

Refinement of gerbil housing and husbandry in the laboratory

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Abstract

Mongolian gerbils (*Meriones unguiculatus*) are a widely used model species in parasitology and epilepsy research. Under standard laboratory housing conditions gerbils develop stereotypic digging, a behavioural abnormality, which is caused by the lack of a burrow in the laboratory cage. Here we show that gerbils reared with access to an opaque artificial burrow (nest-box with access tube) develop significantly less stereotypic digging than those reared with transparent artificial burrows. Subadult gerbils also preferred opaque artificial burrows to transparent ones. Based on these findings we developed an artificial burrow system that could be integrated into laboratory Makrolon Type IV cages to prevent the development of stereotypic digging in gerbils by addressing their behavioural needs. Faecal cortisol levels were measured as a non-invasive method of comparing stress reactions in gerbils given access to the new integrated artificial burrow system or to an equivalent transparent burrow. Behavioural differences were observed between gerbils in the two housing conditions, but faecal cortisol levels were unaffected. We conclude that simple refinement of housing is effective in improving gerbil welfare in the laboratory.

Keywords: animal welfare, cortisol, gerbil, housing, refinement, stereotypies

Introduction

The Mongolian gerbil (*Meriones unguiculatus*) is widely used as a model species in stroke, epilepsy and parasitology research. Under standard laboratory conditions gerbils develop stereotypic digging (Wiedenmayer 1997a,b) which is not seen in semi-natural conditions (Roper & Polioudakis 1977). Laboratory and farm animals housed in spatially confined and poorly structured cages often develop behavioural abnormalities (Fraser & Broom 1990; Mason 1991; Würbel *et al* 1996). Such extreme, stimulus-poor housing may overtax an animal's ability to adapt, since crucial environmental stimuli for behavioural regulation are lacking (Wechsler 1993). As a consequence, abnormal behaviour patterns develop (Mason 1991).

Stereotypic digging in laboratory gerbils was first described by Wiedenmayer (1996). It develops at Day 24, when the duration of digging bouts in the corner of the cage begins to diverge from that of 'normal' digging in the cage-centre. Up until Day 39, the duration of normal digging bouts is less than 6 s in 99.5% of cases, therefore the threshold duration for stereotypic digging is defined as 12 s (Wiedenmayer 1997a,b). Adult animals spend up to 21.9% of their active time digging stereotypically (Wiedenmayer & Brunner 1993). Restricted space allowance in laboratory cages (1700 cm² in Makrolon Type IV cages) is not responsible for the development of stereotypic digging, since cages more than four times larger (7000 cm²) do not prevent this behaviour (Wiedenmayer 1996). Wiedenmayer (1997a,b)

also analysed whether the ability to dig in an adequate substrate, or the end result of digging behaviour (ie a burrow), might be crucial to the control of digging behaviour and the development of stereotypic digging. He offered young gerbils either a tank of dry sand as a digging substrate, or an artificial plaster burrow (2 × 1 m) consisting of two nest chambers and several tunnels. Only the burrow significantly reduced stereotypic digging. Wiedenmayer concluded 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 cannot do so under laboratory conditions. As an alternative behavioural strategy they start to dig a burrow, but under the given conditions (ie no suitable burrowing substrate) they never reach their behavioural goal. Therefore, their motivation to dig is not reduced and digging behaviour persists (Wiedenmayer 1997a,b). Wiedenmayer reduced the artificial burrow both in size and complexity and found that a minimum of a nest-box with an access tube was required to reduce stereotypic digging in young gerbils tested at 36 days of age. There was no reduction without the access tube (Wiedenmayer 1997a). Based on Wiedenmayer's observations we performed two experiments with the aim of developing housing guidelines to reduce stereotypic digging in gerbils. First, we analysed the influence of artificial burrow darkness on the development of stereotypic digging in juvenile gerbils and measured the animals' preferences for transparent or opaque, ie dark, artificial burrows. We hypothesised that

gerbils reared with access to dark burrows would develop less stereotypic digging than gerbils reared with transparent burrows, but also that the animals would prefer dark to transparent burrows. Second, we aimed to develop an artificial burrow system that could be integrated into a standard laboratory cage, based on our own and Wiedenmayer's findings. We then tested the animals' acceptance of such a burrow and the burrow's effectiveness in reducing the development of stereotypic digging.

Methods

Animals and housing conditions

Breeding pairs of Mongolian gerbils from the breeding stock of the University of Zürich Parasitology Institute were used. The gerbils were housed in laboratory Makrolon Type IV cages (34 × 55 × 19 cm) with a stainless steel grid top and 3–5 cm of wood-chip bedding. Food (Mouse chow, NAFAG 850) and water were offered *ad libitum*. Additionally, the animals were fed gerbil pet food (Schweizer, Nager Super) and fresh greens or fruit (eg salad, apple) scattered on the bedding every second day. Once per week, hay and paper tissues were supplied as nesting material. The animals were kept in a climate-controlled room (20 ± 2°C). Illumination was provided on a 12 h light:12 h dark cycle with onset of the light phase at 0830h. After completion of the project some of the animals were given to pet shops and the others were euthanased, using CO₂, and fed to European wildcats (*Felis sylvestris*) in a project developing naturalistic feeding regimes in captivity. The breeding pairs remained as breeding stock.

Experiment I: The effects of a dark versus a transparent artificial burrow

The burrows used by Wiedenmayer (1997a,b) were transparent but covered with black cloth. However, he did not analyse whether the darkness of the burrow structures themselves was important for their effectiveness. Our aim was therefore to analyse the influence of the darkness of artificial burrow structures on the development of stereotypic digging and the burrow preferences of gerbils. Transparent artificial burrows would make it easier for animal technicians to check on the animals. However, several burrow-dwelling rodents, including gerbils, prefer dark housing structures (Arnold & Estep 1994; Van Den Broek *et al* 1995; Würbel *et al* 1998a).

Methods

Ten families of Mongolian gerbils with newborn pups were used (mean ± SD of litter size = 5.4 ± 1.9 pups). One day after birth (Day 1), the families were assigned to standard housing (Makrolon Type IV cages) with five families having access to a transparent Plexiglas artificial burrow and the other five having access to a dark artificial burrow constructed from black, opaque Plexiglas. The artificial burrows consisted of a nest-box (13 × 13 × 10 cm) and an access tube (length 20 cm, diameter 5 cm), and were attached to the back of the animals' cages so as to be accessible through a hole in the back wall. All other housing

factors remained as in standard housing. On Day 16, two male littermates per family were selected as focal animals and individually marked with a fur-shaving pattern for identification. The parents and other siblings were removed on Day 30.

Behavioural data were collected on Day 35. Each focal animal was observed for three 10 min periods, when active, between 1400h and 2100h. This time slot was chosen because the behaviour of gerbils is polyphasic with two activity peaks occurring around dawn and dusk (Susic & Masirevic 1986). Active behaviour and location within the cage (centre, sides, corners, burrow) were recorded by focal continuous sampling (Altmann 1974). Digging was defined as behaviour consisting of a pawing movement with both front paws, interspersed with kicking movements by the hind legs. Freezing during digging was not recorded if it lasted less than one second. Normal (0–12 s) and stereotypic (>12 s) digging bouts were analysed separately. Since the independent units were the 10 focal littermate-pairs, the mean rate and relative duration of stereotypic digging were calculated for each littermate-pair. The data were analysed using rate (number of digging bouts per 30 min observation time) and relative duration (% of total observation time spent digging) of digging behaviour per pair per observation day. The duration of individual bouts was also recorded. The calculations were performed using SPSS 10 for Macintosh (Brosius & Brosius 1996). Significance level was set at $P = 0.05$. Mann-Whitney U -tests were used to compare the mean rate and relative duration of stereotypic digging and to compare individual bout durations of digging between gerbils reared with transparent or dark artificial burrows.

The quantitative documentation of digging behaviour was followed by a preference test for burrow brightness. On Day 48, the two animals of each littermate-pair were transferred together to a new cage with one transparent and one opaque artificial burrow attached side by side at the back. Otherwise, housing conditions remained unchanged. On Day 49, each focal animal was observed for 6 h from 0900h to 1100h and from 1400h to 1800h by continuous sampling, and burrow entrance and exit times were recorded. On Day 50, the two artificial burrows were cleaned and their positions exchanged to control for side preferences. On Day 51, data were collected as on Day 49. We then calculated the proportion of time each animal spent in each burrow relative to the total time spent in the two burrows combined. A burrow preference was demonstrated if an animal spent more than 56% (50% plus two standard deviations [Arnold & Estep 1994]) of total burrow time within it. Additionally, we analysed the distribution of 'Stay Duration' (the total time spent in the burrow on a single visit, measured in seconds) and checked whether the parental burrow type had an influence on burrow preference using univariate ANOVA. On Day 52, the cover of the dark burrow was replaced by a transparent one to enable *ad libitum* sampling, ie unquantified behavioural observation.

Results

In total, 161 digging bouts were observed on Day 35. Considering only normal digging bouts ($n = 149$), gerbils

reared with access to an opaque burrow spent significantly less time digging than those reared with transparent burrows ($U = 3.0, n_1 = n_2 = 5, P = 0.028$). However, digging rate did not differ significantly ($U = 0.5, P = 0.421$). Considering only stereotypic digging bouts ($n = 12$), gerbils from opaque burrows spent significantly less time digging than those from transparent burrows ($U = 2.1, P = 0.022$). In the centre of the cage, digging bouts were significantly shorter than in the remaining cage area or burrow ($U = 17.5, P = 0.005$); they never exceeded 12 s in duration and were, therefore, never classed as stereotypic. Summary data are presented in Figure 1.

During preference testing, on average, gerbils spent $82.5 \pm 12.3\%$ (mean \pm SE) of the total observation time (10 h) in one of the two burrows. All gerbils, except one, clearly preferred the opaque burrow. Between 79.7% and 99.6% of total burrow time was spent in this burrow, independent of parental burrow type. The only gerbil not showing a preference spent 51.8% of total burrow time in the opaque burrow.

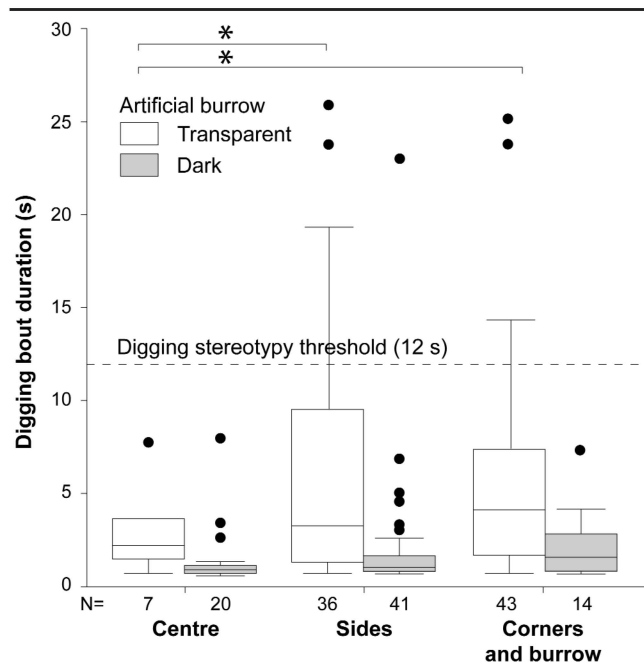
Stay Duration was significantly longer in the opaque than in the transparent burrow ($F = 47.22, df = 1, P = 0.0001$). Gerbils rarely stayed in the transparent burrow for longer than 10 min, in contrast to stays of 30–60 min in the opaque burrow (Figure 2). Parental burrow type also significantly influenced Stay Duration ($F = 9.73, df = 2, P = 0.0001$). The two factors (parental burrow type and burrow type during preference testing) interacted significantly ($F = 3.86, df = 1, P = 0.049$). Animals from both types of parental burrow spent roughly the same amount of time in the transparent burrow (transparent: 84.6 ± 13.3 s; dark: 83.7 ± 20.5 s), but gerbils reared with transparent parental burrows spent more time in the dark burrow (417.8 ± 47.5 s) than animals reared with dark parental burrows (268.7 ± 26.4 s).

The predominant behaviours observed in the transparent burrow were feeding, food storing, self-grooming, urination and defecation, and in the opaque burrow, resting, social grooming and sleeping. However, these behaviours were not quantified. In most cases, the opaque burrow was filled with nesting material, whereas the transparent burrow contained food items, faeces or both.

Discussion

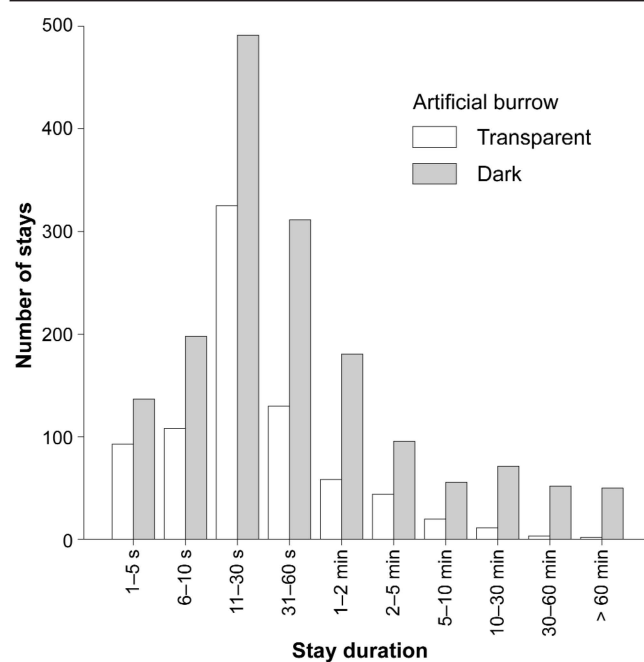
As previous work has shown (Müller 1998), a transparent nest-box with access tube fails to reduce stereotypic digging and is used as a latrine. This suggests that the darkness of a burrow may be crucial for its effectiveness. The results of our first experiment showed that male gerbils reared with access to a dark artificial burrow developed less stereotypic digging than those reared with a transparent burrow. It can therefore be concluded that only a dark artificial burrow reduces stereotypic digging in juvenile gerbils. Our experiment involved only male gerbils. Nevertheless, we assume that the same results also apply to females because Wiedenmayer (1996, 1997a,b) did not find any sex differences in the development of stereotypic digging or the effect of a dark burrow.

Figure 1



Duration of digging bouts performed by 20 35-day-old male gerbils at different locations in their cage, reared with either opaque or transparent artificial burrows. Data are presented as boxplots (bar = median; box = 25% of data above and below median; vertical bars = remaining 25% of data in each direction; points = outliers). * $P < 0.05$

Figure 2



Distribution of Stay Duration of 20 male gerbils (49–51 days of age) in transparent and opaque burrows during preference testing.

Transparent nest-boxes, even with an access tube, seemed to trigger behaviours other than relaxation and resting. The use of the transparent burrow as a food store or latrine, however, indicates that the animals might need additional burrow structures, as well as an opaque nest-box, for spatial separation

Figure 3

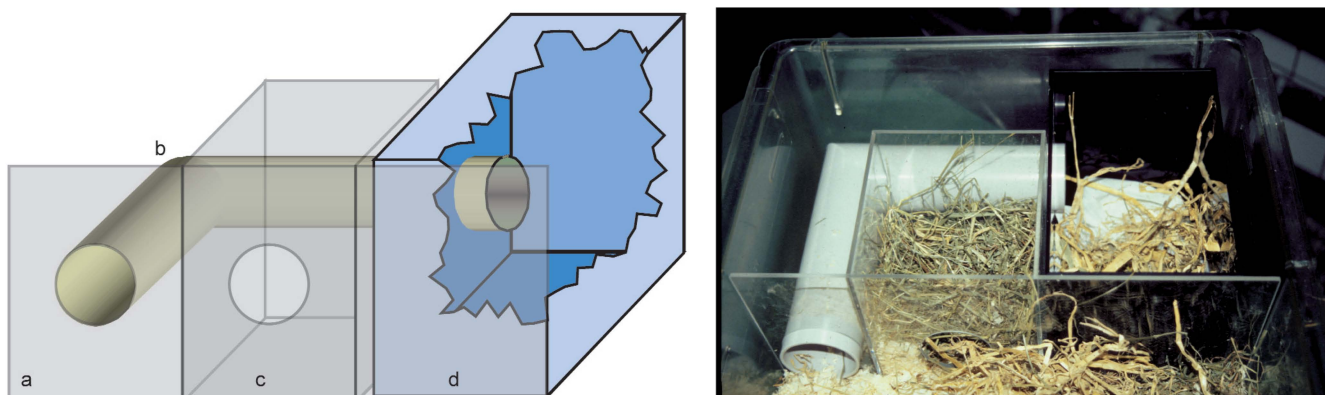


Diagram and photograph of the artificial burrow system. In the diagram, the nest-box has been partially cut away to reveal the end of the access tube. In the photograph, the nest-box lid has been removed. The apparatus comprises (a) a transparent separation wall to separate the burrow apparatus from the rest of the cage, (b) an angled opaque access tube, (c) a transparent box with access hole, and (d) a dark nest-box with lid.

of different activities. This is plausible since gerbils construct chambers for different functions in their natural burrows (Bannikov 1954; Agren *et al* 1989; Brunner 1993). The burrow protects the gerbils from predators and the extremes of the continental climate, and is also used to rear litters and store food (Agren *et al* 1989). In a semi-natural setting (arena of moist sand, $2.0 \times 2.0 \times 0.7$ m), Brunner (1993) excavated burrows constructed by a family of gerbils. She found no fixed layout. A vast network of tunnels connected chambers with various functions such as pup-rearing and nesting, and dry and moist food storage. The burrow's functions are various, and survival in the wild depends directly on the availability of a burrow (Agren *et al* 1989). It can be hypothesised, therefore, that gerbils need to be able to retreat into a dark burrow even under laboratory conditions.

Experiment 2: An artificial burrow system for the laboratory cage

The artificial burrows used in the previous experiment protruded from the back of the laboratory cage, thus preventing stacking in the standard racks. We therefore aimed to develop an artificial burrow system that could be integrated into a standard laboratory Makrolon Type IV cage, but still contain all of the known elements necessary for normal behaviour. Our second experiment analysed the effectiveness of our newly developed integrated artificial burrow system in preventing the development of stereotypic digging, and also looked at its influence on the animals' stress physiology.

Elevated corticosteroid levels are generally viewed as an indicator of stress (Campbell *et al* 2003; Touma *et al* 2004). Corticosteroid concentrations have been analysed in gerbil blood and urine (Fenske 1996). Blood can only be taken invasively and urine is difficult to collect in arid-adapted gerbils that produce very little urine. Housing in metabolism cages (very small cages with perforated flooring to collect excreted urine and faeces in a funnel beneath the cage) was

also considered too restrictive. Therefore, a non-invasive method of faecal steroid monitoring developed for the analysis of primate sexual steroids (Gerber 1998) was adapted for detecting faecal corticosteroids in gerbils (Müller 1998) and used in our second experiment. We used this method to assess the influence of housing in a standard laboratory Makrolon Type IV cage with access either to our integrated artificial burrow system or to an equivalent, but transparent, burrow, on physiological correlates of stress.

Methods

Twelve families of gerbils with one-week-old pups were placed in cages with an integrated opaque burrow system. This artificial burrow system (Figure 3) consisted of a separation wall (18×34.5 cm), a dark nest-box ($19.0 \times 12.5 \times 17.8$ cm) with lid, and an angled access tube (length 34 cm, diameter 5 cm), also opaque, and could be integrated into a standard laboratory Makrolon Type IV cage. In order to optimise space usage and stability, an additional transparent box ($12.5 \times 12.5 \times 18$ cm) was added, accessible through a hole in the separation wall.

The families were observed for 2 h after being offered the artificial burrow system and the latency for the pups to be carried into the burrow was recorded. One week later we measured burrow Stay Duration between 1600h and 2000h.

Additionally, eight other families with one-week-old pups were offered a laboratory cage with two transparent nest-boxes ($13 \times 13 \times 18$ cm and $19 \times 13 \times 18$ cm, with a 20 cm access tube). The two nest-boxes covered the same area as the integrated artificial burrow. Stay Duration was not measured in this experimental group.

On Day 16, one male littermate-pair was selected from each of the 20 families and marked with an individual fur-shaving pattern for identification. The remaining siblings, but not the parents, were removed on Day 30. On Day 34, the marked juveniles were each observed for three 10 min periods by focal continuous sampling between 1600h and 2000h. The frequency and duration of digging bouts were

recorded. The opaque nest-box lid was replaced with a transparent cover for the duration of the observation period. Digging bouts within the opaque tube were not visible; therefore digging in the transparent tubes was not recorded. Since the 20 littermate-pairs were considered as independent units, we calculated the mean relative duration of stereotypic digging as a percentage of observation time per littermate-pair. Non-parametric Mann-Whitney *U*-tests were used to compare relative durations of stereotypic digging. The significance level was set at $P = 0.05$.

On Day 35, one gerbil from each focal pair was isolated in the home-cage for faeces collection, with fresh bedding being provided outside the burrow system. The other focal animal and the parents were transferred, singly, each to a separate cage with fresh bedding and a dark nest-box. Faecal pellets were collected from the bedding of each cage after 8 h and were frozen and stored at -20°C . Extended collection was not possible because separation from group members is stressful for gerbils. The effect of the isolation would have been detectable in faecal cortisol levels after 8 h (Fenske 1996; Hendrie & Pickles 2000).

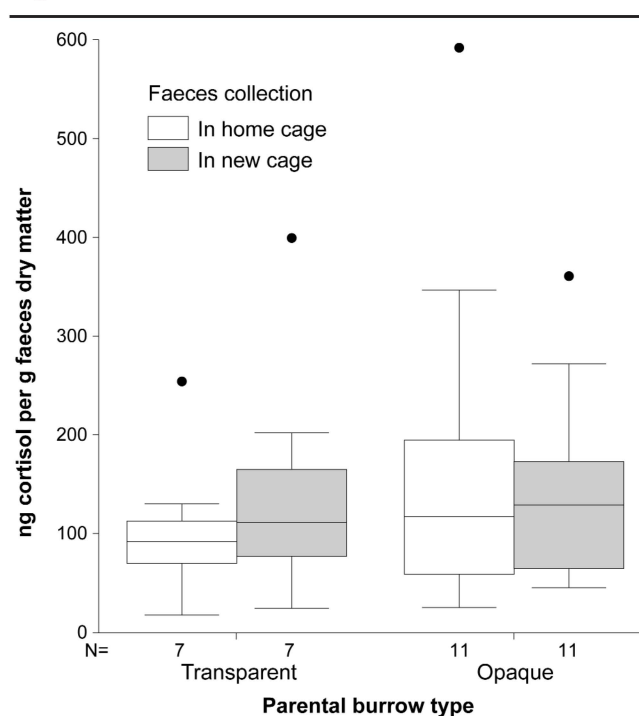
Successful analysis was possible with 20–30 faecal pellets per individual. Sufficient faeces for cortisol analysis were collected from the focal animals of 18 litters (11 with opaque and seven with transparent burrows) and from all 20 parent-pairs. For sample preparation, faeces were thawed and dried in individual bowls for 48 h at 60°C . Each sample was then ground to a fine powder and 50 μg of faeces powder per sample was mixed with 50 μl aqua bidest and 450 μl methanol. Cortisol was extracted by shaking vigorously for 30 min. The samples were centrifuged and 200 μl of the fluid phase stored at -70°C until used in the assay. Exact methods of the cortisol enzyme immunoassay used are described in detail by Gerber (1998). Most samples could be used undiluted since cortisol concentration lay within the sensitivity of the assay. Non-parametric Mann-Whitney *U*-tests were used to compare cortisol concentrations in faeces.

Results

The families immediately accepted the opaque artificial burrow system. Eleven sets of parents carried their pups into the opaque burrow within 1 h, and the remaining pair within 2 h. The families spent 65–95% of total observation time inside the opaque burrow system.

Juveniles from opaque artificial burrow systems developed significantly less stereotypic digging by 34 days of age than did those reared in transparent burrows (relative duration of stereotypic digging: opaque: mean \pm SE = $0.13 \pm 0.02\%$, $n = 12$; transparent: $2.96 \pm 0.19\%$, $n = 8$; $U = 0.0$, $P = 0.0001$; $n = 162$ digging bouts). The rate of stereotypic digging also differed significantly (opaque: 0.8 ± 0.18 bouts h^{-1} ; transparent: 4.8 ± 0.3 bouts h^{-1} ; $U = 13.0$, $P = 0.005$). Despite this difference in stereotypic behaviour, the two groups did not show significant differences in faecal cortisol excretion (opaque: 158 ± 135 ng g^{-1} ; transparent: 115 ± 92 ng g^{-1} ; $U = 145.0$, $P = 0.536$), although

Figure 4



Faecal cortisol levels of 36 35-day-old male gerbils reared with access to either opaque or transparent artificial burrow systems. Faeces were collected 8 h after isolation in either the home-cage or a new cage.

individual variation was high (Figure 4). There were also no significant differences between the faecal cortisol levels of juveniles ($n = 36$) and adult parents ($n = 20$) ($U = 337.0$, $P = 0.097$), or between juveniles isolated for faeces collection in the home-cage and in a new cage ($U = 143.0$, $n_1 = n_2 = 18$, $P = 0.563$).

Discussion

Our results imply that laboratory gerbils should be offered a dark artificial burrow, comprising a nest-box and access tube. For practical reasons such a burrow should be integrated into the cage. The darkness of the burrow seems to be as crucial as the presence of an access tube (Wiedenmayer 1997a,b) for the effectiveness of an artificial burrow in preventing the development of stereotypic digging.

The artificial burrow we developed had several additional advantages: it was easily assembled and cleaned, and required only half of the usual amount of bedding. However, there were also some disadvantages: the tube was susceptible to gerbil gnawing, and animals reared in the burrow seemed shyer, although they could be tamed by regular handling and food treats. Generally, the artificial burrow system can be adapted to suit the needs of an experimenter as long as the two crucial factors (opaque access tube and nest-box) remain untouched. However, if experimental procedures allow gerbils to be housed in large terrariums with a deep layer of bedding for the construction of a burrow, this would be the preferable option. Artificial

burrow systems do not allow either for the construction of new structures or for the regular changing of the nest-chamber — both are behaviours observed in semi-naturally housed gerbils (Brunner 1993).

We conclude from our experiment that non-invasive faecal cortisol monitoring can be used in gerbils, but that the housing factors analysed did not influence cortisol excretion. We suggest that housing in a transparent burrow and the performance of stereotypic digging were not especially stressful for gerbils. On the other hand, stereotypic digging could also be a coping strategy, enabling the animals to reduce stress reactions under sub-optimal housing, as Cooper and Nicol (1996) suggested for stereotyping voles. Preventing animals with established digging stereotypies from performing them is the only way of distinguishing between these two explanations. In mice, preventing the performance of established bar-chewing stereotypies resulted in only a temporary increase in plasma cortisol (Würbel *et al* 1998b). However, this short-term increase in cortisol was due to a temporal reorganisation of behaviour rather than to the prevention of a coping strategy.

Animal welfare implications

To prevent the development of stereotypic digging, laboratory gerbils should be offered an artificial burrow integrated into their laboratory cage and consisting of at least one opaque, undisturbed nest-box with an access tube. Even though the animals tested in this experiment did not show elevated faecal cortisol levels related to housing conditions, other physiological processes that were not analysed here may have been influenced. For example, it has been shown that socially isolated male gerbils, housed in stimulus-poor laboratory cages, develop deficiencies in both prefrontal cortex innervation and working memory, compared to those reared in an enriched, social environment (Winterfeld *et al* 1998). Male knockout mice selectively lacking the *N*-methyl-D-aspartate receptor in the CA1 region of the hippocampus also develop learning and memory deficits if housed under standard laboratory conditions, but overcome these deficits in enriched housing conditions (Rampon *et al* 2000). These results indicate that housing factors can strongly influence cognitive performance and should be taken into account in experiments aiming to analyse behaviour, central nervous system development, learning or endocrinology.

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