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*Behaviour of golden hamsters (*Mesocricetus auratus*) kept in four different cage sizes*

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Abstract

*Cages for laboratory and pet hamsters are usually small. Using video recordings, the behaviour of sixty female golden hamsters (*Mesocricetus auratus*), housed individually in four different cage sizes, was compared in order to draw conclusions about their welfare. The cage sizes were 1,800 cm², 2,500 cm², 5,000 cm², and 10,000 cm². Enrichment items and litter depth were standardised and all cages were equipped with a running-wheel (30 cm diameter). Stereotypic wire-gnawing, usage of the provided space, weight gain, and reactions to mild husbandry stressors were used as welfare indicators. Stereotypic wire-gnawing was observed in all cage sizes, but hamsters in small cages gnawed significantly longer and more frequently. There were no significant differences in running-wheel activity. In small cages hamsters made use of the roof of their wooden shelters as an additional platform more often than in big cages, which could suggest that they needed more space. Therefore, the welfare of pet golden hamsters in cages with a minimal ground floor area of 10,000 cm² seemed to be enhanced compared with smaller cages.*

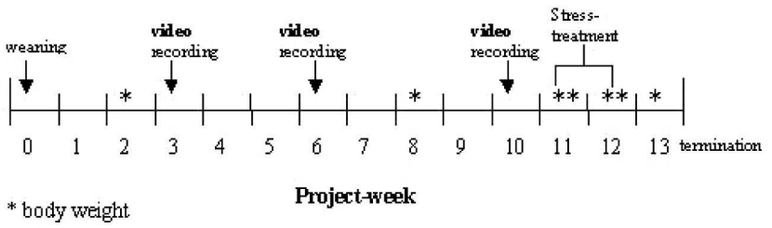
Keywords: *animal welfare, cage size, golden hamster, pet animal, running-wheel, wire-gnawing*

Introduction

Golden hamsters (*Mesocricetus auratus*) are common laboratory animals in biomedical research as well as popular pets. Nevertheless, little work has been done with the specific intent to improve their housing conditions in the laboratory, and even less is known of their housing requirements as pets. Exceptions are studies by Bantin and Sanders (1989) and Kuhnen (1999a) on cage size, by Mrosovsky *et al* (1998) on running-wheel preferences, by Reebs and Maillet (2003) on environmental enrichment, and the recent review by Sørensen *et al* (2005). In the case of Kuhnen (1999a), golden hamsters were individually housed in four different cage sizes ranging from 200 to 1,815 cm². Mean febrile response increased with increasing cage size, whereas mean baseline rectal temperature decreased. These results indicate that housing in small cages induced chronic stress, which affected thermoregulation. The cage sizes used by Kuhnen (1999a), however, were common for laboratory rodents but much smaller than the cages used for pet hamsters. The Swiss guidelines for pet stores provide a cage size of 1800 cm² as the minimum size for golden hamsters. The Swiss statutory minimum size for one hamster is 200 cm². Cage size, ie available space, is of great significance in regard to the welfare of the animals, as shown in the studies mentioned above as well as in the behavioural demand studies by Sherwin and Nicol (1997) and Sherwin (2003, 2004).

Pet rodents spend their whole life in their cages and should have the possibility to meet their behavioural needs. Gattermann *et al* (2001) investigated the natural habitats of golden hamsters. The closest distance between occupied hamster burrows was 118 m. A mean tunnel length of 199.5 ± 92.6 cm and a mean burrow depth of 64.8 ± 17.6 cm were recorded. This shows that the natural territory of a hamster is considerably larger than any cage. Laboratory hamsters did not differ in behaviour compared with wild caught hamsters (Gattermann 2000). Despite decades of domestication they remain capable of surviving in a semi-natural environment as demonstrated by Gattermann (2000). Therefore, domesticated hamsters might need more space than we commonly provide them. Additionally, little is known about the effects of handling and husbandry on the levels of stress experienced by pet hamsters. In laboratory rodents, routine handling and husbandry procedures have been recognised as potential stress factors (Balcombe *et al* 2004). Pet hamsters are frequently caught out of their cages by their owners and carried around. Also, cages are regularly cleaned and moved around. It is to be expected that hamsters kept as pets are also subjected to stressors comparable to routine handling procedures in laboratory hamsters. Therefore, we also included mild husbandry stressors such as handling and pushing cages around in our study. The aim of this study was to analyse behavioural differences of golden hamsters housed in different sized cages and subjected to mild

Figure 1



Timetable of the experiment. The stress treatment was conducted during the weeks 11 and 12.

husbandry routine stressors and to draw conclusions about their welfare. Behaviour can be a good indicator for the state of welfare in animals (Mason 1991; Mason & Mendl 1993; but see Mason & Latham 2004). The welfare of captive hamsters can be assessed by measuring the frequency and duration of wire-gnawing. Wire-gnawing in mice seems to indicate the intention of breaking-out of the cage to explore the environment (Würbel *et al* 1998a, b; Nevison *et al* 1999). It is common in golden hamsters kept in captivity (Gebhardt-Henrich *et al* 2005). The more a hamster performs this, the more welfare could be compromised. Physiological measurements, such as adrenal hormones and adrenal weight can also indicate stress and welfare of the golden hamster. During chronic stress, adrenal weight is increased due to increased hormonal production and can, therefore, be a helpful physiological parameter of stress measurement (Zimmer & Gattermann 1986). Since the study focused especially on pet hamsters, cage sizes considerably larger than common laboratory cages were used. Areas of cages used in this study ranged from 1,800 cm^2 to 10,000 cm^2. The area of the smallest cage was chosen because it provided the minimum for golden hamsters in the Swiss pet shop guidelines. An area of 2,500 cm^2 is a common size for a hamster cage. The Swiss Animal Protection Society (STS) demands a minimum area of 5,000 cm^2 and they recommend a cage of more than 10,000 cm^2 (Lerch-Leemann 2002). In order to reduce variation due to sex, only one sex (female) hamsters were used.

Materials and methods

Animals and housing conditions

The sixty female golden hamsters used for this study were progeny of the strain Crl: LVG (SYR) from Charles River, Germany. During one year the sixty hamsters were bred in three series of 20 hamsters each. We used 17 dams and 9 sires. The age difference of hamsters in one series was mostly four days, up to a maximum of seven. A photoperiod of 12 h light, 12 h dark, dawn at 1300h was maintained. Room temperature was 21 ± 2°C, relative humidity was not regulated, but ranged from 25 to 59%. Hamsters used in this study were born and raised in cages with a wire top and a dark blue opaque plastic dishpan as the bottom (95 × 57 × 45 cm; length × breadth × height) without a running-wheel. Between 24 and 30 days of age, they were placed singly into four differently sized cages: Size 1 was 32 × 57 × 45 cm (length × breadth × height), ie 1,800 cm^2; size 2, 44 × 57 × 45 cm ie 2,500 cm^2; size 3, 95 × 57 × 45 cm ie 5,000 cm^2 and size 4, 105 × 95 × 45 cm ie 10,000 cm^2. All cages were furnished with a wooden shelter (20 × 14 × 14 cm) with one entrance in front, litter (15 cm deep wood shavings), hay, paper-towels, cardboard tubes, twigs, a sand-bath (diameter: 16 cm, chinchilla sand) and a running-wheel (diameter: 30 cm, width of perforated metal plate running surface: 10 cm). Commercial pet hamster food (Witte Molen®, NL-Meeuwen) and water were offered *ad libitum*. This diet was supplemented by dry cat food and vitamin and mineral supplements (Marienfelde Vitakalk). In addition, fresh fruits and vegetables were offered daily. Litter was never changed completely. Only the dirty parts of the litter were replaced when necessary. Due to space restrictions, the experiments were performed in three series. Five cages of each size were used simultaneously. In each of the three series, 20 hamsters were distributed singly in the 20 cages. If possible, hamsters of one litter were placed randomly into all sizes, but the distribution was balanced according to their body mass in cages of four different sizes. The experiment was approved by the Cantonal Veterinary Office, Herrengasse 1, CH-3011, Berne, Switzerland.

Procedure and measurements

Procedure

In week 0, at weaning, the hamsters were approximately 4 weeks of age. During the experiment they were weighed and videotaped on several occasions (Figure 1).

In weeks 11 and 12 each hamster was stressed on two consecutive days. At 17 weeks of age, the hamsters were decapitated after isoflurane-anaesthesia. The stress treatment started with strongly shaking the cage in a manner that the hamster was certainly woken up and probably upset. The animal was then chased briefly and handled for about 30 – 60 seconds once caught. Handling consisted of petting and holding the hamster which was always keen to retreat. After handling, the hamster was placed into a small cardboard box for 30 min and exposed to loud music for three to five minutes before being returned to its cage.

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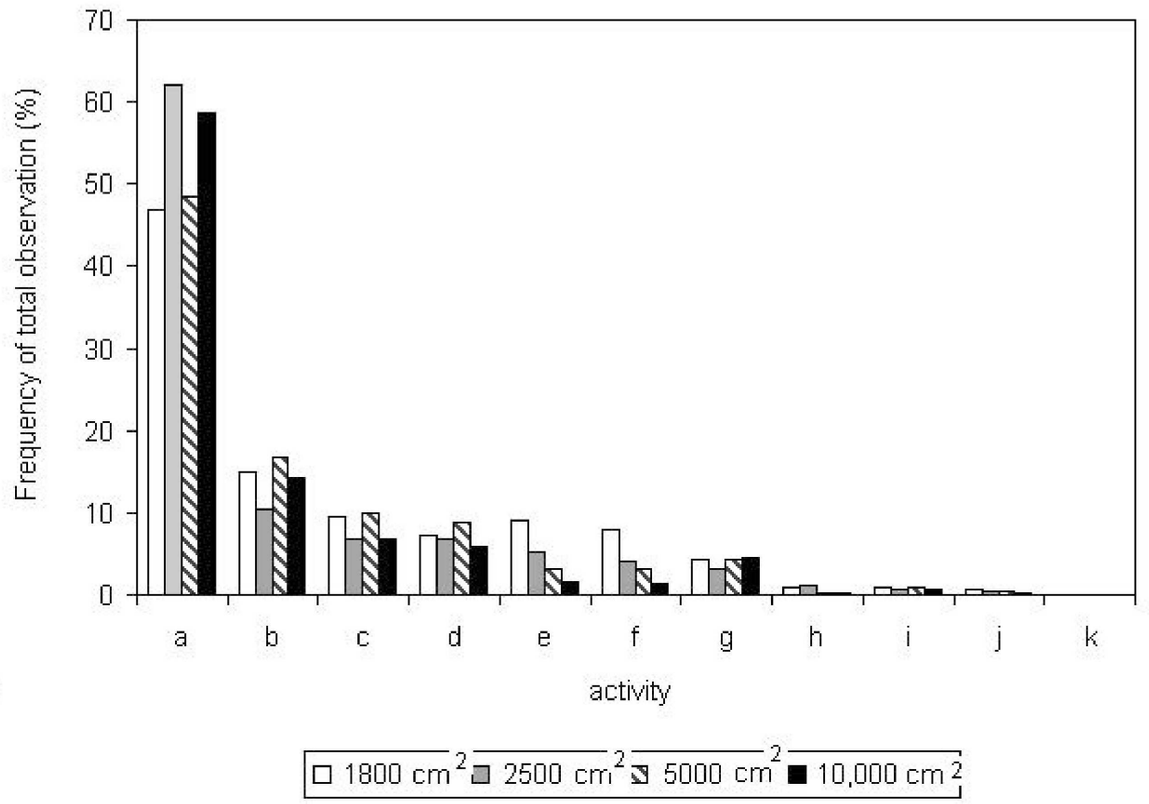
Figure 2



Duration of behaviours in percent of total duration in the different cage sizes: a) wheel-running, b) resting, c) rearing, d) grooming, e) wire-gnawing, f) feeding, g) running, h) gnawing, i) climbing, j) digging, k) drinking.

Additionally, on the first day of stress, half of the litter was changed while, on the second day, a confrontation with another hamster was instigated. At the end of the experiment, immediately prior to euthanasia, the anaesthetised animal was stretched out on a ruler and body length (snout to tip of tail) was measured. The body condition of the hamster was calculated as bodyweight relative to body length (bodyweight at week 13/length^3); as a degree of adiposis. Blood was collected and analysed for corticosterone, cortisol and ACTH. After dissection the adrenal glands, heart, and spleen were weighed and the gastric mucosa was examined for ulcers. As a precaution, all brains were examined for hydrocephalus internus, as the condition was prevalent in the colony, although without any detectable behavioural changes (Edwards *et al* 2006).

Running-wheel activity

Revolutions of running-wheels were constantly registered by the Chronobiology Kit™ (Stanford Software Systems). For the analysis of the running-wheel activity we used the median of the daily revolutions until week 10, prior to stressing the hamsters. For the analysis of the effects of mild stressors, the mean number of revolutions during the 2 days these stressors were applied, as described above, as well as 2 days before and after application, were compared.

Behaviour

The behaviour of the hamsters was recorded 3 times in weeks 3, 6 and 10 by using a light sensitive camera (Ikegami ICD-47E) and a video recorder (Panasonic AG-6730) from 1430 until 1730h. The highest level of activity occurred during this period (Fischer personal observation 2004). A total of thirty minutes of active behaviour per recording, during which period the hamster stayed outside the shelter, ie the subject was awake and clearly visible, was analysed using the Observer™ Version 5.0 (Noldus). The thirty minutes were split into six × five-minute observation intervals. If possible, the intervals were equally spaced over the three recorded hours. If observation intervals could not be equally spaced over the 3 hours of recording, a total of thirty minutes, ie 6 intervals of the time when the hamsters were visible on the tape would, nonetheless, still be analysed. In some cases 4% (7 hamsters, each with 1 observation) of hamsters were active for less than 30 minutes during 3 hours of recording, therefore their observational

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Table 1 ***Post hoc*** **comparisons of running-wheel activity 2 days before (2BS), 2 days during (2DS) and 2 days after (2AS) stressor application.**

Comparison	*T*-Value	*P*-Value	Revolutions per day
2AS vs 2BS and 2DS	3.2059	0.001823	
2AS vs 2BS	2.2127	0.029267	+1188
2AS vs 2DS	3.3436	0.001177	+2115.36
2BS vs 2DS	1.1617	0.248200	+927.36

The number of revolutions per day indicate how many additional revolutions on average hamsters made during the indicated 2 days (first column first term in comparison with the other two days (first column second term).

Table 2 Number of hamsters making use of the roof of their wooden shelter.

Cage size (cm^2)	Observed on shelter	Not observed on shelter	n
1,800	14	1	15
2,500	12	2	14
5,000	5	10	15
10,000	4	11	15
Total	35	24	59

(χ^2_3 = 22.05, $P < 0.0001$). One hamster whose wheel was non-functioning was deleted.

Table 3 The mean (± SD) concentrations of hormones in the serum of female golden hamsters in 4 different cage sizes.

Cage size (cm^2)	n	Corticosterone ($ng\ ml^{-1}$)	Cortisol ($ng\ ml^{-1}$)	Corticosterone/cortisol coefficient	ACTH ($pg\ ml^{-1}$)
1,800	14	7.74 ± 5.43	8.94 ± 6.64	1.34 ± 0.94	9.64 ± 15.31
2,500	13	7.41 ± 4.48	8.88 ± 6.12	1.73 ± 1.56	12.85 ± 11.10
5,000	15	7.44 ± 5.10	8.25 ± 7.21	1.79 ± 2.67	15.20 ± 13.43
10,000	14	6.76 ± 3.51	7.29 ± 6.67	1.26 ± 1.14	13.00 ± 14.61

Table 4 The mean (± SD) masses of organs of female golden hamsters in 4 different cage sizes.

Cage size (cm^2)	n	Adrenals (μg)	Heart (mg)	Spleen (mg)
1,800	14	7.98 ± 1.67	0.53 ± 0.07	0.14 ± 0.03
2,500	13	8.22 ± 2.33	0.54 ± 0.06	0.13 ± 0.01
5,000	15	9.01 ± 2.27	0.53 ± 0.07	0.03 ± 0.02
10,000	15	8.54 ± 2.18	0.50 ± 0.05	0.18 ± 0.22

data was based purely on the time they were active. As one of the hamsters in cage size 2 was never active during the recorded time, behavioural data for this animal are missing. The hamsters were observed continuously and the observed behaviours, and locations of behaviours within the cage, were classified following Vonlanthen (2003). Behavioural data were expressed as the percentage of total observed time, ie 90 min, for all three recordings (total percent duration). Furthermore, mean durations of bouts, and frequencies of bouts were analysed. The open space of a cage was defined as the area of the cage excluding any structures like the running-wheel, shelter, food bowl, sand bath, or wire.

Statistical analyses

All statistical analyses were made with NCSS® 2001, or SAS® 8.02 (SAS Institute, Cary, NC). Data and residuals were checked for normality and transformed if necessary and possible. If normality of residuals could not be achieved, non-parametric tests were used. Transformations and tests are described in the results. Experimental series (1-3) and the occurrence of hydrocephalus were included as factors in the analyses of behavioural data and are only mentioned if they had a significant influence. Correlations were calculated by using Spearman rank correlation coefficients. One hamster was excluded from the behavioural analyses since her wheel was malfunctioning over a long

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Figure 3

Frequency during 30 min observations during the active time of wire-gnawing bouts of individual hamsters in the different cage sizes. Raw data are shown, but for the analyses the data were square root transformed.

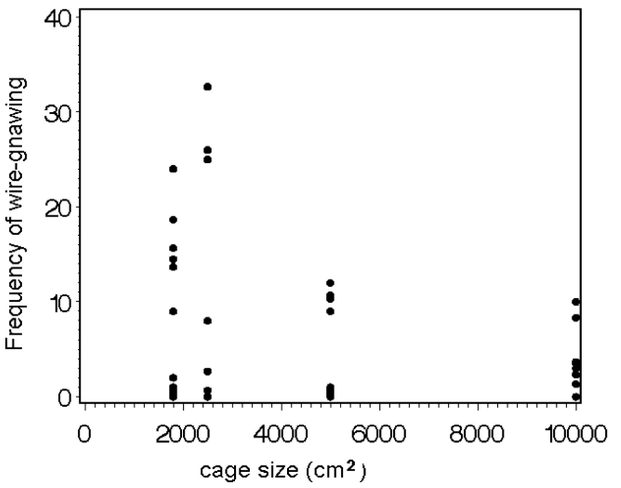
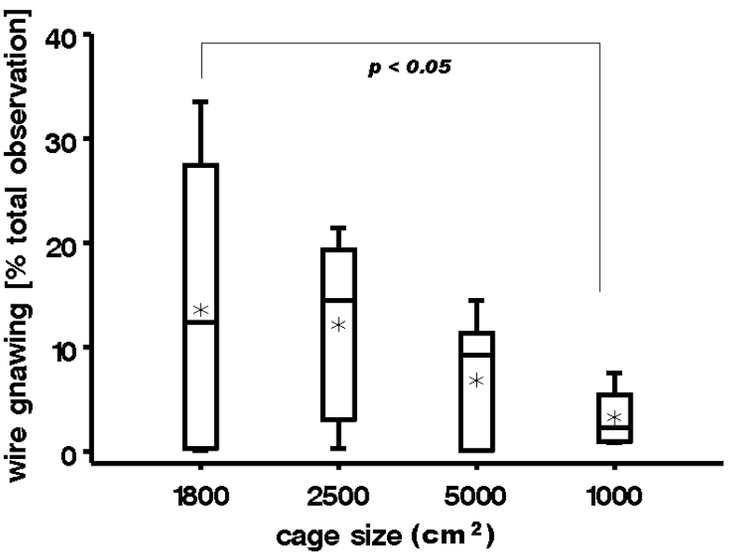


Figure 4

Duration of wire-gnawing (% of the total observation duration) in the 4 cage sizes. Boxes represent the central 50% of the data, the horizontal line represents the median, the vertical lines show 1.5 times the interquartile range, dots are values outside this range, and stars represent the mean value of total duration which was 19.3% for 1,800 cm², 14.5% for 2,500 cm², 9.55% for 5,000 cm², and 4.2% for 10,000 cm². Raw data are shown, for the analyses the data were transformed as per Figure 3.



period of the experiment, which could have had an influence on her behaviour.

Results

Behaviour

Hamsters devoted most of their active behaviour to wheel-running. The remaining time was spent mainly on resting, rearing and grooming (Figure 2).

The results of the different behavioural activities are listed below. The occurrence of hydrocephalus as a main factor was never significant. There was no immediate influence of the stressors on the behaviour of the hamsters.

Running-wheel use

All hamsters used the running-wheel. The average distance was 8.3 km per day (8872 revolutions). The minimum per animal was on average 0.63 km per day; the maximum was 18.56 km per day. These distances are not equivalent to locomotion in a cage or in the natural habitat (Sherwin 1998a). During the 10 weeks before the stress treatment, running-wheel activity of hamsters was not significantly different in all 4 cage sizes (ANOVA, $F = 0.88$, n = 59, ns). However, the more a hamster ran in the wheel, the less it gnawed at the wire ($r_s = –0.7105$, n = 59, $P < 0.0001$) or climbed ($r_s = –0.7261$, n = 59, $P < 0.0001$). The running-

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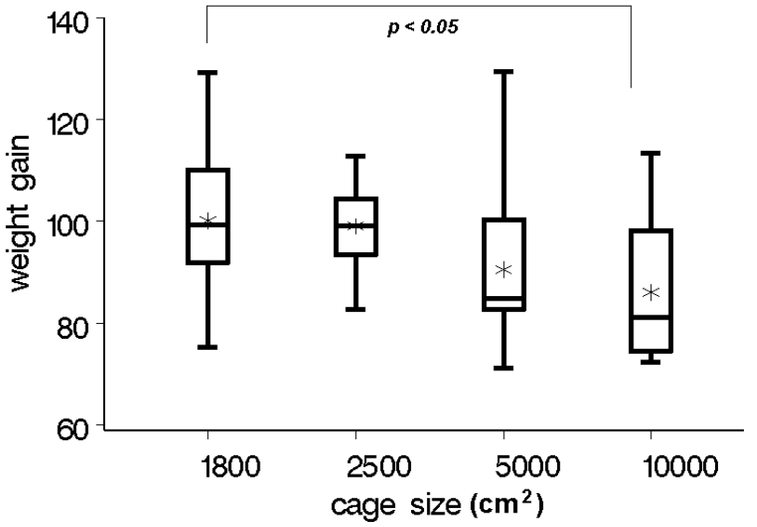
Figure 5

Mixed model REML of weight gain from weaning to week 13 with cage size and series as factor variables. Raw data are shown, for the analysis the data were log transformed. In a pairwise comparison, the difference between the smallest and the largest cages was significant ($P < 0.05$).



wheel data during the two days of stress and the running-wheel data of the two days after the stress treatment were then compared with the running-wheel activity on the two days before the stress was applied.

The stress treatment affected running-wheel activity significantly in all cage sizes. During the two days after stress treatment, running-wheel activity was significantly higher than before and during stressor application (Repeated Measures ANOVA, n = 45, $P = 0.0068$, $F = 5.31$) (Table 1).

From time-to-time some hamsters blocked the running-wheel with litter and in certain instances the running-wheel was not functioning or the transmission of data failed. These data were excluded from the analyses. Furthermore, all running-wheel data of one hamster in cage size 2 were excluded because the transmission of the running-wheel data failed consistently.

The total duration of wheel-running observed in the recordings was significantly correlated with the median of the revolutions per day measured with the Chronobiology Kit ($r_s = 0.60$, n = 58, $P < 0.0001$).

Wire-gnawing

Compared with gnawing at various structures (cardboard tube, twigs, shelter, etc) the hamsters gnawed at the wire for longer periods (Wilcoxon Signed Rank Test: $Z = 4.3439$, $P < 0.0001$). The mean duration of wire-gnawing was 7.6 ± 2.7 s and the mean duration of gnawing at other structures was 0.9 ± 0.7 s. While 13 out of 59 (22%) hamsters showed both behaviours, 17 (29%) showed only wire-gnawing, 3 (5%) gnawed exclusively on other material than wire, and 26 hamsters were never observed gnawing on anything. There was no significant effect of cage size on the number of hamsters performing wire-gnawing. For further analyses a minimum threshold for duration (1% of total observed time) was defined to exclude hamsters that only bit into the bars briefly. Hamsters in small cages gnawed more frequently at the wire than hamsters in larger cages (ANOVA, square root transformation: n = 22, $F = 3.35$, $P = 0.05$) (Figure 3).

Total duration of wire-gnawing was significantly longer in small cages (Mixed model using REML, transformation $y^1 = 2 \arcsin\sqrt{y}$: n = 22, $F = 14.00$, $P = 0.002$) (Figure 4).

Comparing the smallest and the biggest cage size the difference was significant (Tukey's Studentized Range Test for percent duration: $P < 0.05$). Furthermore, wire-gnawing was positively correlated with climbing (Spearman rank correlation coefficient [r_s] = 0.7180, n = 59, $P < 0.0001$), which indicates that hamsters that used to gnaw on the wire also used to climb on the wire. Total duration of wire-gnawing was positively correlated with final bodyweight ($r_s = 0.43$, n = 22, $P = 0.04$).

Location

Hamsters spent most of their active time inside the running-wheel (58% in 1,800 cm², 74% in 2,500 cm², 63% in 5,000 cm² and 70% in 10,000 cm²) (Figure 2). These differences were not significant. The remaining time was spent in the open space, at the wire, in the food bowl, on the shelter, or in the sand-bath. In small cages, more hamsters were observed at least once on top of the roof of their shelter (Fisher's Exact Test, n = 59, $\chi^2_3 = 22.05$, $P < 0.0001$) (see Table 2), but the total duration on top of shelters as well as the total frequency of shelter roof use did not differ among cage sizes (ANOVAS, all $P > 0.1$).

The use of the open space was much more pronounced in big cages (ANOVA, n = 59, $P = 0.0187$, $F = 3.66$). The whole area of all the cages was used regularly.

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Bodyweight

At week 0 bodyweights did not differ significantly in all four cage sizes (ANOVA, log-transformation: n = 60, $F = 2.65$, $P = 0.14$). Weight gain from weaning until week 13 was significantly reduced in big cages (Mixed model on log-transformed weight gains: n = 57, $P = 0.01$, $F_{3, 32} = 4.53$) (Figure 5). Series, age at weaning, and litter size had no effect on weight gain. Body condition also did not differ significantly between cage sizes (ANOVA: n = 57, $F = 1.93$, $P = 0.14$). During autopsy, no difference in the amount of fatty tissue was noticed.

Stress hormones and organ weights

Neither plasma stress hormone levels nor the coefficient of cortisol/corticosterone differed between cage sizes ($P > 0.1$) (Table 3). No differences were found in organ weights including the weights of the adrenal glands (Table 4).

Discussion

The aim of this study was to analyse behavioural differences of golden hamsters housed in different sized cages and subjected to mild husbandry routine stressors and to draw conclusions about their welfare. Size related differences in wire-gnawing, use of the roof of their shelter as additional space, use of open space, and weight gain indicated reduced welfare in small cages. Our investigations showed that, although hamsters displayed wire-gnawing in all cage sizes, hamsters in small cages performed wire-gnawing more often and for longer periods. In small cages, more hamsters made use of the roof of their shelter which could indicate that additional space was increasing welfare. The use of open space was much more pronounced in larger cages and the whole area of the larger cages was used regularly. The cage size did not influence running-wheel activity of hamsters. This was expected because rodents value wheel-running very much as shown in an operant test with mice (Sherwin 1998b).

Hamsters gnawed longer and more frequently on the wire than on other objects in their cage. Gnawing on cardboard tubes, twigs or the wooden shelter serves several purposes, such as helping abrasion and cleaning of the teeth and also to produce nesting material, provide food fibre, etc (Fischer personal observation 2004). Some hamsters shredded the cardboard tube and used its pieces as nesting material. In contrast, wire-gnawing seemed to be ineffective; it could not be prevented by providing natural material to chew on, so wire-gnawing and gnawing at objects presumably have a different cause and/or function. Wire-gnawing might be an attempt to escape from the cage (Nevison *et al* 1999, Würbel *et al* 1998a, b), but it can also be interpreted as redirected behaviour at a replacement object and thus as an abnormal behaviour, or even as a stereotypy. Stereotypic behaviour is commonly defined as repetitive, unvarying behavioural patterns without obvious goal or function (Ödberg 1987), in animals kept under barren housing conditions (Mason 1991). Stereotypies are often observed in captive rodents (Würbel & Stauffacher 1996, 1997, 1998; Wiedenmayer 1997; Waiblinger 1999) and are common indicators of poor welfare (eg review by Mason 1991; Würbel 2001). Wire-gnawing in hamsters in the present study was repetitive, invariant, performed at a particular spot on the wire top of the cage (Würbel *et al* 1996), and without function. Even if this behaviour is not considered a stereotypy but an attempt to escape from the cage, it is still an indication that the wire-gnawing hamsters were not content with their housing.

Therefore, the results of this study indicated that housing in big cages improved the welfare of the hamsters because it resulted in less wire-gnawing. The biggest cage, with a size of 10,000 cm^2, was the one with the shortest duration of wire-gnawing as well as the lowest frequency. Duration and frequency of wire-gnawing in 10,000 cm^2 was half of that seen in 5,000 cm^2 cages, albeit non-significantly. However, even though hamsters in small cages performed more wire-gnawing than hamsters housed in bigger cages, wire-gnawing occurred in all cages. This suggests that even a cage of 10,000 cm^2 was too small for female golden hamsters. If we estimate the natural territory size from the minimum distance between occupied burrows in Syria, our biggest cages represented a mere 0.007% of it.

The positive correlation between wire-gnawing and climbing can be explained by the preference of some hamsters to climb to a particular spot on the front or the top of the cage to gnaw on the wire. Some hamsters used to climb while pausing during wire-gnawing. They usually climbed up and down the front side of the wire top but then returned to the same point and restarted wire-gnawing. Climbing was considered as the source behaviour pattern of stereotypic wire-gnawing in laboratory mice (Würbel *et al* 1996).

In addition to behavioural observations, physiological parameters could be useful to assess the welfare of the golden hamsters. The health of the animals is an important factor for welfare. Obesity and its negative consequences are common in pets. Therefore it is important to give hamsters the appropriate cage size, where the risk of obesity is minimised. Possible reasons for the higher weight gain in small cages could be lower energy expenditure and/or greater food intake. Faster running in big cages, which uses more energy, would explain the higher energy consumption. Hamsters in smaller cages gained more weight and were obviously able to spend more energy on growth. At an advanced age excessive energy will not be used for growth, at which point adiposis could become a problem in small cages. The lack of a running-wheel or other activities with the possibility for high energy expenditure, could further increase adiposis. Therefore, cage sizes 1 and 2 seem to have been too small for the housing of pet hamsters.

The lack of significant differences in hormonal levels could be due to methodological problems (Gebhardt-Henrich *et al* submitted). Due to the sensitivity of hormonal measurements to (sometimes unknown and unavoidable) environmental factors, interpretations of the stress levels of golden hamsters based on these hormones must be made with caution. It is probable that several problems contribute to

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the difficulties of interpreting hormonal measurements with regard to stress and these have been discussed sufficiently elsewhere (Buchanan & Goldsmith 2004; Rushen 1991). However, the measurements of adrenal glands suggest that stress levels did not differ between cage sizes. The stress experienced as a result of common disturbances, mimicked by our stressor treatments, might not be influenced by the size of the cage. Alternatively, 13 weeks in the different cages might not have been sufficient to result in differently sized adrenal glands. The lack of any significant effect of stressors on behaviour could also mean that the stressors were not strong enough to elicit a response. However, the stress treatment increased (short-term) running in the wheel. There are numerous interpretations of the causes of running-wheel activity (see the review by Sherwin 1998a). A possible explanation is that the situation during the stress treatment was aversive to the hamsters and they tried to escape from the area. Running in the wheel might have provided the illusion that they could leave the area. The possibility that running in the wheel helped reduce experienced stress is one that lies beyond the scope of this paper and remains the subject of an ongoing study.

Compared with other studies, all cages in our study were enriched. All cages were furnished with the same structures (enrichment), but there was still more free space in big cages. In big cages, hamsters had the possibility to run longer distances, whereas enrichment items and the chance to perform other behaviours were the same in all cages. It would be interesting to see whether stereotypic wire-gnawing would persist in big cages with more enrichment. Ödberg (1987) found that an increase in cage size did not affect stereotyped jumping in voles, whereas enrichment with twigs reduced it. Although jumping is not analagous to wire-gnawing in hamsters it shows that the structure of the environment can be of greater importance to caged animals than the size of the cage. Spangenberg *et al* (2005) housed rats either singly in small cages (1,092 cm^2) with only one black plastic tube, or in groups in larger cages (3,938 cm^2) which were provided with more and various enrichment. Rats in larger, more enriched cages displayed a more diverse behavioural repertoire which consisted of running, climbing and social behaviours. The size of a cage and enrichment are not independent. Big cages offer more possibilities and space for enrichment than small cages. More enrichment items might lead to less stereotypic behaviour and improve animal welfare (eg Ödberg 1987; Würbel *et al* 1998; Kuhnen 1999b). The combination of a big cage with a corresponding amount of enrichment could be an even bigger improvement of welfare in golden hamsters.

The well-being of caged animals is affected by many factors (Bantin & Sanders 1989). Weiss and Schtick 1982 (in Bantin & Sanders 1989) showed that rats prefer to live in big, narrow cages compared to big, broad cages. Although our cages were much bigger than the cages in the mentioned study, the shape of the cage could also be important for hamsters.

The available free space was used in all cage sizes. Hamsters in the two bigger cages used the whole ground area and spent more time in the open space than hamsters in the two smaller cages. However, the hamsters in the two bigger cages used to walk along the walls, so that trails were formed. Thigmotaxis (ie staying close to the walls and avoiding the centre of an area) is common in rodents and sometimes used as an index of anxiety (Simon *et al* 1994; Syme & Hughes 1972). Therefore one explanation is that hamsters in bigger cages explored more than hamsters in smaller cages, despite an inherent fear of open spaces.

A further factor is an additional platform inside the cage. The Swiss Animal Protection (SAP) postulates an inserted floor in small cages in order to enlarge the available space. The additional space on top of the wooden shelter was used by almost every hamster in the two smallest cages. On the contrary only a few hamsters in the bigger cages used the elevated platform. Although duration and frequency did not differ significantly, this suggests that hamsters in the two smallest cage sizes may have used the top of the wooden shelter as additional space, whereas hamsters in the bigger cages seemed to have enough space and preferred to stay on the floor.

All hamsters used the sand-bath for grooming regularly, but not exclusively. Most hamsters wallowed in the sand. Thus a sand-bath seems very important for the welfare of golden hamsters, whether housed in small or big cages.

Conclusions and animal welfare indications

Since the frequency and duration of wire-gnawing was significantly higher in smaller cages than in the large cages, the welfare of pet golden hamsters might be improved by providing enriched cages of at least 10,000 cm^2. Further investigations should address the behaviour and development of stereotypic wire-gnawing of golden hamsters in differently enriched cages.

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