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Impact of structural and cognitive enrichment on the learning performance, behavior and physiology of dwarf goats (*Capra aegagrus hircus*)

Susann Oesterwind[a,b], Gerd Nürnberg[c], Birger Puppe[a,b], Jan Langbein[b,*]

[a] Behavioural Sciences, Faculty of Agricultural and Environmental Sciences, University of Rostock, Justus-von-Liebig-Weg 6b, D-18059 Rostock, Germany
[b] Institute of Behavioural Physiology, Leibniz Institute for Farm Animal Biology (FBN), Wilhelm-Stahl-Allee 2, D-18196 Dummerstorf, Germany
[c] Institute of Genetics and Biometry, Leibniz Institute for Farm Animal Biology (FBN), Wilhelm-Stahl-Allee 2, D-18196 Dummerstorf, Germany

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ABSTRACT

Intensive husbandry usually offers only limited opportunities for animals to perform their characteristic species–specific behavior and can lead to boredom, stress or frustration. The positive impact of structural forms of environmental enrichment on animal welfare is well investigated because it is relatively low-cost and quickly performed. In contrast, approaches that integrated cognitive enrichment into the housing of animals are hardly investigated. The present study assessed the impact of structural and cognitive enrichment on learning as well as on the behavioral and physiological responses of 34 female dwarf goats (*Capra aegagrus hircus*) using a 2 × 2 factorial design. After weaning at the age of 5 weeks, the animals were randomly allocated to four groups (8–9 goats per group). Two of the animal groups were housed under conditions of structural enrichment; the other two groups under barren housing conditions. One group, respectively, obtained drinking water at a normal water bowl, the other obtained drinking water as a reward for a correct choice at a learning device, which was integrated into the housing pen and presented automatically visual four-choice discrimination tasks. Before the first and after each of three different learning tasks, the reactions of the animals to external challenges in a combined open-field/novel-object test were recorded. An enriched environment was shown to positively affect the learning performance of the goats. Structural enrichment of the housing conditions increased the motor activity of the animals in the external test situation, whereas cognitive enrichment lead to enhanced curiosity toward and prolonged contact with the unknown object. However, there were no differences in stress levels, which were measured through salivary cortisol, between any of the groups. We conclude that the combination of structural and cognitive enrichment in particular can improve the behavioral competence of dwarf goats in challenging situations and may have beneficial effects for their welfare.

1. Introduction

In the wild, there are countless different stimuli and challenges, biotic or abiotic, that have to be perceived and successfully coped with by an animal. Spotting predators, finding food or reproduction partners and rearing offspring, to mention only a few aspects, require animals to exhibit many adaptive capabilities. Innate behavioral strategies as well as learning play an important role in the ability to flexibly and successfully cope with and adapt to an ever-changing environment (Toates, 1998). Captive animals live under artificial housing conditions, where the environment is largely limited and structurally simple (Newberry, 1995). Such barren conditions offer only limited possibilities to exhibit species-appropriate behavior (Averos et al., 2010; Morgan and Tromborg, 2007). These limitations can lead to boredom and frustration, promoting the appearance of stereotyped and other abnormal behavior, which is related to stress and reduced welfare (Mason et al., 2007; Wemelsfelder, 1993). The concept of environmental enrichment refers to the enhancement of the biological relevance of housing conditions by the provision of a variety of new structures, items and challenges that elicit a higher degree of behavioral diversity (Newberry, 1995; van de Weerd and Day, 2009). A comprehensive definition of environmental enrichment has stated that it is "... an animal husbandry principle that seeks to enhance the quality of captive animal care by identifying and providing the environmental stimuli necessary for optimal psy-

* Corresponding author. Fax: +49 38208 68 802.
E-mail address: langbein@fbn-dummerstorf.de (J. Langbein).

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chological and physiological well-being" (Shepherdson, 1998). This definition emphasizes the concept that structural and cognitive needs (Broom, 2010; Wechsler and Lea, 2007) are both important for animal welfare.

The predominantly applied type of environmental enrichment is structural/physical enrichment, with objects or substrates introduced into the housing permanently or temporarily (de Azevedo et al., 2007; van de Weerd and Day, 2009). However, in the majority of cases of structural enrichment, a loss of novelty of the introduced items and the habituation that follows rapidly counteract the initial positive impact of the enrichment (Tarou and Bashaw, 2007; Trickett et al., 2009).

The least investigated or applied type of environmental enrichment is cognitive enrichment of the housing environment (de Azevedo et al., 2007). Thereby animals are required to meet moderate challenges by using their cognitive/learning abilities and actively interact with their environment (Manteuffel et al., 2009; Meehan and Mench, 2007). Clark (2011) gives a comprehensive definition of cognitive enrichment: "cognitive enrichment is a task (or tasks) whose use (1) engages evolved cognitive skills by providing opportunities to solve problems and control some aspect of the environment, and (2) is correlated to one or more validated measures of wellbeing". Achievable learning tasks that are implemented within the normal housing routine and linked to the supply of a rewarding item, such as food, provide "a context within which animals can learn to increase their chance of achieving a desired goal through the performance of appropriate behavior" (Carlstead and Shepherdson, 2000). So learning tasks may have important implications for animal welfare concerns (Sambrook and Buchanan-Smith, 1997). Supplying animals in captivity with the opportunity to interact with a more sophisticated environment by challenging their cognitive abilities and offering them the possibility to gain control of the environment as a result of successful interactions and to anticipate a rewarding outcome seems an effective way of reducing the absence of challenges and therefore the negative consequences of boredom on well-being, health and behavior.

Langbein et al. (2004) trained dwarf goats on visual-discrimination tasks using an automated learning device. They found that initially, when learning success was low, heart rate increased; however, heart rate then decreased as the goats started to master the task. These findings were interpreted as evidence that the goats first perceived the task as challenging, but later perceived it as a 'positive' stressor. Similarly, Lyons et al. (2000) challenged monkeys by relocating their familiar feeding place to a new site. As a direct reaction, levels of cortisol increased in the monkeys. Later on, cortisol levels decreased again, but only in those monkeys that successfully found the new feeding site. Mackay (1981) found that dolphins continued to whistle at a specific frequency to activate a food dispenser even when the disperser was not active anymore. Similar results were found in dwarf goats (Langbein et al., 2009). When giving the chance to obtain a reward for free or only after solving a discrimination task, a large number of goats preferred to work for the reward. This phenomenon, known as contrafreeloading, has been discussed in different contexts (Inglis et al., 1997; Kacelnik, 1987). In cattle, Hagen and Broom (2004) found that learning an operant task to receive a food reward induced greater excitement than receiving an identical food reward for free.

In the present study, we examined the impact of structural and cognitive enrichment on the learning performance, behavior and stress response of dwarf goats. Two groups of goats were kept under barren housing conditions, while two other groups were kept under enriched housing conditions. In each condition, one group obtain drinking water from a nose paddle water bowl, while the two other groups had to solve a visual-discrimination task presented at an automated learning device that was integrated into the animals' home pen to obtain drinking water as a reward. Changes in behavior and physiological stress parameters were investigated repeatedly under challenge by testing the animals in an open-field/novel-object test.

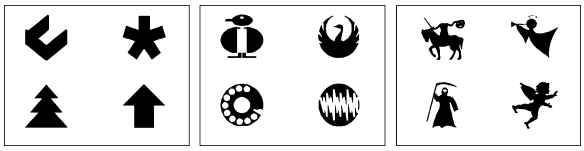

Fig. 1. Three visual four-choice discrimination tasks were consecutively presented to groups 1 and 2 for 14 days, respectively. The rewarded symbol (S^+) within each task is placed in the upper left corner in this example. After each choice, the symbols switched positions on the monitor.

2. Animals, materials and methods

2.1. Animals and experimental groups

The experiment was performed with 34 female Nigerian dwarf goats (*Capra aegagrus hircus*) from a line bred at the Leibniz Institute for Farm Animal Biology (FBN, Dummerstorf, Germany). Until weaning, goats were housed in mixed groups of up to four goats with their lambs with straw as bedding, two times concentrate per day, hay and water ad libitum. Human contact was reduced as far as possible. After weaning at the age of 5 weeks, the animals were randomly allocated to four groups (2×2 design). The animals in groups 1 and 3 ($n = 8$ and 9, respectively) were housed under structurally enriched conditions for the duration of the whole study. The pens (12 m^2) provided straw as litter, a wooden two-floor climbing rack, a round feeder to deliver concentrate (200 g/animal/day) and a hayrack (hay *ad libitum*). The goats in groups 2 and 4 ($n = 9$ and 8, respectively) were housed under barren conditions. The pens provided only a little straw, no round feeder and no climbing rack. They got concentrate and hay at the same amount as the goats in the enriched groups. The goats in groups 1 and 2 received additional cognitive enrichment. They obtained drinking water as a reward only at an automated learning device, while the goats in groups 3 and 4 obtained drinking water from a nose paddle water bowl.

2.2. Training

After weaning, the pens of group 1 and 2 first contained a simplified learning device. The goats were stepwise shaped to press one of two buttons to obtain drinking water (Langbein et al., 2004). After shaping (six weeks), the goats in all four groups were moved to the experimental pens. The housing conditions corresponded to those used during shaping, meaning structural enrichment for groups 1 and 3 and barren conditions for groups 2 and 4. In the pens of groups 1 and 2, a learning device was now used to deliver drinking water. The goats were trained consecutively on three different four-choice discrimination tasks (Fig. 1), using an automated learning device developed at the FBN, which were used for cognitive enrichment. Each task ran for 14 days. Goats in groups 3 and 4 continued to obtain drinking water from a water bowl as before.

2.3. Learning device

The learning device was integrated in a separate compartment of the pens housing groups 1 and 2. All of the animals were provided with a responder (Urban, Wuesting, Germany) for individual recognition at the device. The goats had access to the device 24 h a day, so the animals were able to determine the time spent at the learning device as well as the number of trials to perform. Only one goat could use the learning device at a time. Opaque walls,