in that the animals had a learnt expectation that novel sounds presented in specific context were asociated with either reward or punishment. Approaches to the hatch following the ambiguous cue were neither reinforced nor punished.

This first cognitive bias test (test 1) was performed at the end of 5 weeks training while the pigs were still housed in their initial environment. The groups of pigs were then moved to the opposite environment and the test performed on the second day in the new environment (test 2) and again after they had been in their new environment for seven days (test 3). The pigs were then returned to their original environments and tested on the second day (test 4) and again on the seventh day (test 5). The experimental design is summarised in Table 1.

2.3. Training details

The pigs were first classically conditioned to associate the positive auditory cue with the presentation of apple delivered through a novel 1 m, white, plastic pipe. During this phase of training the cue and reward were presented simultaneously. The pigs were then trained to approach the hatch for the reward (initially using the pipe as a target). The next phase in training involved restraining the pigs behind a pig board, 1.5 m from the hatch, until the auditory cue was sounded, whereupon the pig was released to approach the hatch and received a slice of apple reward. Training required two people.

Once the pigs were performing the task, formal assessments of their learning were recorded for each session. The pigs were held in the holding area of the test arena behind the pig board, the cue was sounded and the pig released immediately. Each pig had a maximum of 30 s to "go" to the hatch before being returned to the holding area for another 30 s before the sounding of the next cue. Twenty positive cues were presented to each pig on each training day (10 in the morning and 10 in the afternoon). We defined an approach to the hatch as occuring if within 30 s of the start of the trial the pig moved such that its snout was within 20 cm of the hatch. This phase of training continued until all the pigs were approaching the hatch on hearing the positive

auditory cue on at least 16 out of the 20 trials (binominal test, $p < 0.05$) presented on a given training day.

The next phase of training involved introduction of the negative cues. The pre-cue procedure was the same as for the positive cue. The pig was held behind the pig board, the negative cue was sounded, the pig released and, if the pig approached the hatch, a plastic bag was waved in the pig's face. The bag was an orange polyethylene disposable supermarket carrier bag that had the property of rustling when shaken. The experimenter at the hatch presented the bag, extended it 40 cm into the pen, waved it three times in an arc of approximately 25 cm and then retracted it. This event took approximately 3 s. On each training day pigs received a total of 20 trials (10 in the morning and 10 in the afternoon) comprising equal numbers of positive and negative cues in a pseudorandom sequence (the trial type was determined by flipping a coin until 10 trials of either one of the two trial types had been given). A correct response was defined as approaching the hatch (i.e. a "go" response) within 30 s following a positive cue and not approaching the hatch (i.e. a "no-go" response) within 30 s following a negative cue. Training continued until all the pigs had acquired a significant discrimination of the positive and negative cues. The criterion adpoted for discrimination was that a pig made the correct response on at least 16 out of the 20 trials (binominal test, $p < 0.05$) completed on a given training day. Latency to approach the hatch was also measured, with a maximum of 30 s being assigned if a "no-go" was recorded.

2.4. Cognitive bias test

The cognitive bias tests were identical to the discrimination trainging with the exception that an additional 10 trials were incorporated in which the ambiguous cue was presented. The positive and negative cues were reinforced/punished during the test if the pig approached the hatch exactly as in the discrimination training. Trials in which the ambiguous cue was presented were never reinforced or punished, and were terminated either when the pig approached the hatch or after 30 s which ever came sooner. On each test day pigs received a total of 30 trials (15 in the morning and 15 in the afternoon) comprising equal numbers of positive, negative and ambiguous cues presented in a pseudorandom sequence. The trial type was determined by rolling a 6-sided die with two faces allocated to represent each of the three auditory cues. If 10 trials of a given trial type had already been performed, the die was rolled again until one of the two remaining trial types came up. Once 10 trials of each of two types had been performed the remaining trials were all of the remaining incomplete type.

Immediately prior to each morning or afternoon test session, the previously learnt discrimination was reinforced. Each pig was presented with the positive cue and simultaneously rewarded with apple. It was then presented with the negative cue and the plastic bag was shaken at the hatch. These "reminders" were not counted in the subsequent 15 trials of the cognitive bias test. Pigs received a total of five cognitive bias tests spread over the course of the experiment (see Table 1 for details).

For each of the three trial types the number of "go" responses and the latency to respond (maximum of 30 s) were recorded.

2.5. Statistical analyses

The proportion of "go" responses was arcsine square root transformed and latency data were log transformed to correct the distribution of the data and hence permit use of parametric statistics where possible. In cases where the distribution could not be corrected with transformations, non-parametric statistical analyses were used instead. All means reported in the text and plotted in the figures are based on untransformed data. An alpha value of 0.05 was assumed in all statistical tests.

3. Results

3.1. Task acquisition

It took 9 days training (i.e. 180 trials) for all the pigs to reach criterion in approach to the hatch for reward following the positive cue. It took a further 10 days of training (i.e. 200 trials) for all the pigs to reach criterion on the go/no-go discrimination task. Thus, all 10 pigs acquired a signficant discrimination of the positive and negative cues. In the final 3 days of discrimination training there was no significant difference in the proportion of correct responses between Group EBE (enriched housing: mean = 0.87, S.D. = 0.0247) and Group BEB (barren housing: mean = 0.83, S.D. = 0.105; Mann–Whitney test: n1 = 5, n2 = 5, $U = 11.50$, $p = 0.832$). There was also no significant difference between the groups in the mean latency to respond to either the positive cue (Group EBE: mean = 10.2, S.D. = 3.50; Group BEB: mean = 13.6, S.D. = 1.84; Mann–Whitney test: n1 = 5, n2 = 5, $U = 5.00$, $p = 0.117$) or the negative cue (Group EBE: mean = 26.8, S.D. = 1.66; Group BEB: mean = 27.7, S.D. = 2.46; Mann–Whitney test: n1 = 5, n2 = 5, $U = 6.50$, $p = 0.209$). Thus, there were no significant differences between the groups in task performance immediately prior to the first cognitive bias test.

3.2. Cognitive bias tests

Fig. 1 shows the mean proportion of approaches to the hatch (panels a and b) and the mean latency to approach the hatch (panels c and d) for pigs in both groups, in response to all cues for all five cognitive bias tests (tests 1–5). Fig. 1 shows that both groups' response to the positive and negative cues maintained the high performace established during training and varied very little between tests. However, the pigs' response to the ambiguous cues was intermediate between their response to the positive and negative cues and varied considerably both between tests and between groups. We therefore focus the remainder of the analysis on the pigs' response to the ambiguous cue.

Test 1 was, performed when the groups had been housed in their initial training environment for 5 weeks and we therefore used this test to explore how the training environment affected the behaviour of the pigs in the
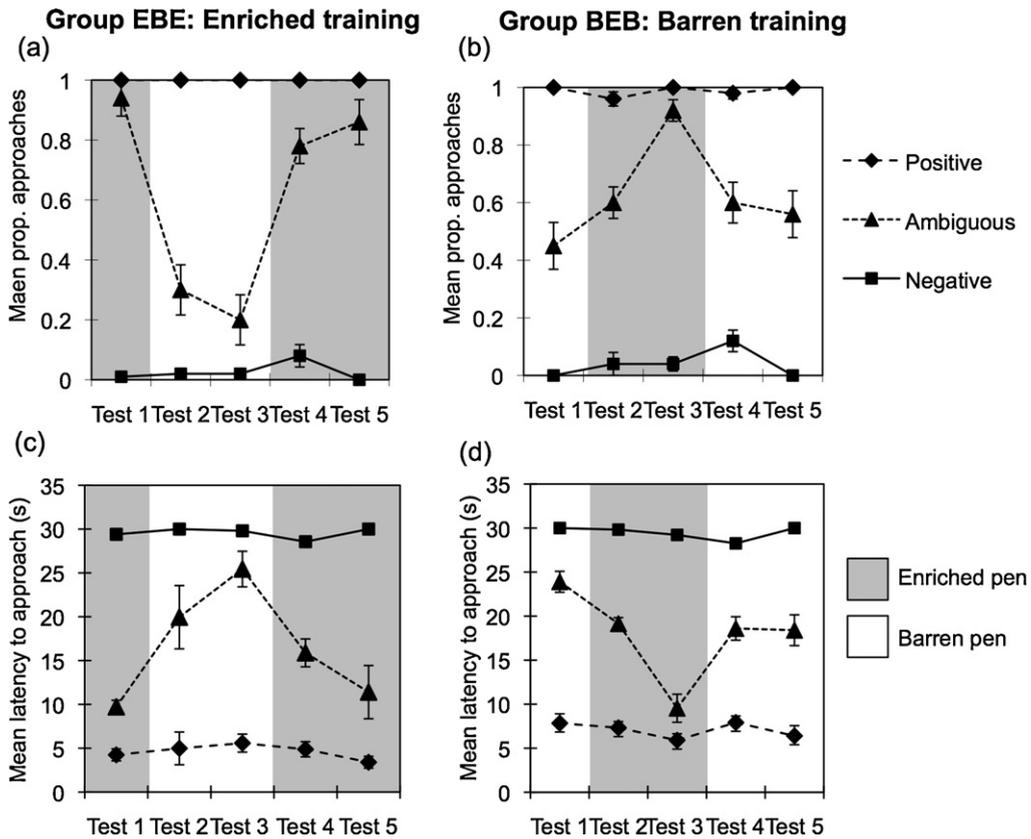
Fig. 1. Response to the three cue types in cognitive bias tests 1–5. Panels (a) and (b) show the mean proportion of trials on which a pig approached the hatch (i.e. made a "go" response) in response to each of the three different cues in Groups EBE and BEB respectively. Panels (c) and (d) show the mean latency to respond to each for the three different cues for pigs in Groups EBE and BEB respectively. The data points represent the mean ± 1 S.E. of the values for the five pigs in each group. The grey shading indicates the data from tests conducted when the pigs were housed in an enriched pen.

cognitive bias test. In Test 1 there was a significant difference between groups in the proportion of "go" responses to the ambiguous cue, with the group trained when housed in the enriched environment having a higher proportion of optimistic "go" responses than the group trained when housed in the barren environment (Group EBE: mean = 0.9, S.D. = 0.13; Group BEB: mean = 0.4, S.D. = 0.18; one-way ANOVA on arcsine square root-transformed proportions with group as the between-subjects factor: $F(1,8) = 26.1$, $p = 0.001$). For latency to approach the hatch, there was also a significant effect of group with pigs trained when housed in the enriched environment approaching the hatch more quickly following the ambiguous cue, than the group that had been trained when housed in the barren environment (Group EBE: mean = 9.7 s, S.D. = 1.7; Group BEB: mean = 23.9 s, S.D. = 2.7; one-way ANOVA on log-transformed latencies with group as the between-subjects factor: $F(1,8) = 95.5$, $p < 0.001$).

Tests 2–5 were performed two and seven days after the pigs had been switched to the opposite environment to that last experienced, and we therefore used these tests to examine the interaction between current environment and training environment on cognitive bias. In order to simplify the analyses that follow, we took the mean of the two cognitive bias tests performed in each environment for each pig (i.e. the mean of tests 2 and 3 and the

mean of tests 4 and 5). Fig. 2 shows the same data on approaches to the amibiguous cue in tests 2–5 that were presented in Fig. 1 replotted to facilitate comparison of the effects of current environment and training environment. Fig. 2(a) shows the mean proportion of approaches in response to the ambiguous stimulus for each group in each environment. Repeated measures ANOVA using the arcsine sqaure root-transformed proportions with one between-subjects factor (training environment) and one within-subjects factor (current environment) shows a significant effect of current environment, whereby both groups, regardless of their training environment, were more likely to approach the hatch (i.e. were more optimistic) in the enriched environment than the barren environment ($F(1,8) = 163.5$, $p < 0.001$). There was also a training environment × current environment interaction ($F = 45.5$, df = 1,8, $p < 0.001$) whereby the pigs trained whilst housed in the enriched environment were less likely to approach the hatch (were more pessimistic) in the barren environment than the pigs trained whilst in the barren environment.

Fig. 2(b) shows the mean latency to approach the hatch in response to the ambiguous cue for each training group in each test environment. Repeated measures ANOVA on the log transformed data with one between-subjects factor (training environment) and one within-subjects factor
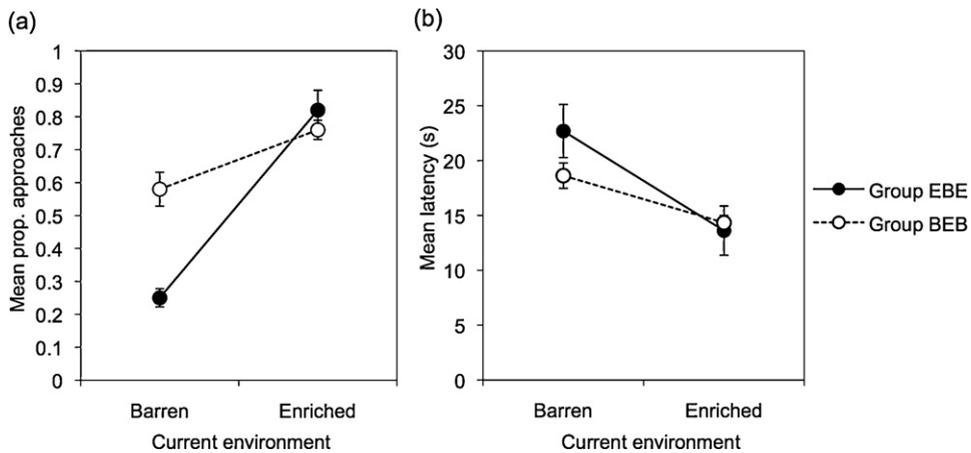
Fig. 2. Effects of training environment and current environment on response to the ambiguous cue. Panel (a) shows the mean proportion of trials on which a pig approached the hatch (i.e. made an optimistic "go" response) to the ambiguous cue in Groups EBE and BEB as a function of the current testing environment. Panel (b) shows the mean latency to approach the hatch in response to the ambiguous cue in Groups EBE and BEB as a function of the current testing environment. For both panels, the data points represent the mean ± 1 S.E. of all 20 probe trials conducted in each testing environment (i.e. the mean of the data from tests 2 and 3 and the mean of the data from tests 4 and 5).

(current environment) shows a significant effect of current environment ($F(1,8) = .13.6$, $p < 0.01$) with both groups of pigs approaching the hatch more quickly in response to the ambiguous cue in the enriched environment. There was no significant effect of training environment and no interaction between training environment and current environment on latencies to approach. Although the interaction was not significant in this analysis, it is interesting to note that the pattern of latencies echoes that seen with the approach data, whereby the pigs trained in the enriched environment appeared slower to approach the hatch in the barren environment than the pigs trained in the barren environment.

4. Discussion

Pigs currently housed in an enriched enviorment were more likely to respond to an ambiguous auditory cue by approaching a hatch at which food had previously been received than pigs currently housed in a barren environment. This optimistic cognitive bias was also evident in the pigs' latency to approach the hatch, with pigs currently housed in the enriched environment responding more quickly to the amibiguous cue than when housed in the barren environment. Analyses of the approach data also indicate an interaction between past and current environment, whereby the pigs initially housed in an enriched environment were less likely to approach the hatch when they were transferred to a barren environment than the pigs initially housed in the barren environment. Our data therefore support the hypothesis that an enriched enviorment induces a more optimistic cognitive bias indicative of a more positive affective state and hence better welfare. Importantly, this effect of housing quality on the pigs' affective state was apparent within two days of experiencing the environment, as evidenced by the rapid changes in cognitive bias when the pigs were switched between environments (Fig. 1).

Bateson and Matheson (2007) only found an effect of housing on cognitive bias when their European starlings had just experienced a decline in environmental quality. Contrary to that study, test 1 in our study shows that the pigs housed in the barren conditions initially were not as optimistic as the pigs housed in the enriched environment. Prior to the extended training period, all animals had been housed in relatively barren conditions (fully slatted pens in controlled environment rooms). An effect was therefore seen between groups based on housing before the enriched training group experienced a decline in environmental quality, and before the barren training group experienced the difference in quality of environment. This suggests that pigs are able to display distinct cognitive bias without a decline in quality of environment. In context, it is annecdotally argued that if a pig has not experienced an enriched environment, then "it does not know what it is missing", and therefore such an impoverished environment will not be detrimental to that pig's welfare. Our results refute this argument and suggest a pig does not have to have experienced better conditions to be negatively influenced by its current housing. However, we also show some evidence for a contrast effect, whereby the sequence in which the pigs experienced the different quality of environments appeared to have had an impact on cognitive bias and affective state. The significant interaction between training environment and current environment (Fig. 2) indicates that when the pigs had experienced a prolonged duration of enriched environment (i.e. were housed in an enriched environment during the 5 week training phase) they were more sensitive to a reduction in the quality of environment (demonstrating a greater pessimistic response) than pigs which had only previously experienced the enriched environment for a 7 day test period. This contrast effect mirrors that reported previously for cognitive bias in starlings (Bateson and Matheson, 2007) and in other studies which have shown that other behaviours, as a proxy for welfare, are affected by prior experience of a resource or quality of environment (Day et al., 2002;

Beattie et al., 1995). This has significant implications for the pig industry where a reduction in environmental complexity is often experienced in progressive stages of the pigs life.

Previous attempts to demonstrate changes in cognitive biases associated with changes in housing conditions have not always been successful (e.g. Brilot et al., 2010). Although one explanation is that the environmental manipulations were insufficient to provoke a change in affective state demonstrable through tests of cognitive bias, other possibilities relate to shortcomings in the methodologies used. One such problem is that the aversive consequence associated with the negative cue failed to be a sufficient deterrent as "there may be a general tendancy for all subjects to respond to intermediate probes.. as if they predict the positive reinforcer because the cost of getting it wrong and receiving the negative reinforcer is relatively small" (Mendl et al., 2009). These negative consequences commonly include delayed food reward, a smaller food reward or no food reward. We increased the liklihood of success of our methodology by carrying out several pilot trials to establish auditory stimuli that the pigs could be trained to reliably discriminate between and appropriate food preferences for reinforcement. We also had to research a suitably aversive negative outcome: we initially planned to use food incorporating English mustard but, although aversive to some pigs, others developed a liking for it. The use of the shaken bag was finally chosen as being demonstrably aversive but harmless to the animals (it did not inflict pain, the animals sought to avoid the bag but continued normal behaviour after its presentation and withdrawal). The results demonstrate that pigs can be trained reliably in a go/no-go task based on positive and negative auditory cues, as the probabilities of response varied very little between test days and showed a high degree of differentiation, irrespective of the environmental quality. Similar learnt auditory discrimination has been demonstrated in calling pigs individually for feeding by Ernst et al. (2005).

Our task differs from previous cognitive bias tasks in using an ambiguous probe stimulus that was qualitatively as opposed to quantitatively different from the two trained stimuli. This departure from normal cognitive bias methodology was necessitated by the failure of the pigs to learn to discriminate two notes differing only in frequency in the available time. It could be argued that the ambiguous cue we chose was more akin to a novel object than a typical ambiguous cue used in a cognitive bias test, raising the question of why it is necessary to train the animals at all? Would it not be possible to achieve comparable results simply by assessing the pigs' responses to a novel object with no prior training? We argue that our test differs in important respects from a simple novel object test. During the training the animals learnt the outcomes associated with the positive and negative cues and learnt to perform appropriate and clearly discriminable responses (go versus no-go). On hearing a novel auditory cue presented in the same context as the trained cues they had to decide what to do based on this established knowledge, and their decisions gives us a clear readout of whether their judgement of the novel cue was optimistic or pessimistic. A novel object test

without any prior training would be likely to yield much more variable results and would be less easy to interpret, since an animal's spontaneous response to a novel object or cue is likely to be subject to a whole variety of influences.

Over the course of the five cognitive bias tests conducted in this study the pigs were each exposed to a total of 50 presentations of the unreinforced ambiguous cue. In some previous cognitive bias studies with starlings and sheep there has been evidence that the animals have learnt that ambiguous cues are never reinforced, imposing a limit on how many cognitive bias trials are possible (Brilot et al., 2010; Doyle et al., 2010b). However, if such learning had occurred in the current study it would have been reflected in a gradual decrease in the proportion of optimistic "go" responses over time as the pigs learnt that the ambiguous cues were never reinforced and this pattern is not seen in the data (Fig. 1). We can only supposed that since the go/no-go discrimination task was relatively hard for the pigs to learn (up to 380 trials), they learnt about the ambiguous cue equally slowly.

One potential criticism of our study is that although the pigs were trained and tested individually, the pigs in each of the two groups were housed together in a single pen. Weary and Fraser (1998) raise the issue of using the behaviour of individuals from the same group as independent measures, because factors such as shared social interactions could mean that the behaviour of individuals from a particular group may not be independent. Hence, in our study, it could be argued that some other shared aspect of the pen mates' experience other than the manipulated aspects of the environment (e.g. social experience directly prior to testing) could have been responsible for the observed results. In response to this potential concern we note that it was not possible for there to have been a direct effect of social interaction during the task, as pigs were tested individually, having been escorted individually to the pen and held individually prior to performing the test. Pigs were with their companions before the test, which could theoretically influence their performance in the test. However, if this were the case we would expect to see less clear effects of our environmental manipulations.

A related criticism is that with only one enriched environment and one barren environment, we effectively have a sample size of one for our environmental manipulation. However, this would only be a concern if the primary aim of our study was to test the effects of environmental enrichment on welfare. Other studies employing proper replication have shown positive welfare benefits of environmental enrichment in farmed pigs (e.g. Beattie et al., 2000; Bolhuis et al., 2005; Scott et al., 2007). We argue that we were merely using this proven effect to manipulate the affective state of the pigs in our current study, and therefore that the lack of replication of the affective manipulation we used does not devalue our findings.

Tests of cognitive bias, such as the one described in this paper, would be useful to conduct alongside traditional physiological or behavioural welfare indicators to provide more information about the valence (positive or negative) of the pigs' response and consequently

the pigs' welfare (Mendl et al., 2010b; Paul et al., 2005). This information on valence would be particularly useful where studies have used welfare indicators which might also reflect increased arousal, e.g. cortisol, which could result from either excitement or fear. Cognitive bias tests would also be useful for further validation of qualitative behavioural assessment, for example as proposed in the Welfare Quality Assessment Protocols (Welfare Quality, 2009). This is because the methodology can demonstrate positive affective states, an important area of animal welfare but historically neglected by scientists (Balcombe, 2009; Boissy et al., 2007). Assessing postive welfare and positive affective states is becoming an increasing priority in livestock science, animal welfare science and government policy (FAWC, 2009). Cognitive bias methodology can be used to measure increases in welfare beyond the minimum of alleviating negative states such as fear or stress and be used to encourage management practices that promote positive welfare.

As a final point, it is important to reiterate that our use of the terms 'optimism' and 'pessimism' implies nothing about the subjective experience of the animals. Affective states in humans are characterised by a suite of changes in physiology, cognition and behaviour as well as by subjective feelings. In non-human animals we have no direct way of assessing the valence, or indeed the presence, of subjective feelings, and rely instead on the measurement of objective changes in physiology, cognition and behaviour to infer their likley affective state. Mendl et al. (2009, 2010b) have argued that the cognitive changes that we call optimism and pessimism (and define operationally) are central to the evolutionary function of core affective states such as happiness, satisfaction, anxiety and depression and hence should be good candidate indicators of these states across species. Hence by showing that housing quality alters cognitive bias in pigs we can be reasonably confident that it alters affective state, but we need to be clear that this does not prove conclusively that pigs have subjective feelings of happiness or satisfaction associated with their state. By providing cognitive evidence for positive effects of environmental enrichment in pigs our study adds to the growing literature suggesting that provision of environmental enrichment improves pig welfare (e.g. Bracke et al., 2006; van de Weerd and Day, 2009) since positive affect is assumed to be a central component of good welfare (Dawkins, 2008).

5. Conclusion

This study is the first to successfully apply a cognitive bias methodology to pigs and the first to demonstrate a change in cognitive bias consequent on environmental enrichment in farm livestock. We found that environmental enrichment induces optimistic cognitive bias indicative of a postive affective state. Validating this methodology for use in a farm species is an important contribution to studies of animal welfare, giving a novel and objective insight into an animal's affective state. This technique can now be extended to other ages of pig, other important welfare questions and other farm species.

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