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Effects of cognitive enrichment on behavioural and physiological reactions of pigs

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HIGHLIGHTS

- We investigated the effects of cognitive enrichment on pigs' behaviour and physiology.
- Experimental pigs were individually fed using an auditory discrimination paradigm.
- They showed reduced aggression and had lower sympathetic activation during feeding.
- The pigs were more explorative and less fearful in external tests compared to controls.
- Cognitive enrichment may induce positive emotions and improves animal welfare.

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ABSTRACT

Cognitive enrichment, a special form of environmental enrichment, addresses the cognitive abilities of animals in captivity. Through cognitive interaction with the environment, the animals regain a certain control over their environment, and essential resources, such as food or water, act as a reward for successful coping. It is assumed that this process has important implications for animal welfare, especially in the intensive housing systems of farm animals. This study investigates the effects of cognitive enrichment on welfare-relevant behaviour (agonistic interactions and behavioural reactivity in a repeated open-field test) and autonomic control (heart rate variability during feeding, resting and in a repeated open-field test) in domestic pigs. A total of forty-eight pigs, *Sus scrofa*, were housed in groups of four. In six replicates, an experimental group was compared with a conventionally fed control group. The pigs in the experimental group were confronted with a cognitive challenge that was integrated into their familiar housing environment. Pigs were rewarded with food after they successfully mastered the discrimination of an individual acoustical signal followed by an operant task. The pigs in both groups reacted with sympathetic arousal to feeding announcement (increased heart rate (HR)). During feeding, the experimental pigs' HR decreased, and heart rate variability (HRV) increased, while the control pigs' HR stayed highly elevated and HRV decreased. These results are supported by a considerably larger number of agonistic interactions during feeding in the control group. During resting, the basal HRV of the experimental pigs increased (during operant conditioning) compared to the control. In the repeated open-field test, the experimental pigs displayed less locomotion and elimination as well as more contact with the wall and an unknown object compared to the control group. We conclude that cognitive enrichment leads to relaxed feeding and evokes longer lasting positive emotions. Moreover, the pigs displayed more explorative and less fearful behaviour in stressful situations. These findings support the use of cognitive enrichment to improve animal welfare.

1. Introduction

In recent decades, animal welfare issues have become increasingly important to the public as well as science [1–3]. Welfare problems are often caused by monotonous and impoverished housing conditions that inhibit the ethological and psychological needs of animals and hypostimulate the animals' senses and cognitive abilities [4–6]. These conditions lead to boredom and behavioural problems that may include impaired health and performance [7–9]. Environmental enrichment is one major method to combat animal welfare problems [10]. 'Problems' are defined predominantly as behavioural problems because enrichment reduces abnormal or undesirable behaviours and/or supports natural or desirable behaviours [11–13].

The dominant type of environmental enrichment is structural enrichment, with objects or substrates introduced into the housing permanently

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or temporarily [14,15]. However, the effects of habituation and extinction can rapidly counteract the positive impact of the enrichment [16,17]. The least investigated form of environmental enrichment, especially for farm animals, is cognitive enrichment of the housing environment [14]. In this type of enrichment, animals must meet moderate challenges by using their cognitive abilities and interacting actively with their environment [18]. These challenges should be appropriate to the sensory, behavioural and cognitive abilities of the species, and the degree of difficulty should not be too simple nor too challenging [9,19]. According to the principle of allostasis, a certain amount of stress or challenge in the environment is necessary to maintain or enhance the flexibility of biological functioning, including behaviour, physiology and cognition [6]. Recent studies of farm animals used operant conditioning in cattle [20], dwarf goats [21] and domestic pigs [22] to create cognitive challenges and to increase the effort needed for continued learning and performance. In these studies, after mastering the challenge, the animals were rewarded with food or water, which have high incentive values. This approach is much more effective in sustaining motivation, preventing habituation and activating the central nervous reward system over the long term than any form of structural enrichment [16,23]. Operant conditioning facilitates behavioural and cognitive interaction with the environment, which gives animals a certain control over their environment and essential resources. This sense of control has important implications for animal welfare concerns [24]. To measure the impact of environmental enrichment on animal welfare, Broom [25] and Manteca [26] suggested using a set of sophisticated measures and parameters ranging from 'simple' measures of production and behaviour to physiological and neurophysiological parameters.

Recently, our research group developed an experimental design that integrates cognitive enrichment based on auditory conditioning into the familiar group housing conditions of domestic pigs [22]. Interacting with the so called 'call feeding station' (CFS) positively affected the behaviour [27], health [28] and meat quality of the pigs [29]. Moreover, pigs appear to interact emotionally positively to the cognitive enrichment, as indicated by short-term affective alterations in their heart rate variability [30] and long-term changes in their brain opioid receptor gene expression [31]. Furthermore, we have demonstrated that the determination of the parameters of heart rate variability is a useful approach in the study of animal affects and emotions [30], which are considered to be the key elements of animal welfare [32–34]. The CFS has been successfully used as a modular extension of a conventional electronic feeder (PigTekINTEC MAC) communicating via ISOagriNET [35]. The current study used this experimental design to investigate the long-term effects of cognitive enrichment on welfare-related behavioural and physiological reactions in domestic pigs.

2. Materials and methods

2.1. Animals, housing and husbandry

The study was conducted at the experimental pig unit of the Leibniz Institute for Farm Animal Biology (FBN) in Dummerstorf, Germany. In each of six replicates, four sibling pairs of castrated male pigs from different litters of the German Landrace breed were used (n = 48). All of the pigs were born and raised at the experimental pig unit of the FBN. At the age of 28 days, the piglets were weaned, and non-siblings were randomly grouped together in two adjacent 2.00 m × 1.50 m pens with a fully slatted floor to form two stable social groups with four piglets each. In both groups, feeding occurred ad libitum at a trough with five feeding places.

At the beginning of the 10th week of life (average weight 26 kg), the piglets in one group were provided with individual ear responders and transferred to an experimental pen measuring 3.00 × 4.25 m (partially slatted floor, 3.00 × 2.08 m concrete/3.00 × 2.17 m plastic slat). The second group was transferred to an adjacent pen similar to the experimental pen. This group was visually separated from the experimental group and served as the control group. For bedding, both groups were provided with some straw and hemp pellets daily. In the experimental group, feeding occurred at two CFSs. Ernst et al. [22] described the CFSs in depth. Briefly, the CFSs consisted of a wooden chamber with a feeding trough, two loudspeakers, an antenna and a press button. The CFSs were controlled by a computer system that assigned an individual acoustic signal to each pig. The daily food supply for the pigs was assessed according to the feeding recommendations that are commonly used for commercial pig production [36]. The control group was provided with the same amount of food that the experimental group had earned through successful performance at the CFSs on the previous day (see Section 2.2). The control group was fed once daily at 8 am from two small piglet troughs that provided access for two animals simultaneously. All of the animals had continuous access to water at nipple drinkers.

The cognitive challenge provided by the CFSs in the experimental group was planned as a special type of environmental enrichment (cognitive enrichment) and was the subject of this research. To prevent interactive effects, no other environmental enrichment was offered.

At the end of the 16th week of life (average weight 55 kg), all of the pigs returned to the standard production management at the FBN and were fattened until they reached slaughter weight. One piglet was excluded from the experiment due to a rectal prolapse (n = 47).

The study was approved by the Scientific Committee of the FBN, and the experimental setup was generally licensed by the ethics committee of the federal state of Mecklenburg-Western Pomerania, Germany.

2.2. Experimental setting

The conditioning paradigm for the experimental group was modified from that of Ernst et al. [22] and was described in detail in [30]. Briefly, the experiment consisted of three consecutive phases (Fig. 1). In phase 1, the association phase, pigs were classically food-conditioned to individual acoustic signals that were emitted by the CFSs. In phase 2, the discrimination phase, pigs were individually called by their individual signals from 28 to 33 times per day to receive one portion of food. In phase 3, the working phase, the pigs also needed to press a press button at the CFS after being called, initially once (fixed ratio (FR) 1) and later five times (FR 5), to receive one portion of food. Before the start of the experiment, as well as at the beginning, middle and end of each experimental phase, the heart beat activity of all pigs (experimental and control) was measured for 3 h (8–11 am) on two consecutive days (referred to as a measuring period, see [30] and Fig. 1). During this time, the behaviour of the pigs was videotaped. Because of technical problems, there was only one day of measurement at the end of phase two. To estimate the impact of the cognitive enrichment setting on the pigs' ability to cope with challenges, their behavioural reactivity was analysed using a combined open-field/novel-object test (OF/NO test). The test was conducted separately in a square open field (2.80 × 2.80 × 1.25 m) that was located in a noise-reduced room. The test order of the piglets was randomised, and the open field was cleaned after each observation. The test lasted 10 min and was repeated three times: first, before the start of the conditioning paradigm; second, after three weeks (at the end of experimental phase 2); and third, at the end of the experiment (end of phase 3 FR5; see Fig. 1). In each test replication, a new novel object was used (1: flexible wooden parts for birds, 2: soft star-like dog toy, 3: traffic cone).

2.3. Agonistic interactions

The aggressive behaviour in both groups was estimated by analysing the videotapes from each measuring period (see above). The number of agonistic interactions (biting and head knocking) was counted at the group level, distinguishing different situations such as trough (aggression during feeding and near the feeding trough/CFS area), resting (aggression while lying down and resting) and pen (aggression during active behaviour in the pen). The counts