THE EFFECT OF ENVIRONMENTAL ENRICHMENT ON LEARNING IN PIGS

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Final Acceptance: 18 January 2000

Abstract

Animal Welfare 2000, ***9:*** 373-383

This study examined the effects of enriching the environment on the learning abilities of growing pigs. Eighty-four pigs were housed in either barren or enriched environments from birth to 14 weeks. The barren environments were defined as intensive housing and the enriched environments incorporated extra space, including areas which contained peat and straw in a rack. The learning abilities of pigs from both environments were tested at 15–17 weeks using an operant task which involved pigs learning to push a panel for a reward and a maze test which involved spatial learning. Pigs from enriched environments learned both the operant task and the maze task more rapidly than their counterparts from barren environments. These results suggest that the cognitive development of pigs may be impaired in intensive housing systems.

Keywords: *animal welfare, environmental enrichment, learning, pigs*

Introduction

There is now considerable evidence that many of the harmful behaviours commonly observed among pigs in intensive husbandry systems can be reduced by the provision of environmental enrichment in the form of a rooting medium (Schaefer *et al* 1990; Beattie *et al* 1995a). It has been suggested, that the higher incidence of tail biting and other harmful behaviours in environments lacking such enrichment may be due to redirected exploratory behaviour (Van Putten 1979). Environmental enrichment, therefore, may improve the welfare of pigs by offering them the opportunity to express important behaviours.

This approach of providing enrichment in order to reduce problem behaviours has been applied across a wide range of other situations where animals are held in relatively unnatural environments such as zoos (Robinson 1998) and dog shelters (Wells & Hepper 1992). Research in this area has often displayed a very practical focus, being directly concerned with the effectiveness of particular enrichment procedures in improving the health and behaviour of animals.

However, there is a quite separate and older tradition of psychological research addressing the issue of environmental enrichment – particularly through the study of laboratory rodents.

Rosenzweig *et al* (1972) found that brain weight and activity was greater in rats reared in an enriched rather than in an impoverished environment. Exposure of laboratory rodents to an enriched environment has been shown to improve performance on a range of learning tasks (Paylor *et al* 1992; Nilsson *et al* 1993; Escorihuela *et al* 1994); to improve working memory (Escorihuela *et al* 1995); to reduce age deficits in learning (Diamond 1993); to increase the speed of recovery after brain injury (Rose *et al* 1992); and to increase cortical weight (Bennett *et al* 1996).

There is little overlap between these two research traditions. Although environmental enrichment has been used to improve the welfare of captive animals in zoos and in agricultural settings, its effect on learning ability has not been examined. The present study attempts to link these two traditions by examining the effect of enrichment on learning in an agricultural context. Therefore, this study investigated the learning ability of growing pigs from barren and enriched rearing environments.

Animals, materials and methods

The effect of rearing pigs in different environments (enriched and barren) on performance in two learning tasks was examined in a two–treatment design with six replicates.

Animals

Eighty-four pigs (42 boars and 42 gilts) were the subjects of this study. Forty-two (six groups of seven) were allocated to the barren environment and 42 (six groups of seven) to the enriched environment. These 84 pigs were the offspring of 12 Large White x Landrace multiparous sows which farrowed in crates at approximately the same time.

Housing

Pre-weaning (1-4 weeks)

In the pre-weaning stage, piglets were housed either in a farrowing pen (barren environment) or a straw-bedded pen (enriched environment) with their dams.

In the barren environment, the farrowing pen measured 2.6x1.6 m and had a plastic slatted floor. Part of the pen was enclosed by a kennel (0.5x1.5 m) that was accessible to the piglets but not to the sow (the creep area) and had a solid floor. Sows in the barren environment were restrained in the farrowing crate for the entire stage. In the enriched treatment, the sow and her litter were moved to a straw-bedded pen 3 days post-partum and remained there for 4 weeks. The straw-bedded pen measured 3.6x2.2 m and had a solid floor bedded with unchopped straw. The sow had unrestrained access to the entire pen except for a creep area of 1.6m^2 partitioned off to allow access to the piglets but not the sow.

Growing stage (5-14 week)

Twenty-one boars and 21 gilts from the group allocated to the barren treatment were mixed at weaning, divided into groups of seven (three or four males and three or four females) balanced for weight, and moved to flat deck cages measuring 2.4x1.2 m which had expanded metal floors. Twenty-one boars and 21 gilts from those pigs in the enriched condition were similarly mixed, split into groups of seven and moved to enriched environments.

The enriched pens measured 14m^2 and were divided into five areas, all with solid floors (except area 4) as follows:

Area 1. A peat area of 2.8m^2 with a 12cm-high surround and approximately 6cm depth of peat which was replenished when necessary.
Area 2. A straw area of 6.8m^2 containing a straw-hopper that allowed the pigs to control the amount of straw used.
Area 3. An enclosed kennel of 1.8m^2 bedded with shredded paper and accessed through a curtain of polythene strips forming the sleeping area.
Area 4. A drinking area of 0.6m^2 with two water nipples situated 0.5 m above the fully slatted floor.
Area 5. A feeding area, which was defined as the area immediately around the feeder and occupied approximately 2m^2 including the feeder.

Husbandry schedules

At all stages both environments had a day/night cycle, with full lighting between 0800h and 1700h, and dimmed lighting for the remainder of the time. In the barren, pre-weaning housing, the environmental temperature was maintained at approximately 18°C while the average temperature of the enriched pre-weaning environment was 15°C. Localized supplementary heating was supplied by infrared heat lamps over the creep areas in both environments for the first 3 weeks (250W for the first 5 days and 125W thereafter). The ambient temperature outside the sleeping kennels of the enriched environments ranged between 10°C and 22°C during the growing stage, while that of the barren environment was kept at 21°C. Lactating sows were fed to appetite, and from 10 days of age creep feed was provided for piglets in both environments. Water was available from birth for the piglets via one water nipple in both environments. During the growing stage in both environments, feed was offered *ad libitum* in a four-space dry feeder and water was continuously available from two water nipples (see, *Diet*). In the enriched housing during the growing stage, peat and straw were replenished as necessary.

Diet

Lactating sows in both environments were offered 7.5kg d^{-1} of a pelleted cereal/soya based diet which was manufactured at the Agricultural Research Institute of Northern Ireland (ARINI). This supplied 13.8MJ digestible energy (DE) and 9g of lysine kg air-dry diet^{-1}. Piglets up to 4 weeks old were offered a commercial creep feed (Milkiwean; SCA, Dublin, Eire). Weaned pigs from 4–6 weeks of age were offered a commercial link diet (Thrift; SCA, Dublin, Eire), and from 7–14 weeks were offered, *ad libitum*, a pelleted cereal/soya based diet supplying 14.2MJ DE and 12g of lysine kg air-dry diet^{-1} which was manufactured at ARINI.

Operant test

A single-space feeder (Verba Wet Feeder; L Verbakel BV, Sint Oedenrode, The Netherlands) was modified to deliver measured amounts of food after a number of pushes at a nose-operated metal plate. All 84 pigs were tested individually on this apparatus at 15–17 weeks of age. The number of pushes required and the food delivery could be varied by specially written software run on a BBC microcomputer. The feeder was mounted at one end of a bare, solid-floored room measuring 3.5x2 m. A ceiling-mounted camera allowed each pig's behaviour to be observed on a monitor in the control room and recorded on videotape. The pigs were first familiarized with the room and the feeder by being allowed to explore freely in groups of seven for 30min. They were then removed to a holding pen and reintroduced individually to the feeder room for training.

During the first training trial, a pig was left in the room until it had either made 20 responses at FR2 (two pushes required for each food reward) or 30min had elapsed. During the second training trial, at least 4h later the same day, the pig was left in the room until it had either made 20 responses at FR3 (three pushes required for each food reward) or 30min had elapsed. Approximately 48h later, each pig was given a further test trial lasting 30min with the feeder schedule set at FR3. The number and pattern of responses, and the behaviour of the pig were again recorded.

Maze test

Mazes have progressed from the simple T-mazes used in the early years of the century (Watson 1924) to more explicit tests of spatial learning, such as the radial arm mazes developed by Olton in the 1970s (Olton *et al* 1977), the Morris water test (Morris 1981) and spatial arenas (Biegler & Morris 1993). In the present study, a spatial arena, consisting of a flat enclosed area (7.2x4.5 m) divided into 12 squares of 1.8x1.5 m was used. Seven of the squares were fitted with small containers which were attached to the floor (Figure 1). At 15-17 weeks, each pig was trained to find food in one randomly assigned food container. It was then tested when no food was present and the time taken by the pig to reach its food position and the directness of its route were measured.

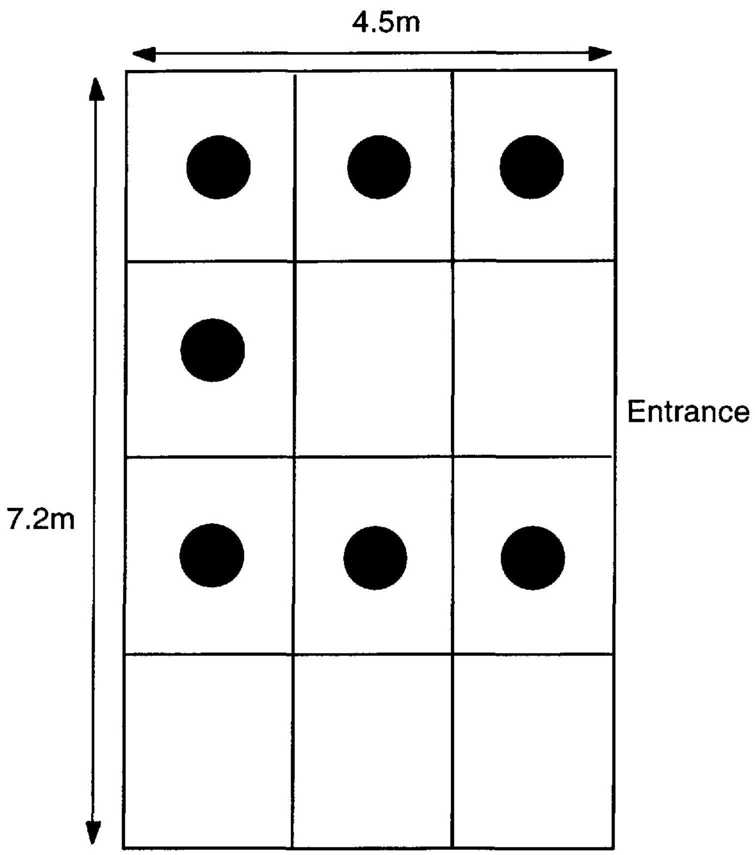

Figure 1 **Plan of the maze test arena. Black circles denote possible food sites.**

The pigs were first familiarized with the layout of the array by being allowed to explore the pen freely in groups of seven for 45min. They were then removed to a holding pen and reintroduced individually to the array for training. Each pig was randomly assigned one of the seven food container positions. Although the container position was different for each pig, the same food container was always used in order to avoid the presence of many containers smelling of food. The container was unbolted at the end of each trial and swapped with the container from the new position. During training trials, approximately 25g of the same food as available in the home pen was placed in the allocated container and the pig left in the arena until either it found and ate the food or 5min had elapsed. Each pig was given four training trials on day 1. Because of the schedule of training, testing did not take place until approximately 48h after training. Therefore, each pig was given one further training trial (a 'reminder trial') immediately before testing. All containers were then washed thoroughly with disinfectant solution to remove odours before each pig was tested in the maze. Each pig was tested three times in a 90-min period and the times taken for each to reach and put its nose in the correct container and the routes followed to the container were recorded. All training and test trials were observed on a video monitor during the trial and were recorded on videotape.

Statistical analyses

Operant test

The cumulative number of responses (ie the number of deliveries of a food reward) was calculated for 5, 10, 15, 20 and 25 min for each pig, and also the mean number of responses per minute across the entire 25min period. The latency to first response was defined and calculated as the time taken to attain the first food reward in each of the three sessions. We also calculated the time taken to reach a performance criterion, set at obtaining five deliveries of food within 2min. An analysis of variance (ANOVA) using Genstat, version 5 (Lawes Agricultural Trust 1989) was performed across both treatments and gender for all variables and any effects of interaction examined.

Maze test

The time taken to identify the correct container was recorded for each of the 84 pigs. The number of visits to 'deviant' squares was also recorded. (These were visits to squares within the arena which were not necessary to reach the target container.) A pig was deemed to have visited a square if both front legs entered the square. Unsuccessful trials were recorded when a pig did not visit the target within a 5min period. An ANOVA (Genstat, version 5 [Lawes Agricultural Trust 1989]) was performed across both treatment and gender for the four training sessions and the three test sessions. A Student's *t*-test was performed to determine whether two particular means with equal variances were significantly different.

Results

Operant test

Pigs reared in the two experimental treatments showed considerable differences in response rates during both training and testing (Table 1). During FR2 training, pigs from enriched environments showed consistently higher response rates than those reared in barren environments. The average response rate (mean number of responses min^{-1} over 25min) of enriched pigs was significantly higher than that of barren pigs ($P < 0.05$; Table 1). During FR3 training the difference in rates of responding failed to reach significance but, as Table 1 indicates, significant differences were again present during the test phase of the experiment,

Table 1 **The operant test – treatment differences in mean cumulative response frequencies at specified time intervals during training and testing and in the mean number of responses min^{-1} (over 25min). (ns – not significant.)**

Trial/test	Treatment		SEM[1]	*P* value
	Barren	Enriched		
FR2 training				
5min	2.0	5.7	1.14	< 0.05
10min	4.9	12.4	2.27	< 0.05
15min	10.8	22.9	3.67	< 0.05
20min	16.7	32.1	4.69	< 0.05
25min	22.6	38.0	5.15	< 0.05
Mean no of responses min^{-1}	0.8	1.5	0.20	< 0.05
FR3 training				
5min	10.0	13.2	1.85	ns
10min	20.5	26.4	3.47	ns
15min	27.2	37.0	4.73	ns
20min	31.9	43.8	5.47	ns
25min	36.9	49.5	6.03	ns
Mean no of responses min^{-1}	1.3	1.8	0.24	ns
Testing				
5min	4.9	11.4	1.54	< 0.005
10min	11.2	24.9	2.89	< 0.001
15min	16.4	36.1	3.97	< 0.001
20min	20.8	43.3	4.91	< 0.005
25min	26.0	49.7	5.87	< 0.005
Mean no of responses min^{-1}	1.0	1.9	0.24	< 0.05

[1] A Single SEM was calculated as the ANOVA assumed equal variability within treatments as there were equal numbers of observations per treatment.

when the average rate of responding of enriched pigs was significantly higher than that of barren pigs ($P < 0.05$). Neither latency to first response nor time taken to reach the specified criterion differed significantly (ie all $P > 0.05$) between the groups in training or testing (Table 2).

There were no interactions between environment and gender and there was little consistent pattern to the sex differences in response rates. During the FR2 phase of training, females responded at a higher rate than males until the average cumulative frequency of responding reached significance after 25min (M = 23.1 vs F = 37.8, SEM = 5.16; $P < 0.05$). This was reflected in the overall average rate of responding during the FR2 training, where the higher rate of female responding approached but did not reach significance (M = 0.9 vs F = 1.4, SEM = 0.21; $P < 0.1$). This pattern was not repeated in either FR3 training or in testing. There were no significant sex differences in the mean latencies to first response or in the mean times taken to reach the specified criterion.

Table 2 **The operant test – treatment differences during training and testing for mean latencies to first response and mean times to reach the specified criterion (see text for details). (ns – not significant.)**

Trial/test	Treatment Barren	Enriched	SEM[1]	*P* value
Mean latency to first response (s)				
FR2 training	374	319	58.6	ns
FR3 training	228	261	60.0	ns
Test	292	303	60.5	ns
Mean time to reach the criterion (s)				
FR2 training	733	553	71.2	< 0.1
FR3 training	255	280	51.9	ns
Test	525	344	70.1	< 0.1

[1] A Single SEM was calculated as the ANOVA assumed equal variability within treatments as there were equal numbers of observations per treatment.

Maze test

In the maze test, the pigs reared in the enriched (E) and barren (B) environments again showed differences in response patterns in both the training and testing phases. Across the training sessions, pigs in both treatments showed a reduction in the time taken to reach the food reward (Figure 2) but pigs reared in the enriched environment were significantly faster than those reared in barren conditions (E = 40.97 vs B = 120.41, SEM = 11.32; $P < 0.05$). There was no significant difference between the speeds at which males and females gained the food reward during training trials (M = 66.49 vs F = 94.89, SEM = 11.32; ns). Nor was there was an interaction between treatment and gender for any of the variables measured.

During the testing trials there were neither treatment nor sex differences in the speed with which the pigs reached the target food container. However, during this phase of the study, the route taken by each pig to reach the target container was also recorded, and the number of deviant squares they entered calculated. The ANOVA indicated a significant interaction between the treatment and the number of test trials. The mean number of deviant squares increased across test trials for pigs reared in barren environments: by test 3, they were entering significantly more deviant squares than pigs reared in enriched environments (E = 2.95 vs B = 6.71, SEM = 1.26; $P < 0.05$).

Discussion

Enriching the pigs' rearing environment had a clear influence on their ability in the two learning tasks. In the operant task the enriched pigs mastered the task more quickly during the training phase. In the maze task the enriched group again showed more evidence of learning during the training phase and demonstrated stability of learning by making fewer errors during parts of the testing phase.

The effects of environmental enrichment on the behaviour of pigs have been well documented. Changes in behaviour, such as reduced tail biting and increased exploratory behaviour, have been observed when the resident pen is enriched (Simonsen 1990; Bøe 1993; Beattie *et al* 1995a). These changes may be expected as pigs in enriched environments are surrounded by different stimuli from pigs in barren environments. However, recent research has shown that when pigs reared in enriched environments are put in novel test situations they behave differently from pigs reared in barren environments (Schouten 1991;

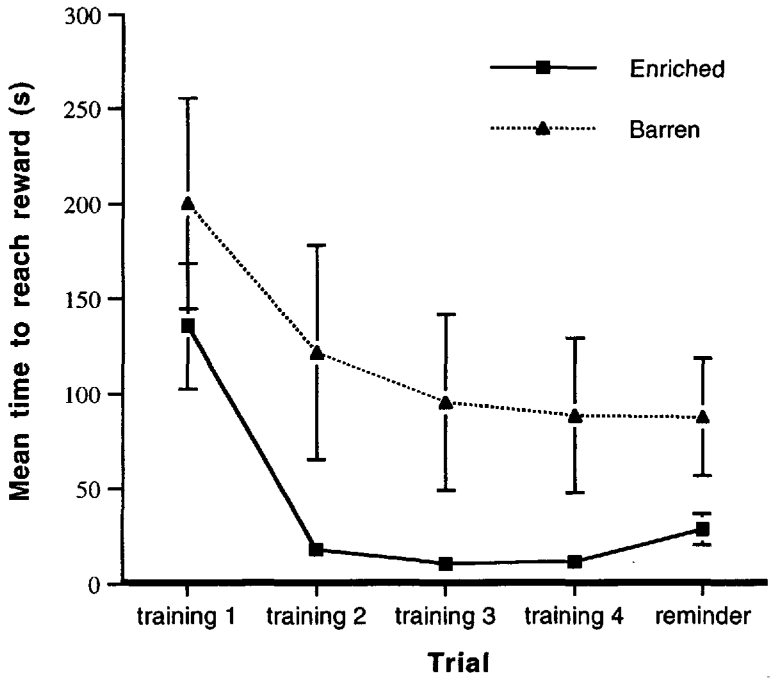

Figure 2 **Mean (± SEM) time taken to reach a reward in the maze test for pigs in the two rearing conditions across the four training trials and the reminder trial.**

Beattie *et al* 1995b; De Jonge *et al* 1995). The suggestion from these studies is that the rearing environment influences how pigs cope with stressful situations. Following on from this idea, the present work suggests that the differences observed in behaviour may be linked to differences in the pigs' cognitive abilities.

Research with rats has shown that environmental enrichment influences brain development by increasing overall brain weight (Rosenzweig *et al* 1972), increasing cortical thickness (Diamond *et al* 1984) and cortical weight (Bennett *et al* 1996). Associated with these physical brain changes are improvements in learning ability (Paylor *et al* 1992; Nilsson *et al* 1993). Rosenzweig (1984) suggested that learning ability might be related to the capacity to process information in the brain and that an index of this might be the activity of acetyl cholinesterase in the cerebral cortex. In relation to Rosenzweig's work, the interesting finding was that environmental enrichment was found to be effective in altering cortical acetyl cholinesterase activity (Krech *et al* 1960; Rosenzweig *et al* 1962).

No similar link between enrichment and learning ability has been shown in farm animals. A study examining the effects of handling on the learning ability of foals showed no difference between those handled regularly and those not handled (Mal *et al* 1994). However, work with farmed species shows a link between the social dynamics created by the environment and learning ability (Boissy & Le Neindre 1990; Coussikorbel & Fragaszy 1995). In the present study the animals were reared in groups. It is, therefore, possible that the influence of the experimental treatments on learning ability was somehow mediated through differences in social factors. Recent work by O'Connell and Beattie (1999) has shown that social behaviour and group dynamics differ between pigs reared in enriched environments and their counterparts reared in barren ones. Therefore, the influence of enrichment on learning abilities in pigs may not be related solely to the environment, but the result of an interaction between social dynamics and environmental enrichment. Further research is required to determine whether cognitive development is influenced directly by the physical environment or is mediated by social factors.

Animal welfare implications

It has been argued that the study of cognition can inform discussions about the treatment of animals, in that having knowledge in the area of cognition will help identify situations, social and otherwise, which might lead to pain, suffering, boredom or frustration (Bekoff 1994; Allen 1998).

By investigating learning ability, this study raises questions about housing pigs in barren environments. The comparison between 'enriched' and 'barren' environments is, of course, a relative one – and even the 'enriched' environments used in this and other studies must surely be impoverished in comparison with any natural environment encountered by the animals' ancestors. If this is so, then rather than the 'enriched' environment providing cognitive enhancement, it is surely the 'barren' environment which is imposing a cognitive impairment. This would suggest that in addition to the harmful behaviour and injuries which are the obvious consequences of barren environments, there may also be hidden cognitive damage.

Two aspects need to be considered in relation to welfare. Pigs are very adaptable animals – and it could be argued that they simply mould their behaviour to the environment they occupy. However, if there are changes in cognitive development underpinning the differences in behaviour observed in barren and enriched environments, it may not be so easy to switch responses to changing environments. While it is not difficult to envisage an animal improving its cognitive development when switched from a barren to an enriched environment, it is less conceivable that an animal could reverse the developmental process when switched from an enriched to a barren one. Therefore, it could be argued that once a pig has been exposed to an enriched environment it may be less able to adapt its behaviour to a barren one. This implies that we should not tinker with welfare by enriching a pig's environment for only part of its life.

We already know that pigs reared in barren environments throughout their lives suffer a range of behavioural and physical problems – and to this must now be added the knowledge that they may suffer cognitive impairment. This means that we must face the ethical issues relating to rearing animals in conditions which are known to result in impairment. If rearing pigs in barren environments impairs cognitive development, as suggested, then current production systems are restricting the development of domestic pigs and need to be changed.

Acknowledgements

The authors wish to thank Dr D J Kilpatrick and Mr Alan Gordon for help with the statistical analysis. Thanks are also due to the technicians and stockmen of the Agricultural Research Institute of Northern Ireland's Pig Unit for care of the animals. Finally, the authors wish to acknowledge the constructive advice of two anonymous referees.

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