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*Shelter choice by Syrian hamsters (*Mesocricetus auratus*) in the laboratory*

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Abstract

*The preference of Syrian hamsters (*Mesocricetus auratus*) for different in-cage shelters was tested. First, 15 males and 15 females were made to choose between a cage with a shelter and one without. Different shelters were tested consecutively: short (10-cm) or medium (15-cm) pipes made of black acrylonitrile butadiene styrene (ABS), 7.6 cm in diameter and open at both ends; and short or medium boxes made of black acrylic panels and open at only one end. The strongest use of the shelter cage for nesting (about 75% of days) was in the case of the medium open pipe, for both males and females. The strongest use of the shelter itself for nesting was also in the case of the medium open pipe (52% of days). A second experiment gave a choice between pairs of shelters (of seven different types) to 10 males and 10 females. Both sexes nested significantly more in a medium pipe closed at one end than under a wheel, and tended to nest more in that medium, semi-closed pipe than in a medium, open pipe. Also, females tended to nest more in the medium, semi-closed pipe than under an aluminium cover. Other pairings did not yield significant differences. Direct use of the shelters for nesting was rather low, except for the medium semi-closed pipe (about 50% of days). Semi-closed ABS pipes are inexpensive, easy to clean, and do not interfere with running wheels, and they could be recommended as environmental enrichment for hamsters.*

Keywords: *animal welfare, environmental enrichment, preference test, sex differences, shelter, Syrian hamster*

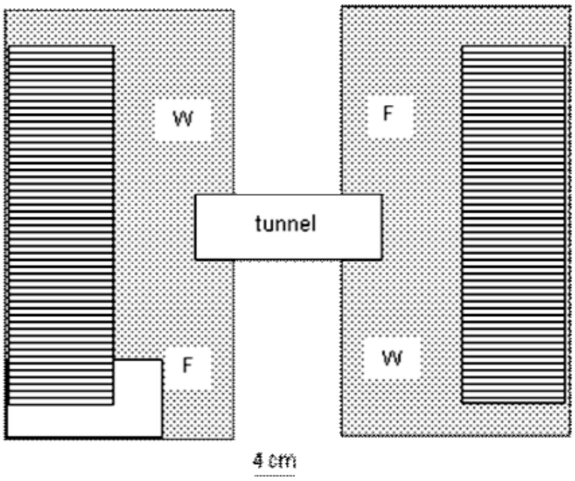
Introduction

Animal welfare is an important issue that has seen a rise in its study and application in the past few decades (Fraser 1999; Dawkins 2006). One definition of welfare is the provision of means so that a captive animal can still express a varied repertoire of naturalistic behaviours (Poole 1997; Galef 1999; Peace *et al* 2001; Van der Harst *et al* 2003; Sørensen *et al* 2005). Environmental enrichment, which can be defined as modifications to the environment that can increase the behavioural repertoire, is one way to improve the welfare of animals (Duncan 1978; Beaver 1989; Van de Weerd 1998a,b; Patterson-Kane 2002). The value that animals assign to different types of enrichment is often measured through preference tests (Sherwin 1996a; Würbel *et al* 1998; Würbel 2001; Olsson & Dahlborn 2002; Olsson *et al* 2003; Sørensen *et al* 2004; Stewart & Bayne 2004; Baumans 2005; Sørensen *et al* 2005; Van Loo *et al* 2005) and these tests can sometimes be used to gain insight into the motivation of animals to obtain specific resources (Manser *et al* 1996, 1998b; Sherwin 2003; Jensen & Pedersen 2008).

One kind of enrichment is the addition of shelters, structures in which nests could be built and that could provide a refuge against light (especially in the case of nocturnal animals, such as most laboratory rodents) or conspecifics (Sherwin 1996a). Shelters have often been shown to be valued by animals (Ottoni & Ades 1991; Townsend 1997; Manser *et al* 1998a; Patterson-Kane 2003; Moons *et al* 2004), and they are amenable to preference tests. For example, Patterson-Kane (2003) found that rats (*Rattus norvegicus*) preferred shelters that were opaque, enclosed and made from solid materials. Other aspects can be studied as well. In mice (*Mus musculus*), for example, Van de Weerd *et al* (1998a) found strain and sex differences in the choice of shelters.

Syrian hamsters (*Mesocricetus auratus*) are often used in immunological, chronobiological and behavioural research. They are territorial and therefore usually kept in individual cages. In the laboratory, they are nocturnal and commonly build nests out of bedding or nesting material in which they sleep during the daytime, relatively exposed to view and to light. The nests, however, need not be in the open; they could also be built inside a shelter. Yet few studies have investigated the preference of hamsters for shelters. Kuhnen (2002) recommended the use of U-shaped open shelters for these animals (three opaque surfaces, one at the bottom, one vertical and one at the top). Ottoni and Ades (1991) found that hamsters preferred to nest in glass bottles or plexiglass boxes that were, in an order of decreasing importance, darker, larger, and closer to resources such as food, water and nesting materials. Other structures have not been studied.

Figure 1



Overhead view of the cage set up in Experiment I. Hatched lines show wheel placement, the grey background shows bedding, and the white square shows shelter placement. W and F represent water and food, respectively.

In our laboratory, where all cages include a running wheel (an important enrichment for hamsters; Sherwin 1998), the animals almost always build their nest out of bedding material (Lanteigne & Reebs 2006) in a corner of the cage underneath the wheel. Thus, the wheel seems to act as a partial shelter for the nest as well as a toy. However, whether the animals would prefer to have a true shelter added to their cage in addition to the wheel has, to our knowledge, never been tested. In the present study, we therefore offered hamsters a choice between two cages, one with a wheel only, and one with a wheel and a shelter. We tested different types of shelter but focused on types that were inexpensive, easy to build (or buy) and to clean, and of a size likely to fit in a cage without interfering with wheel function. In a follow-up experiment, we also offered hamsters a choice between various shelter types but in cages without wheels, to determine whether the shelter type that was preferred in the first experiment could also be recommended for an environment devoid of wheels, and to see whether its value remained high when set against a greater variety of other shelter types.

In a preliminary fashion, we also asked whether light intensity, experience, and gender could influence the choice or use of shelters. We predicted higher shelter use under stronger light intensity as hamsters are mostly nocturnal and might have an aversion to bright light. We had no particular prediction for experience or gender, but we point out that minor sex differences can sometimes be found in welfare studies on hamsters (eg Beaulieu & Reebs 2009; Veillette & Reebs 2010) and therefore that it is worthwhile to test both sexes separately (see also Zucker & Beery 2010).

Experiment 1

Materials and methods

Animals, materials and methods

Methodology was approved by the Université de Moncton, Canada, animal care committee (protocol # 07-10). Syrian hamsters (15 males and 15 females) were purchased from Charles River, Canada. Each was 60 days old at the start of the experiment. None had experienced shelters before. Sexes were tested separately to prevent olfactory or acoustical interaction between them. Each sex was placed in a room where temperature was set at 20°C and humidity at 45–60%. The light:dark cycle was 14:10 h, provided by a mixture of incandescent and fluorescent lights. Depending on the experimental conditions, light intensity was either 30–45 lux (dim) or 700–1,000 lux (bright) as measured with a Gossen Lunasix® photometer (Gossen Foto und Lichtmesstechnik, GmbH, Nuremberg, Germany) at cage level. The first intensity is about that of an unlit room with north-facing windows, whereas the second corresponds to a brightly lit room. These values were judged suitably different to cover the range of light intensities likely to be found in most laboratory settings, and to test for any possible effect of bright light.

Each hamster was housed singly in a set-up made of two Nalgene® polypropylene cages (Nalge Nunc International, Penfield, NY, USA) (white and opaque, each 42 × 22 × 21 cm [length × width × height]) that were connected together by one Habitrail® (Hagen Inc, Montreal, Quebec, Canada) section (a transparent tube 18 × 6.4 cm [length × diameter]; Figure 1). In each cage, hamsters had access to a stainless steel running wheel (Nalgene®, F-size for rats; 35 cm in diameter), food pellets (Pro Lab Diet, PMI Nutrition International, St Louis, Missouri, USA) in an overhead food hopper, and distilled water (also overhead). Pine shavings (Royal Wood Shavings Inc, St Nicholas, Quebec, Canada) were used as bedding; 1 cm deep. These are the cages (single, not connected) that are routinely used to house hamsters in our laboratory (eg Reebs & St-Onge 2005; Beaulieu & Reebs 2009) and in which hamsters normally build nests in a corner underneath the wheel.

This experiment offered a choice between a cage that contained a shelter and a cage devoid of a shelter. Four shelter types were tested: short pipe, medium pipe, short box, and medium box. The pipes, made of acrylonitrile butadiene styrene (ABS), were 7.6 cm in diameter, and either 10-cm long (short) or 15-cm long (medium). They were open at both ends. The boxes were made of acrylic panels and either 10 × 7.6 × 7.6 cm (short) or 15 × 6.4 × 7.6 cm (medium). They were open (ie panel missing) on the bottom and at one end only. All these shelters were black and opaque, and all shelter materials were obtained from local hardware stores.

The tests consisted of consecutive timeperiods, each lasting 9–10 days, except for periods 6(a) and (b) which, for logistical reasons, lasted only 4–5 and 7–8 days, respectively. First, the light intensity was set to dim. Then, period 1 took place, and this was simply a habituation period during which no shelter was present in any of the two cages. Then, in period 2, half of the hamsters were assigned a short pipe and half a short box. The shelters were randomly assigned to a side (left or right cage), and the other cage in the pair had no shelter. In period 3, the hamsters were given the opposite shelter (ie hamsters that had had the pipe got the box and *vice versa*). The same methods were applied for periods 4 and 5, but with the medium box and medium pipe. In period 6(a), the short pipe was brought back for all hamsters, to see if experience (prior exposure to shelters) would have altered their preference for this shelter type. Then, in period 6(b), the short pipe remained but the light intensity was increased from dim to bright, to see if bright light would increase the animals' use of the shelter. Finally, for period 7, the light remained bright and the medium pipe was brought back for all hamsters. Between each period, a day was used for cage cleaning, during which the animals were closely inspected and weighed.

Each day throughout each period, twice during the daytime but separated by a minimum of 4 h, each cage was observed to note where nest sites were (ie where the animals slept). Nest sites were defined as a mound of bedding pushed up around the hamsters. We decided to carry out observations twice a day in case the animals would change nest location during the same day, but such moves turned out to happen very seldom (less than 4% of hamster-days). Hamsters, however, often changed nest location from day-to-day (or, more precisely, from one block of consecutive days to another block of consecutive days). Data analysis was performed on the percentages of observations, but here we often use the term 'percentage of days' as a more informative approximation of the hamsters' behaviour. Both percentages were very similar.

Data analysis

Presence of the nest in the cage with a shelter (whether the nest was in the shelter *per se* or outside of it) was coded as '1' and presence in the other cage was coded '0'. Binomial tests were first used to determine whether the proportion of animals that used the shelter cage more than the non-shelter cage was significantly different than random. Then, Cochran-Mantel-Haenszel statistics using the FREQUENCY procedure in SAS® version 9.1 (SAS® 2007, SAS Institute Inc, Cary, NC, USA) were used to test associations between shelter type and cage choice controlling for gender according to methods in Stokes *et al* (2000). If an association was found, a generalised estimating equation (GEE) was developed with the GENMOD procedure (SAS® 2007) and used to control for the effect of repeated measures. It was also used, with independent contrasts, to test for any effect of light intensity (comparing period 6[a] with 6[b], and periods 4 and 5 with 7), experience (periods 2 and 3 versus 6[a]), order of shelter presentation (period 2 versus 3, and period 4 versus 5), and shelter type. The contrasts were done on the sexes separately. All significance thresholds were placed at the 0.05 level. *P*-values between 0.05 and 0.10 were considered a tendency and are reported as such.

Results and discussion of Experiment 1

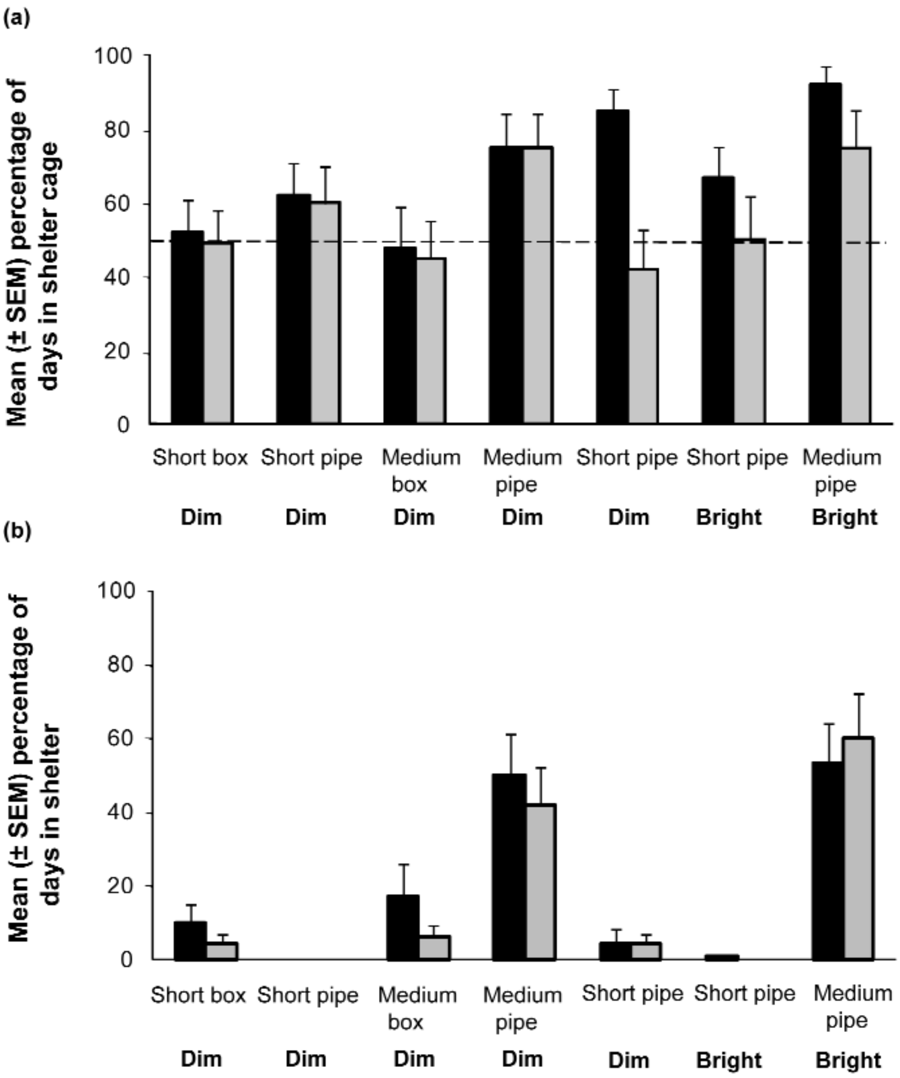
Figure 2(a) shows the percentage of days males and females were found nesting in the shelter cage (whether the nest was in the shelter *per se* or outside of it). The only times binomial tests showed a significant proportion of the animals using the shelter cage more often than the non-shelter cage was when the shelter was the medium pipe (periods 4–5, 11 out of 15 females and 12 out of 15 males, and period 7, 14 out of 15 females and 12 out of 15 males), and also (but only for females) the second time the short pipe was presented (periods 6[a], 14 out of 15 females, and 6[b], 12 out of 15 females). These preferences are also reflected in a significant Cochran-Mantel-Haenszel statistic (males [3] = 91.25, $P < 0.0001$; females [3] = 85.73, $P < 0.0001$) and in independent contrasts showing that both males and females had a tendency to use cages with pipes more than cages with boxes (males: $\chi^2 = 3.64$, df = 1, $P = 0.056$; females: $\chi^2 = 3.55$, df = 1, $P = 0.059$) and used cages with medium pipes more than the other three shelter types (males: $\chi^2 = 3.84$, df = 1, $P = 0.049$; females: $\chi^2 = 3.92$, df = 1, $P = 0.047$).

There was no significant effect of the order of shelter presentation for either sex (ie the results of periods 2 and 3 were similar, as were the results of periods 4 and 5). There was also no significant effect of light intensity and experience for males. There was a significant effect of light intensity for females, but only in the case of cages with medium pipes, which were used more often in period 7 than in periods 4–5 ($\chi^2 = 4.45$, df = 1, $P = 0.035$). There was also a significant effect of experience for females, as the shelter cage was used more the second time the short pipe was presented ($\chi^2 = 4.71$, df = 1, $P = 0.03$). This effect of experience casts doubt on whether the previously mentioned effect of light intensity was truly about light, as it could also be an effect of experience.

Figure 2(b) shows the actual use of the shelters themselves for nesting (ie the hamster and surrounding mound of bedding material were inside the shelter). For males, the mean (± SEM) percentage of days spent in the different shelter types, all periods confounded, was 2 (± 1)% for the short pipe, 4 (± 3)% for the short box, 9 (± 4)% for the medium box and 53 (± 8)% for the medium pipe. For females, the average percentage of days was 2 (± 1)% for the short pipe, 10 (± 5)% for the short box, 17 (± 9)% for the medium box and 51 (± 8)% for the medium pipe. The number of hamsters nesting in the medium pipe consistently (more than 50% of the time) was 21 out of 30 hamsters. In contrast, only 2 out of 30 hamsters consistently used the short pipe, 2 out of 30 for the short box, and 3 out of 30 for the medium box. When not nesting in the shelters provided, the hamsters nested under the wheel an average of 95% of total observations.

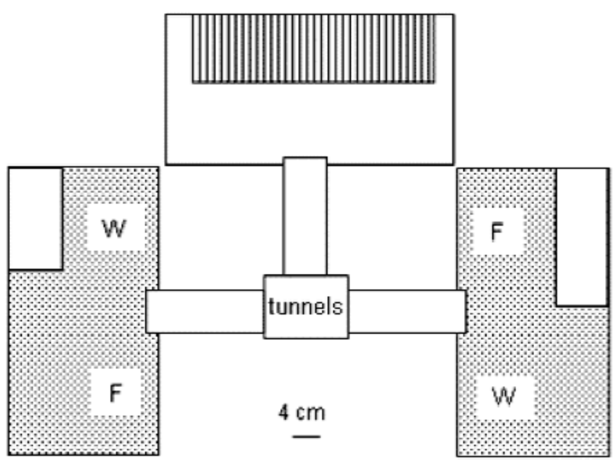
These results show that, of the four shelter types tested, only the medium pipe holds potential as a recommendation for enrichment in cages with wheels. Cages that held such a shelter were significantly preferred over cages without. However, actual use of the shelter itself for nesting was only moderate (around 50% of days). This suggests that pipes hold an attraction not only as shelters but perhaps also as toys (to climb onto, for example) or as means to add complexity to the environment.

Figure 2



Mean (± SEM) proportion of days when male (dark bars) and female (grey bars) hamsters were found in (a) the shelter cage or (b) in the shelter itself in Experiment 1 (n = 15). The dashed line at 50% in (a) shows the random choice level. The shelter types and light intensities on the X-axis are presented in chronological order.

Figure 3



Overhead view of the cage set-up in Experiment 2. Legend as in Figure 1.

Experiment 2

Materials and methods

Animals, materials and methods

Again, the methodology was approved by the Université de Moncton animal care committee (protocol # 07-10). On this occasion, 10 male and 10 female Syrian hamsters were used, all 60 days old at arrival from Charles River, Canada, and all without prior experience of shelters. As in the first experiment, males were tested separately from females. The light:dark cycle was kept at 14:10 h. The same two light intensities as in Experiment 1 were used: dim (30–45 lux) and bright (700–1,000 lux) at cage level. Temperature was again set at 20°C and humidity between 45 and 60%.

Three Nalgene ® polypropylene cages (as in the first experiment) were connected by a Habitrail® tunnel system that formed a 'T' (Figure 3). The cage at the tip of the T had a 35-cm running wheel (Nalgene®, F-size for rats) and nothing else (especially no bedding, thus discouraging the animals from nesting there). The left and right cages had pine shavings as bedding (1 cm deep), as well as water and food pellets (Pro Lab ®, Lab Diet) accessible from a hopper, but no wheels. Such a set-up maintained wheel access for the hamsters (an important enrichment for them) but allowed shelters to be compared in pairs in cages that were used as living quarters without a wheel being present in them.

The shelter types studied were: (i) medium, open pipe: the same 15-cm long ABS pipe that had been preferred in Experiment 1; (ii) medium, semi-closed pipe: the same but with one end blocked with an ABS cover; (iii) long, open pipe: an ABS pipe 20-cm long open at both ends; (iv) medium semi-closed box: the same 15 × 7.6 × 7.6 cm acrylic box as in Experiment 1; (v) wheel: a 35-cm running wheel (additional to the one in the third cage); (vi) aluminum cover: aluminum paper covering about a quarter of the top of the cage (24 × 15 cm [length × width]); or (vii) deep bedding: a layer of pine shavings 10-cm deep instead of 1 cm, allowing hamsters to dig a nest in it.

During 10 consecutive periods lasting 10 days each, different pairs of shelters were given, with the exception of period 1 which was a habituation period with no shelters present. Table 1 presents the pairs used in each period.

As in Experiment 1, nest location was noted via instantaneous sampling twice daily throughout each period. In-between each period, a day was used for cage cleaning, animal inspection and weighing.

Data analysis

The percentage of days when the nest was inside a given shelter was the only dependant variable considered (as opposed to Experiment 1, where we also looked at shelter cage use). Pair-wise differences between shelters were tested with a Wilcoxon matched-pairs signed rank (Siegel 1956) following a False Discovery Rate adjustment (Benjamini & Hochberg 1995). To test for the effects of light intensity and experience on differences in shelter choice, a non-parametric ANOVA was used (the conditions for a parametric test were not respected, so variables were rank-transformed). All assumptions for these tests were verified by looking at the symmetry of differences. Repeated measures were not considered because of the small sample size, but there was no indication that this would significantly affect the analysis as the tests were adjusted for experiment-wise error and the variability within subjects was fairly low across the periods. The significance threshold was set at 0.05 and *P*-values between 0.05 and 0.10 were considered as tendencies. All analyses were performed on SAS® version 9.1 (SAS®, SAS Institute Inc 2007).

Table 1 Pairs of shelters and light intensity used in Experiment 2.

Period	Shelter A	Shelter B	Light intensity
1	None	None	Dim
2	Medium, open pipe	Long, open pipe	Dim
3	As 2	As 2	Bright
4	Medium, semi-closed pipe	Medium, semi-closed box	Dim
5	Medium, semi-closed pipe	Deep bedding	Dim
6	Medium, semi-closed pipe	Aluminium cover	Dim
7	As 2	As 2	As 2
8	Medium, semi-closed pipe	Wheel	Dim
9	Medium, semi-closed pipe	Medium, open pipe	Dim
10	As 6	As 6	Bright

Results and discussion of Experiment 2

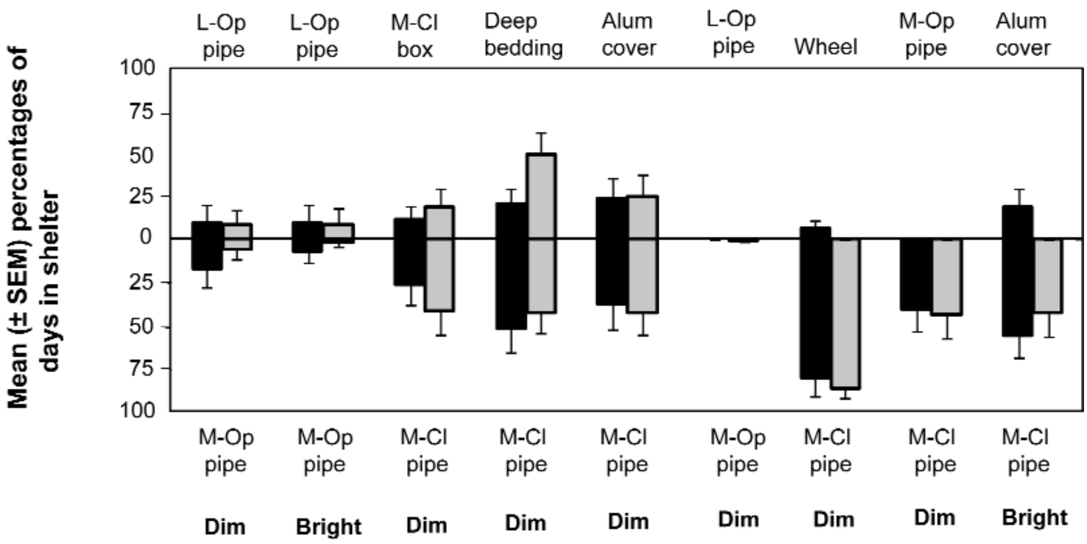
No hamster nested in the wheel cage at the tip of the 'T' (with only one exception, and this only on one day), and no hamster moved bedding there in any significant amount. Very few hamsters changed nest location within the same day (3% of observations for males and 2% for females). These few nest translocations may have been caused by disturbance during the earlier daily observation, even though great care was taken to minimise such disturbances.

Figure 4 shows shelter use in the different periods, and Table 2 summarises the results of the tests for the effects of experience and light intensity. For the effect of experience, periods 2 and 7 were compared. For the effect of light intensity, period 2 was compared to 3 and period 6 to 10. No significant effect of either experience or light was found. The only tendency was for a lesser use of the aluminum cover in period 10 as compared to 6.

For the Wilcoxon signed rank sequential tests, some periods were dropped because the number of hamsters having nested in a shelter at least once (n) was too low to perform the test: period 2 (males: n = 3; females: n = 4), period 3 (males: n = 2; females: n = 2) and period 7 (males: n = 0; females: n = 1). These periods had the medium and long open pipes as shelter types. The percentage of days these shelters were in use for nesting never exceeded 15% on average. This was considered indicative of a lack of preference for these shelter types and it justified not pursuing the analysis of these periods any further.

Among the other periods, only period 8 showed a significant difference between shelters, the medium, semi-closed pipe being preferred over the wheel, and this for both sexes (adjusted $P < 0.05$). Some periods also showed a statistical tendency toward differences between shelters (non-adjusted $P < 0.05$; adjusted $P = 0.09$ for males, adjusted $P = 0.06$ for females): medium, semi-closed pipe over medium open pipe (period 9), and medium semi-closed pipe over aluminum cover in bright light (period 10, for females only). The other pairs yielded no significant differences. It is noteworthy, however, that in both periods 5 and 6 the mean use of the medium, semi-

Figure 4



Mean (± SEM) proportion of days when male (dark bars) and female (grey bars) hamsters were found directly nesting in the different shelter types in Experiment 2 (n = 10). Pairs of shelters (top versus bottom) and light intensities are presented in chronological order along the X-axis. L = long; M = medium; Op = open; Cl = semi-closed.

Table 2 Non-parametric ANOVA results for experience and lighting effects on shelter use by Syrian hamsters. Bold values show a statistical tendency.

Gender	Test		ANOVA *F*-value	df	*P*-value
Males	Experience	Medium pipe	2.161	1, 18	0.159
		Long pipe	1.000	1, 18	0.331
	Light	Medium pipe	0.479	1, 18	0.498
		Long pipe	0.005	1, 18	0.946
	Light	Semi-closed pipe	1.475	1, 18	0.240
		Aluminium	3.299	1, 18	**0.086**
Females	Experience	Medium pipe	1.003	1, 18	0.330
		Long pipe	1.140	1, 18	0.300
	Light	Medium pipe	0.472	1, 18	0.501
		Long pipe	0.002	1, 18	0.967
	Light	Semi-closed pipe	0.062	1, 18	0.806
		Aluminium	3.620	1, 18	**0.073**

closed pipe was higher than that of its alternative, except for females with deep bedding in period 5 (Figure 4).

If the hamsters did not nest in the shelters, they often nested next to the shelters (for males and females, respectively, 69 and 71% of all observations of hamsters not in shelter). Also, if the hamsters did not use the shelter as nest sites, they often used them as latrines or for food storage (M Veillette, personal observation 2008).

Overall, these results indicate a general preference for the medium, semi-closed pipe. The average (mean [± SEM]) use of this shelter, calculated as a percentage of days in the shelter independent of period, light intensity and experience, was 49 (± 8) (7/10 individuals above 50% mean use) for males, and 50 (± 7) (5/10 above 50% mean use) for females. Conversely, the average percent use of the other shelters by males and females was only, respectively, 7 (± 5) and 6 (± 4) for the long, open pipe; 6 (± 3) and 2 (± 2) for the medium, open pipe; 12 (± 7) and 19 (± 11) for the medium, semi-closed box; 21 (± 9) and 49 (± 13) for the deep bedding; 22 (± 8) and 12 (± 7) for the aluminum cover; and 6 (± 5) and 0 for the wheel.

The low use of the medium, open pipe is curious when compared to the 50% use of this shelter in Experiment 1. This result, however, can be explained (and reconciled with a preference for a semi-closed pipe) when one considers the different placement of the open pipes between the two experiments. In the first experiment, the shelters were placed between the wheel and the walls (Figure 1) and pushed against the side wall, as this was the only location that did not hamper access to food and water. In the second experiment, the shelter could be placed parallel to the long axis of the cage (Figure 3) since the absence of a wheel guaranteed access to food and water even with the shelter present. The shelter placement of the medium open pipe in the first experiment could be considered as semi-closed as the hamsters could not push the shelter as far off the wall as in the second experiment, and the wall of the cage commonly blocked one end. In the second experiment, the pipe remained open at both ends. Thus, the difference in medium, open pipe use between Experiments 1 and 2 can actually be seen as support for the notion that a semi-closed pipe is preferred.

That the hamsters preferred a semi-closed pipe is interesting as this type mimics the burrow chambers these animals would build in the wild. These chambers would consist of a main nesting chamber (10–20 cm wide) with a few side chambers for soiling sites and storage and many exit tunnels (Gattermann *et al* 2001).

It is noteworthy that female hamsters nested in the deep bedding as often as in the semi-closed pipe in period 5. In part, this may reflect the fact that of all the shelter types, deep bedding was the only one for which choosing its cage guaranteed the use of that shelter (hamsters choosing the deep bedding cage had no choice but to nest in the bedding), thus boosting its use index. Nevertheless, the 49% use of deep bedding by females was markedly higher than the 21% use by males over the same period. It may be that females are more prone to building well-insulated nests, something that is easier to do in deep bedding, but this remains to be studied further.

General discussion

Overall, changes in light intensity had little effect on shelter use, which was in stark contrast to our expectations. Most rodents prefer a dark shelter to a transparent one and will use it slightly more often under stronger light intensity (Ottoni & Ades 1991; Manser *et al* 1998b). Perhaps the lack of effect observed here was a function of habituation, as young hamsters do not have access to shelters at the breeding farm we purchased them from. By 60 days of age, they may have been sufficiently exposed to room lights to remain unaffected by them. It is also possible that lighting levels higher than those used here might have an effect. The high intensity given to the hamsters here was equivalent to that of a brightly lit room. It would be interesting to see whether a level closer to daylight would increase shelter use; however, such a level would be unrealistic for most laboratory settings. Finally, we varied light intensity only for a small subset of all shelters tested. There may yet be some types of shelter for which an effect of light intensity could be found. However, the preferred shelter (the medium semi-closed pipe) was tested under both light intensities, without any significant change in its use by hamsters, and thus the recommendation we make for it (see below) should apply to normal lighting conditions in the laboratory.

There was also little effect of experience on shelter use or choice. In Experiment 1, the males did not alter their use of the shelter cage the second time the short pipe was presented. In Experiment 2, both males and females did not alter their choice and use of shelters the second time the medium, open pipe versus long, open pipe pairing was presented. The only effect of experience was found in Experiment 1 and only for females, as they used the shelter cage more often the second time the short pipe was presented. All these results must be considered preliminary only, as we did not test all shelters for experience and did not test over very long periods of time. With the caveat of possible sex differences in mind, our tentative conclusion is that experience does not greatly alter shelter use and choice in the short term.

Results from males and females were remarkably similar, the most notable exception being the greater use of deep bedding as a shelter by females. It seems likely that conclusions from studies on sheltering hamsters could be safely extended from one sex to the other, though small peculiarities might be missed were only one sex tested (see Zucker & Beery 2010).

As was found with mice (Van Loo *et al* 2005), hamsters discriminated between some of the different shelters offered. Of all the shelters tested, the medium, semi-closed pipe was favoured. In our first experiment, hamsters occupied cages with a medium pipe more than cages without shelters (other than the wheel) and more than cages with other types of shelter. They also nested directly in medium pipes more than in short pipes or in boxes. In our second experiment, there was a general preference for nesting directly in the medium, semi-closed pipe.

Despite being the favourite choice, the medium-length, semi-closed pipe was not used for nesting more than 55% of the time on average, even when no wheel was present in the cage. Perhaps other shelter types could exert a stronger attraction (see Duncan 1978 for more on this common shortcoming of preference tests). For example, the semi-closed pipe was only of medium length (15 cm). Perhaps a longer one (20 cm, a length we tested in Experiment 2 but only for open pipes) would be even better. However, one should bear in mind that the longer or larger a shelter is, the more likely it is to interfere with the running wheel in a standard-size cage. Hamsters seem to place great value on running wheels as environmental enrichment (Sherwin 1998), and ideally shelters should be selected not only for their intrinsic value, but also with a practical view to fit them in a cage that already contains a running wheel.

Another practical aspect of shelters is that they should not interfere unduly with visual inspection of the animals. As such, the semi-closed pipes were not ideal for they completely hid the hamsters. This may be why, in fact, the animals preferred them, though this remains to be tested by comparing opaque and transparent pipes (see also Ottoni & Ades 1991). Tipping the pipes to extract the hamster would cause undoubted stress and probably damage the nest inside. However, it was our subjective impression that hamsters in pipes were not more difficult to handle and did not become more aggressive than others. A similar finding has also been reported for mice (Moons *et al* 2004). Nevertheless, the possible negative impact of opaque and semi-closed shelters on frequent visual observations or frequent manipulations of hamsters (ie for blood sampling and weighing) remains to be evaluated.

Finally, it should be noted that the present study concentrated only on the usefulness of shelters as potential nesting sites. It is likely that sheltering structures could also be used as toys or for climbing, pushing, or storing (M Veillette, personal observation 2008; Olsson & Dahlborn 2002), but we did not conduct any observations at night and therefore have no data on such use. Some shelters could also be used as a gnawing substrate, though we saw no evidence of this on the ABS and acrylic structures used here, at least for the limited duration of our experiments. Future studies would be needed to directly observe and measure multiple uses of shelters by hamsters, and conduct preference tests accordingly, possibly pitting shelters against other types of toys. The fact that hamsters can manipulate their shelters also has an impact on the possible recommendation of some shelter types. For example, hamsters in our experiments sometimes overturned their boxes (M Veillette, personal observation 2008), thus decreasing their usefulness as shelters. The circular pipes did not have this drawback.

Animal welfare implications and conclusion

Overall, hamsters of both sexes preferred semi-closed 15-cm long ABS pipes to other shelter types. They nested directly in such pipes approximately 50% of the time, even when a running wheel was available to them to nest under. ABS pipes are relatively inexpensive and easy to obtain (all parts were bought from a hardware store) and are easy to clean. Moreover, up to a certain length they do not interfere with running wheels. With further study on the strength of the animal's motivation to obtain shelters of this type (eg Sherwin 1996b), and with the caveat that such shelters may completely hide the animal from view, it is possible to recommend the use of semi-closed ABS pipes as an environmental enrichment for laboratory hamsters.

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