

Refinement of Gerbil Housing and Husbandry in the Laboratory

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Summary — Mongolian gerbils, *Meriones unguiculatus*, are widely used as model species in parasitology, and in research on epilepsy and ischaemia. When kept under standard laboratory housing conditions, gerbils develop two distinctive behavioural abnormalities: stereotypic digging and bar chewing. Our work centred on assessing the mechanisms leading to these stereotypies. We aimed at finding practical housing and husbandry solutions that would prevent the development of such stereotypies in the laboratory by addressing the behavioural needs of gerbils. Faecal cortisol levels were used as a non-invasive method to compare stress reactions in gerbils housed under different conditions. Stereotypic digging was caused by the lack of a burrow in the laboratory cage, while stereotypic bar chewing was caused by premature separation of juveniles from their family before the birth of younger siblings. An integrated artificial burrow system is presented that prevents the development of stereotypic digging in gerbils, and adaptations in husbandry routines are suggested that significantly reduce the incidence of bar chewing. We conclude that simple refinement of housing is effective in improving gerbil welfare in the laboratory.

Key words: *cortisol, gerbil, housing, husbandry, refinement, stereotypies.*

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Introduction

The Mongolian gerbil (*Meriones unguiculatus*) is widely used as a model species in ischaemia, tinnitus, ageing and epilepsy research, as well as in parasitology. The Mongolian gerbil originates from the central Asian dry, sandy steppes with sparse vegetation and a harsh continental climate (1–3). Gerbils live socially in extended family groups with several generations of offspring (1, 4). Adult offspring stay with the family, but are usually reproductively inactive (5, 6). In the wild, gerbils construct extended burrow systems, measuring several meters across and reaching more than a meter in depth (1, 3, 7). A vast network of tunnels connects chambers of various functions (pup nest, sleeping nest, dry and moist food chambers, latrines; 7, 8).

When kept under standard laboratory conditions, gerbils often develop two distinctive behavioural abnormalities: stereotypic digging in the corners of the cage and chewing of the cage-top bars (9, 10), which is not seen under semi-natural housing conditions, even with cage-tops present (11). Laboratory and farm animals kept in spatially confined and poorly structured cages often show behavioural abnormalities not seen in semi-naturally kept or wild con-specifics (12, 13). Such intensive, stimulus-poor housing may overtax the ability of an animal to adapt, since crucial environmental stimuli for behaviour regulation are lacking (14, 15).

This then leads to the development of abnormal behaviour patterns (10, 16, 17). Some of these abnormalities answer the definition of a stereotypy: repetitive, invariant and locally fixed behaviour patterns lacking an obvious goal or function (16, 18). Whether stereotypies represent a behavioural disorder or can rather be understood as coping behaviour is a matter of current debate and empirical analysis (19–23).

Why is refinement of gerbil housing and husbandry necessary?

Housing can induce changes in brain and behaviour: behaviour control mechanisms evolved in a species' natural environment and require a specific set of environmental and social stimuli to function properly (24). Despite decades of domestication, important behavioural traits and behavioural regulation mechanisms have been retained in most laboratory animals, as have their behavioural needs (25–31). However, the barren laboratory cage lacks crucial environmental and social stimuli involved in eliciting and regulating behaviour, as well as stimulating behaviour and brain development. As a result, behavioural expressions become chronically thwarted, and the animal's ability to adapt to these conditions might be overtaxed (16, 32–34). Rearing rodents in such impoverished laboratory cages can result in impaired cognitive functions, inappropri-

ate and ill-regulated behavioural responses, stress reactions, abnormal behaviours such as stereotypic digging and bar chewing, altered brain functions and reduced stress tolerance in adulthood, which, as a consequence, might threaten the validity of experimental results gained from such animals (32–37). Housing and husbandry should therefore be adapted to provide the animals with an appropriate set of stimuli to regulate behaviour and to forestall the development of stereotypes.

The aim of this project was to document the ontogeny of stereotypic digging and bar chewing in laboratory gerbils, to analyse the causes and to suggest refinement solutions in housing and husbandry that prevent the development of such behavioural abnormalities.

Causes of Stereotypic Digging and Their Implications for Gerbil Housing

Stereotypic digging in gerbils was first described by Wiedenmayer (38, 39). Stereotypic digging develops around the age of 30 days. At this age, digging bout duration in the corner of the cage starts diverging from digging bout duration at the centre of the cage, where digging is performed in the substrate. Up to the age of 39 days, normal digging bout duration was less than 6 seconds in 99.5% of the cases; therefore, the threshold duration for stereotypic digging was defined as 12 seconds (35). Adult animals spent up to 21.9% of their active time with stereotypic digging (39). Insufficient space allowance in laboratory cages was not responsible for the development of stereotypic digging (40). Wiedenmayer further analysed whether the performance of digging in *adequate substrate* or the result of digging behaviour, a *burrow*, might be crucial to correctly control digging behaviour and to prevent stereotypic digging. Only a burrow significantly reduced stereotypic digging. Wiedenmayer further that the lack of a burrow induced the development of stereotypic digging in laboratory gerbils. He hypothesised that gerbils are constantly motivated to retreat into a burrow, but under laboratory conditions cannot do so. As an alternative behaviour strategy, they start to dig a burrow, but never reach their behavioural goal under the given conditions, so the motivation to dig will not be reduced, and the digging behaviour itself will not be stopped (10, 12, 16, 17). A minimum of an opaque nest-box with an access tube is required to reduce stereotypic digging (17). A transparent nest-box with access tube placed within the laboratory cage failed to reduce stereotypic digging (41).

We therefore aimed at developing an artificial burrow system that could be integrated into a standard laboratory cage and that would be effective in reducing stereotypic digging in laboratory gerbils.

Experiment 1

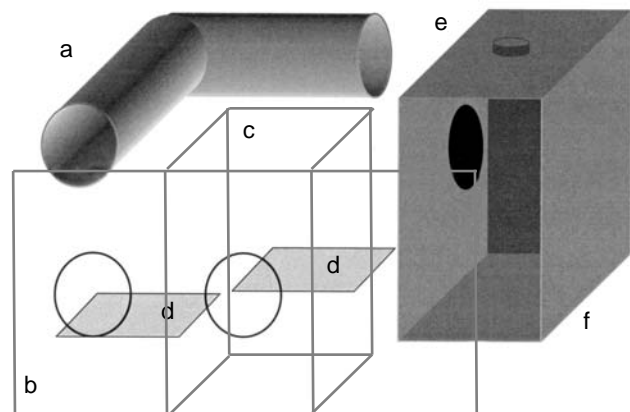
Based on Wiedenmayer's results, we constructed an artificial burrow system that can be integrated into a standard laboratory cage type IV, and analysed its effectiveness in preventing the development of stereotypic digging. We also non-invasively measured faecal cortisol to assess the influence of housing in different types of artificial burrow systems on physiological stress correlates.

Methods

The artificial burrow system consisted of a separation wall, an either opaque or transparent nest-box with a lid, and an angled access tube, also opaque, and could be integrated into a standard laboratory cage type IV (55 × 34 × 19cm). For reasons of optimal space use, an additional transparent box was added, accessible through a hole in the separation wall (Figure 1).

Twenty-four families of gerbils with one-week-old pups (mean litter size 5.4 ± 1.9 pups, mean and SD, respectively) were placed in cages with this integrated burrow system, half of them in transparent burrows, the other half in opaque burrows. The families were observed for two hours after being offered the artificial burrow system, and for four

Figure 1: An artificial burrow system to prevent the development of stereotypic digging in gerbils growing up in this system



a) Opaque access tube (5cm diameter, 30cm length, angled); b) transparent separation wall; c) extra transparent chamber with access hole (5cm diameter); d) supports for tube; e) removable lid of nest-box with handle, held in place by cage-top pressing down on it; f) opaque nest-box, here front removed.

hours during main activity in the evening a week later. One same-sexed, individually marked littermate pair in each of these 24 litters was observed on three occasions, for 10 minutes each time, at the age of 34 days, and frequency and duration of digging bouts were protocolled. The protocols were spread over the entire light phase, because the behaviour of gerbils is polyphasic (42). Since the independent units were the 24 littermate-pairs, the mean duration of stereotypic digging as a percentage of observation time was calculated per littermate-pair. A non-parametric Mann-Whitney U test was used to compare digging duration, as well as duration in the burrow. The significance level was set at $\alpha = 0.05$.

Faeces for cortisol analysis were collected from littermates of 18 litters (12 with opaque, 6 with transparent artificial burrow systems) at the age of 35 days, and from 12 litters (3 with opaque, 5 with transparent artificial burrow systems) at the age of ten weeks. For faeces collection, one gerbil of each litter was isolated in the home cage, where the bedding outside the burrow system was replaced; the others were placed singly each in a separate cage with nest-box. Faecal pellets were collected after six hours and stored frozen. Extended collection was not possible, since after eight hours, the effect of the isolation for faeces collection would have been seen in the faecal cortisol level, since separation from group members is stressful for gerbils (43, 44). Exact methods of faeces and sample preparation, as well as cortisol assays are described in detail elsewhere (41, 45–47). Data analysis was similar to that described above.

Results

All experimental animals immediately accepted the opaque artificial burrow system. Eleven out of 12 parent-pairs carried their pups into the dark nest-box within one hour of being offered the burrow, the remaining pair within two hours. The families passed 65 to 95% of their time inside the dark artificial burrow system. When compared to gerbils from transparent artificial burrow systems, gerbils raised in opaque artificial burrow systems developed significantly less stereotypic digging (opaque: mean stereotypic digging duration 0.13% of observation time, SD 0.07%; transparent: mean 2.95%, SD 1.3%; MWU = 2.12, $p = 0.017$, $n = 161$ digging bouts).

Despite this difference in stereotypic behaviour, no significant differences in faecal cortisol excretions were found, neither at the age of five weeks (opaque: 158ng cortisol per gram faeces dry matter [SD 135ng/g]; transparent: 115ng/g [SD 92ng/g]) nor at 10 weeks (opaque: 105ng cortisol per gram faeces dry matter [SD 137ng/g]; transparent: 105ng/g [SD 46ng/g]), but large individual variations were apparent. Nevertheless, the non-invasive

faecal cortisol monitoring methods previously used in primates can also be applied to gerbils.

Discussion

These results imply that laboratory gerbils should be offered a burrow, which must have an access tube, be opaque and undisturbed and — for practical reasons — be inside the cage, even if faecal cortisol levels did not differ between gerbils raised in opaque or transparent artificial burrow systems. This suggests that housing in a transparent artificial burrow and the performance of stereotypic digging probably does not represent a stressful situation for gerbils. On the other hand, stereotypic digging can also be interpreted as a coping strategy that enables gerbils to maintain physiological homeostasis by reducing stress reactions under sub-optimal housing conditions, i.e. transparent housing. Only by preventing animals with established digging stereotypies from performing digging could one discern between the two explanations. In mice, prevention of the performance of established bar-chewing stereotypies resulted in an increase of plasma cortisol, but only temporarily (23). It is therefore questionable whether bar-chewing stereotypies in mice are coping strategies.

Causes of Bar Chewing and Their Implications for Gerbil Husbandry

Bar biting, wire gnawing or bar chewing have been described as stereotypies in laboratory and farm animals. Bar biting has been observed in sows (12, 48, 49) and dairy cows (12, 50, 51), and wire gnawing has been seen in rabbits (52–54), golden hamsters (55), laboratory mice (15, 56) and juvenile gerbils (9). Under seminatural conditions, gerbils do not show bar chewing, even if they have access to cage-lids to chew on (11). In his preliminary study on the development of bar chewing in young laboratory gerbils, Wiedenmayer (9) observed that bar chewing was first performed at the food hopper. At the age of 18 days, when bar chewing was first shown, it was preceded by sniffing at the bars (52% of the cases) or rearing up to the bars (27%), and was followed by sniffing (45%) or feeding (21%). He hypothesised that the bars in the feeding trough interfere with feeding activity and may have induced or reinforced bar chewing.

In gerbils, on the other hand, bar chewing might be linked to shredding behaviour. Intensive shredding behaviour can be observed when the animals are provided with straw, hay, paper towels, or twigs (57). The shredded material is often used to build a nest (1, 11). Under standard laboratory conditions, the animals are only provided with small-grained wood-chip bedding. The bars resemble the usual

nesting material, being long and thin. Therefore the question was whether the bars of the cage-lid might be replacement objects for redirected shredding behaviour when nesting material is not present under standard housing conditions.

Experiment 2

We predicted that gerbils develop less bar chewing if the pelleted food is scattered on the bedding and when they are given chewable nesting material throughout their lives.

Methods

Twenty-four same-sexed littermate-pairs ($n = 24$ families) were allocated to one of four treatment groups in a 2×2 factorial design. Factor one was the presentation of chewable nesting material; half the pairs were kept on standard laboratory bedding, the other half were additionally provided with straw and paper towels. Factor two was the location of the food pellets, provided *ad libitum* either in the food hopper or scattered on the bedding. The bars of the stainless steel cage lid were 2mm in diameter and spaced 12mm apart. Until day 34, the animals were kept with their parents and littermates. On day 35, each littermate-pair was transferred to a similar cage with new bedding. The active behaviour of the subjects was observed for 42 minutes per week by continuous sampling. The duration of bar chewing was calculated as a percentage of observation time per littermate-pair per week. To analyse the main effects, the data were grouped in three categories: before separation (i.e. days 21–34), after separation (days 36–50) and adult age (days 91–106). An arcussinus-squareroot transformation was conducted before a repeated measures ANOVA model was calculated with the location of the food and the presence of nesting material as between-subject factors and the three age-categories, i.e. age, as within-subjects factor.

Results

Neither food location nor presence of nesting material had a significant effect on the development of bar chewing, but the gerbils tended to show more bar chewing and shredding behaviour when provided with nesting material (repeated measures ANOVA, between-subjects factor presence of nesting material; $F = 3.14$, $df = 1$, $p = 0.091$). In all treatment groups, bar-chewing duration was low before, and high after separation as well as in adulthood: the gerbils performed significantly more bar-chewing from day 36 onwards (repeated measures ANOVA, within-sub-

jects-factor age; $F = 41.1$, $df = 2$, $p < 0.001$). No significant interactions between this factor and the between-subject factors were found.

Discussion

Both environmental enrichment factors — additional nesting material and/or scattered food — failed to prevent the development of bar chewing. However, both types of enrichment offer opportunities for the performance of natural behaviours like shredding, collection of nesting material and nest building, as well as foraging. These enrichments should, therefore, be considered as a simple way of gerbil housing refinement. In adult male laboratory mice, chewable cardboard tubes provided from weaning reduce wire gnawing (58). This effect was not due to an increase in cardboard gnawing, but due to an increase in resting behaviour inside the tubes.

The significant rise in bar chewing in gerbils at the age of 36 days, however, could have been caused by one of the following factors: transfer to a new cage with fresh bedding or separation from the parents. In a third experiment, the influence of these two factors was analysed.

Experiment 3

We predicted that gerbils develop more bar chewing when transferred to a new cage with fresh bedding and/or when separated from their parents at the age of 35 days than when further kept with their families in their native cage.

Methods

Sixty-four same-sexed littermate-pairs ($n = 64$ families) were allocated to one of four treatment groups. Group 1 was subjected to standard husbandry routine: the subjects were separated from their families and transferred to a new cage with fresh bedding. Group 2 was subjected to a separation from the parents by removing the parents while the subjects stayed in their native cage. Group 3 subjects were transferred to a new cage with fresh bedding together with their parents, and group 4 subjects stayed with the parents in the native cage as a control. Treatment took place at the age of 35 days. Additionally, half the littermate-pairs in each group had witnessed the birth of younger siblings before treatment took place. All animals were observed two days each before and after treatment for 42 minutes per animal. Housing conditions besides experimental treatment, data transformation and analysis were identical to Experiment 2.

Results

We found a significant rise in bar chewing after treatment only in groups that were separated from their family before younger siblings were born (ANOVA, $F = 24.208$, $p < 0.0001$, *post hoc* Kruskal Wallis H-Test, $H = 6.2512$, $df = 2$, $p = 0.044$). Transfer had no significant influence on the development of bar chewing.

Discussion

These results imply that laboratory gerbils should not be prematurely separated from their parents, at least not until a new litter of younger siblings is born. It is advisable to leave juvenile gerbils with their parents even longer. Generally, gerbils are sexually inactive when always staying with their parents well after puberty and even sexual maturity (6, 59). Gerbils having had the opportunity to gain experience in pup care with younger siblings will later on be much more successful in raising their own pups, an effect which is independent of their sex (5, 60).

Conclusions

Laboratory gerbils should be offered an artificial burrow integrated into the laboratory cage, consisting of at least one opaque, undisturbed nest-box with access tube. These measures prevent the development of stereotypic digging. Non-invasive faecal cortisol monitoring can be used in gerbils. However, housing in different types of artificial burrow systems did not affect faecal cortisol levels.

Juvenile gerbils should not be separated from their parents before a new litter of younger siblings is born, otherwise bar chewing will increase significantly in prematurely separated animals.

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