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The effects of mirrors on the welfare of caged rabbits

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Abstract

Mirrors can enrich the environment of some social animals kept in isolation. In this study, the effect of mirrors on the behaviour of isolated, or partially isolated, caged rabbits was tested. In a changeover experiment, four treatments were investigated: isolated without mirrors; partially isolated (with a conspecific housed behind a partition) without mirrors; isolated with mirrors; and partially isolated with mirrors. Behaviour was recorded during the first hour for which the rabbits were in the cages with the stimuli, and then again after one week. Initially, the rabbits' alertness increased, which may be because they perceived the mirror image to be a potential threat. The mirrors also stimulated investigation by the rabbits, which initially scraped them rapidly with their forepaws (scrabbling) and sniffed them. Although sniffing was maintained until the end of the week, scrabbling was not, probably because the rabbits failed to elicit the normal reactions of a conspecific from their mirror images. Mirrors also reduced the time rabbits spent sitting in their living area looking out of the cage, and increased their behavioural complexity, as determined from the number of behaviours performed per minute. In a second experiment, the responses of seven rabbits to four stimuli were recorded: a conspecific; a toy animal; a mirror; and a blank card. The rabbits were presented with pairs of stimuli at either end of a marked board. The responses of the rabbits to mirrors were more similar to their responses to a blank card or to a soft toy than to a conspecific. Although the rabbits did not respond to mirror images as if they were conspecifics, the mirrors may have had benefits to the complexity of behaviour of rabbits in small cages.

Keywords: *animal welfare, behaviour, cage, isolation, mirror, rabbit, reflection*

Introduction

Domestic rabbits (*Oryctolagus cuniculus*) kept as laboratory animals and pets are commonly housed singly in cages that are small relative to the animal's size. However, the behavioural repertoire of domesticated rabbits remains similar to that of wild rabbits (Stauffacher 1992); colonies of which can occupy areas of up to two acres (Vastrade 1987). Therefore, space restrictions may lead to reduced welfare by the prevention of specific behaviours, eg full-length hops (Podberscek *et al* 1991), rearing and stretching (Gunn & Morton 1995). Other behaviours, eg digging, may be prevented by the solid floor of the cage (Podberscek *et al* 1991), and there is also limited exposure to variations of odours, textures and diet (Gunn & Morton 1995).

Adult does, bucks and older pups kept in mixed groups have been observed to congregate and huddle together, or engage in mutual grooming when resting (Stauffacher 1992). Does prefer to live in pairs or groups rather than alone (RSPCA undated) and there is evidence that paired rabbits seek to enter larger colonies (Lockley 1961). Social isolation can induce physiological symptoms of stress, which are relieved by the presence of conspecifics (Held *et al* 1995). Individually caged rabbits may show stereotypic behaviours such as cage chewing and, where space allows, somersaulting. They are also less active than group-housed rabbits, performing less marking and investigatory behaviour (Podberscek *et al* 1991). Although aggression may occur in group-housed rabbits even after the establishment of the dominance hierarchy, particularly in bucks (Lidfors 1997), does still have a strong preference for a group pen over a small, barren, solitary pen (Held *et al* 1995).

Well-designed group housing is most suitable for breeding does, but housing in pairs is more common (Stauffacher 1992). Attempts have been made to enrich individual cage systems with fibrous food (eg hay, Berthelsen & Hansen 1999; grass cubes in a bottle, Lidfors 1997; or fresh grass, Leslie *et al* 2003); fitting cages with boxes; and raising the height at the back, which reduces restlessness, grooming, bar-gnawing and fear of being captured (Berthelsen & Hansen 1999).

Mirrors have been demonstrated to temporarily enrich the environment of some social animals when they are kept in partial isolation: they reduce stereotypic weaving in horses, at least in the short term (McAfee *et al* 2002; Mills & Davenport 2002). Since a reduction in weaving is also achieved by providing social contact, it is possible that this is how mirrors improve the horses' behaviour. However, movement, novelty or a change in the apparent level of confinement could also be responsible for the effect. Mirrors reduced endocrine and physiological responses to partial isolation in sheep (Parrott *et al* 1988), and the authors report that the sheep were attracted to the image in

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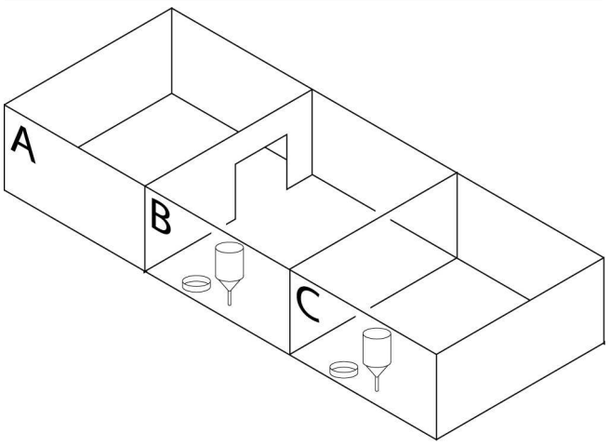
Figure 1



The cage used to house a rabbit with a conspecific in Experiment 1, containing (A) an enclosed chamber, (B) a living area and (C) an additional area for a conspecific.

the mirrors. Mirrors have also reduced the heart rate and movement in isolated cattle (Piller *et al* 1999) and enriched the cages of chimpanzees (Lambeth & Bloomsmith 1991). However, laboratory mice have been found to avoid mirrors when given the choice and particularly avoid feeding in a chamber with mirrors (Sherwin 2004).

Some higher mammals, such as great apes (eg Gallup 1970) and dolphins (Reiss & Marino 2001), appear to show self-recognition in mirrors; however, monkeys, lesser apes, elephants and African grey parrots do not (Reiss & Marino 2001). These are generally believed to have greater cognitive powers than rabbits, so it is unlikely that rabbits are capable of self-recognition. Upon initial exposure to a mirror, many animals appear to respond as though the image represents another animal. This response could be present in rabbits as they can recognise individuals in their territories in the wild (Lockley 1961); however, olfactory or tactile signals may be equally important.

The reactions of rabbits to mirrors as a form of cage enrichment were investigated, and their visual attractiveness compared to that of related stimuli was tested. The aims of this study were to establish how mirrors influence the behaviour and welfare of rabbits, and to investigate the rabbits' response to a mirror image in relation to other stimuli.

Materials and methods

Experiment 1 The effects of providing mirrors on the walls of cages on the behaviour of rabbits housed individually or in pairs

Six unrelated and unfamiliar female rabbits — three Dwarf Lop and three Lionhead — were obtained from a breeder. These rabbits were aged between 7 and 12 months and had previously been kept in groups of 3–4, in cages approximately 1.2 × 0.5 m (length × width). After the experiment the rabbits were returned to the breeder. The rabbits were habituated to the environment for two days before the start of the experiment. Four test rabbits — two of each breed — were then randomly allocated to the four treatment sequences of a balanced Latin Square (Davis & Hall 1969), with four one-week periods and four treatments applied to the cages: isolated without mirrors (I-M); partially isolated without mirrors (P-M); isolated with mirrors (I+M); and partially isolated with mirrors (P+M). Partial isolation was achieved by housing another rabbit in an adjoining part of the cage separated by a plastic mesh. The two rabbits used as conspecific stimuli in this way were not observed. Two of the test rabbits were known to chew their cage before the experiment.

Four cages were used: two double and two single for the treatments partially isolated (P) and isolated (I), respectively. Each test rabbit had access to an enclosed chamber of average size 1700 cm^2, with four solid sides and a small door into the main area of approximately 2400 cm^2, which had three solid sides and a wire grill in the front (Figure 1). The living areas for paired rabbits were divided by a plastic mesh barrier from the back to the front of the main area of the cage to prevent aggression, with a further 2500 cm^2 being available for the conspecific. Mirrors were added to the rear and both side walls of the living areas for rabbits in treatments I+M and P+M, ensuring that the mirrors on the side walls were not parallel to avoid multiple reflections. Because of small differences in the size of the cage compartments, and to ensure that mirror effects could not be affected by the cages, the mirrors were changed between cages after the first two periods. The cage floor was covered with newspaper and straw, which was changed after each period, and the rabbits were offered hay *ad libitum* and a daily carrot each at 0900h. Fresh hay and approximately 30 g of concentrate rabbit feed (Bunny Brunch Mix: H and C Beart Ltd, King's Lynn, Norfolk, UK) were offered daily at 1600h. Clean water was provided *ad libitum* in drinking bottles. Cages were weather-proofed with roofing felt, and the cages were positioned just outside and facing a building so that rain could not enter.

The rabbits were placed in their test environment on day 1 at 1500h. A 1 h observation was conducted immediately to determine the rabbits' initial responses to the stimuli. On day 7 of each period rabbits were observed from 0800h to 1430h. Rabbits were observed from within a building approximately 2 m from the cages to minimise the effect of the observer on the rabbits. Test rabbits were observed continuously in pairs, with the two pairs being observed for alternate minutes. At the end of each 1 min period, the duration and number of occurrences of all behaviours were recorded. A *post hoc* analysis was conducted to determine which behaviours (termed 'long duration' behaviours) were of sufficient length to be analysed according to their duration (regarded as those that had lasted for more than 1 min on more than 50% of occasions), and according to their number of occurrences (all other behaviours, termed 'short duration' behaviours).

The long duration behaviours recorded were: lying (resting with their trunk on floor and limbs under the body or outstretched); sitting (rear end and forepaws on floor with

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forelimbs straight in front of body); and eating concentrate. Short duration behaviours were: ambulation (any movement involving all four legs); scrabbling (rapid scraping and scratching with the forelimbs) on the floor, the barrier, the mirror, the walls or front wire grill; rearing (standing or sitting on hind limbs with both forepaws off the ground); sniffing (nose in contact with floor, wall, mirror, barrier); feeding on hay; drinking; alert (sitting/standing with ears pricked and eyes wide open); and looking out of cage (at the front of the cage with nose close to wire mesh, head facing forward).

Statistical analysis

The total time spent performing each long duration behaviour and the total number of occurrences of short duration behaviours were tested for distribution of the data. Data that were normally distributed, as assessed by the Anderson-Darling test (Ryan *et al* 1980), were analysed for factorial treatment effects by a generalised linear model of the Latin Square design (Davis & Hall 1969), using the statistical package Minitab (Ryan *et al* 1980). Residual effects from the previous period were initially included in the model, but none was significant and the term was excluded from the final model:

$$X_{ijk} = \mu + M_i + I_j + M_iI_j + P_k + R_l + O_m + O_mM_i + \varepsilon_{ijk}$$

where X_{ijk} was the element response; μ the overall mean; M_i the effect of mirror; I_j the effect of isolation (partial or full) as fixed effects; P_k the effect of period; R_l the effect of rabbit; O_m the effect of observation time (beginning or end); and ε_{ijk} the residual error term. Non-parametric data were analysed for main treatment effects using the Kruskal-Wallis test.

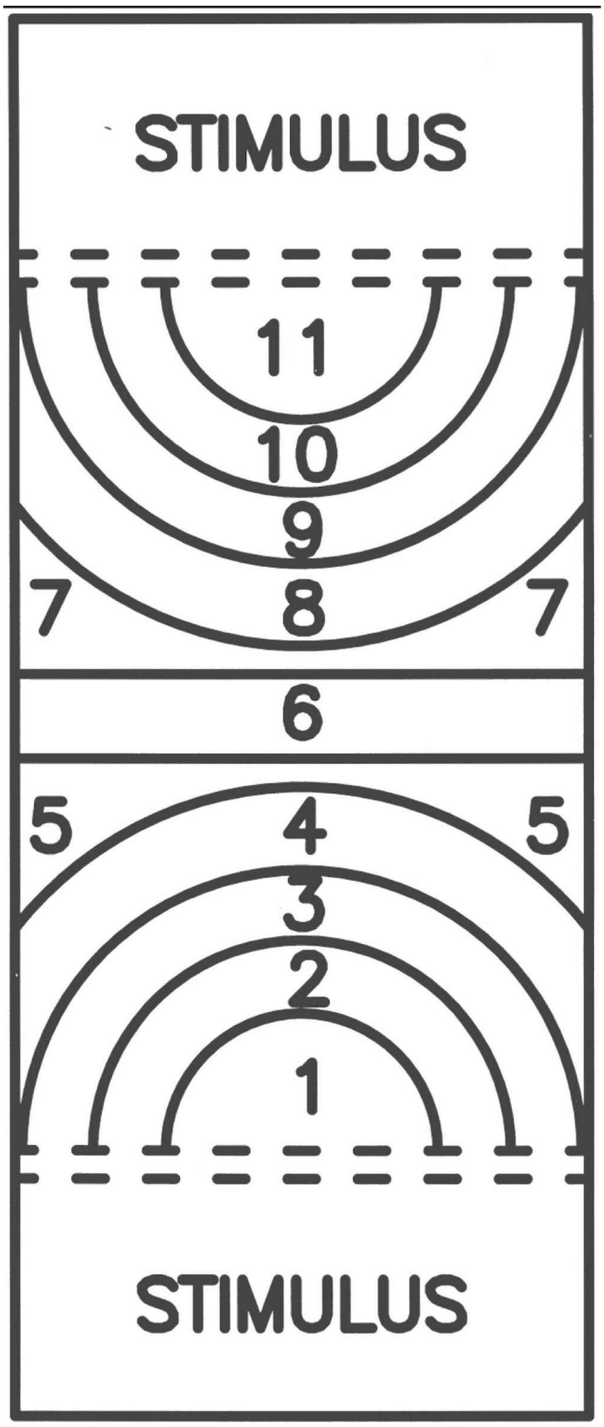
The probabilities of 1 behaviour, 2 behaviours, 3+ behaviours etc occurring in any given minute were calculated using the frequencies for each number of behaviours. The probability of 3+ rather than just 3 behaviours occurring was used because individual probabilities for more than 1 behaviour were low and less likely to indicate treatment effects.

The start and end of the period observations were analysed separately so that the immediate effects of a mirror or conspecific, and their effects at the end of one week, could be evaluated. The pooled data from both sets of observations were then analysed so that the observations at the start of the week, at the end of the week, and the responses to treatment could be compared. The data were examined for normality and analysed by a generalised linear model or the Kruskal-Wallis test for the effects of treatment.

Experiment 2 A comparison of the response of rabbits to a mirror with the response to other stimuli

Eight female Dwarf Lops and one female Lionhead rabbit were obtained from the same breeder as in Experiment 1 and were returned to the breeder after the experiment. Seven of the rabbits, including the Lionhead, were approximately 4 months old. They were housed in two cages and their responses to different stimuli were investigated. The two remaining rabbits, which were approximately 7 months old, were used as conspecific stimuli and housed as a pair.

Figure 2



Open arena for testing the response of rabbits to two different stimuli in Experiment 2, with 11 demarcated areas. Rabbits were initially placed in area 6.

Each rabbit was placed in the test chamber with a stimulus at each end (Figure 2). Their responses to four stimuli were recorded: a conspecific; a toy animal; a mirror; and a blank

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Table 1 The mean time (s per 3 min, and standard error [SE]) spent by rabbits in each area, 1–11, in Experiment 2.

Area	Mean	SE
1	20.3	3.2
2	30.8	7.8
3	13.1	1.3
4	10.2	1.1
5	4.2	2.0
6	20.7	2.3
7	2.1	0.5
8	12.1	2.3
9	11.4	2.4
10	31.2	3.5
11	23.2	2.5

brown card. The mirror and blank card were both 60 × 30 cm (length × height). The soft, grey toy animal, which was of similar size to the conspecific (approximately 30 × 15 cm [length × height]), was moved continually by fine threads attached to it at either end. Rabbits were presented with the pairs of stimuli in an incomplete changeover design with five rows (Davis & Hall 1969), representing five of the seven possible stimuli combinations. After an initial test series the numbers of the rabbits were re-randomised and the test series repeated.

The test chamber consisted of a marked board of dimensions 196 × 122 cm (length × width), with a stimulus at either end on a grassy area 50 × 122 cm (length × width). The test chamber was completely enclosed by a wire mesh pen. Eleven areas were marked on the board in concentric circles radiating out from the position of each stimulus at the two ends. The stimuli were separated from the marked board by a wire mesh, so that the rabbits could see and smell the stimuli but could not directly interact with them, and also so that the conspecific could not leave the stimulus area. The stimuli were placed halfway between the end of the marked board and the end of the pen to standardise the distance of the images from the test rabbit. Each test rabbit was initially placed in the area in the centre of the marked board (number 6 in Table 1) with its flanks parallel to the stimuli so that it did not face either stimulus. The areas the rabbit then entered (as determined by the position of the front foot) were recorded every 10 s for 3 min. The tests were conducted over a period of one week. The following factors were randomised using a Gellerman's series: the end of the pen at which each stimulus was placed; the conspecific; the placement of the test rabbit; and the side of the pen that the recorder stood.

Statistical analysis

For each pair of stimuli tested, the results are presented as though the same stimulus of a pair was at the end nearest area 1, and the other stimulus nearest area 11 for each repetition. Areas 1 + 2 and 10 + 11 were within 50 cm of the two stimuli. Because more time was spent in these regions than in other sectors (Table 1), and treatment effects were also more evident, these pairs of areas were combined to give a single value for each repetition that indicated attractiveness of the stimulus. The mean time spent in areas 1 and 2 was subtracted from the time spent in areas 10 and 11 as a measure of relative attractiveness between the two stimuli. To develop an order of attractiveness, the relative attractiveness was calculated for each stimulus when it was presented with any of the others. The Student's *t*-test with 29 degrees of freedom was used to detect any significant differences in attractiveness between the different stimuli.

Results

Experiment 1

There were no significant interactions between the two factors, mirror and conspecific ($P < 0.05$), and therefore results are presented for the single factors only.

Initial responses

Mirror

Rabbits housed in cages with mirrors showed some alert behaviour, whereas rabbits without mirrors did not (Table 2). The provision of a mirror approximately doubled the amount of sniffing of vertical surfaces, but did not affect the amount of sniffing of the barrier or the front grill; therefore, the increase in sniffing was of the mirrors. Mirrors reduced the number of 1 min periods in which only one behaviour was recorded and increased the number of periods in which more behaviours were recorded.

Conspecific

The presence of a conspecific significantly increased the amount of rearing and drinking and decreased the amount of feeding on hay. It also increased the number of 1 min periods in which 5+ and 7+ behaviours were recorded.

Responses at the end of one week

Mirror

The mirror increased the time that rabbits spent sitting, and decreased the time spent looking out of the cage (Table 3). It increased the time spent sniffing vertical surfaces, mostly of mirrors. The mirror also increased the frequency of multiple behaviours being observed in 1 min.

Conspecific

The conspecific caused a significant amount of rearing, and increased the time spent sniffing vertical surfaces, but not the walls or grill; therefore, the extra sniffing was at the barrier between the conspecific and the focal rabbit. The presence of the conspecific also increased the number of periods when 3+ and 5+ behaviours were shown in each minute.

Differences between initial behaviour recording and that after one week

The rabbits spent more time performing exploratory behaviour during the initial period — ambulation, rearing

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Table 2 Behaviour of rabbits with and without mirrors and conspecifics in the first hour post treatment application. I = full isolation, P = partial isolation, –M = without mirror, +M = with mirror.

	Isolation		Mirror provision			*P*	
	I	P	–M	+M	SED	Isolation	Mirror
Body posture							
Lying (median min per 30 min)	5.0	0	0	0	–	0.43	0.86
Sitting (mean min per 30 min)	2.8	1.6	2.0	2.5	0.86	0.22	0.60
Ambulation (mean no per 30 min)	10.5	23.3	14.3	19.5	6.20	0.07	0.44
Alert (median no per 30 min)	0	0	0	1	–	0.95	0.03
Rearing (median no per 30 min)	2.5	16	3.5	9	–	<0.001	0.29
Looking out of cage (mean no per 30 min)	13.6	11.9	13.7	11.8	2.67	0.55	0.50
Investigatory behaviour							
Sniffing							
Vertical surfaces (mean no per 150 min)	15.4	25.6	13.9	27.1	5.35	0.08	0.03
Plain walls/grill (median no per 150 min)	7.3	7.1	7.2	7.2	2.41	0.92	1.00
Floor (mean no per 150 min)	1.9	2.4	2.5	1.8	1.02	0.63	0.47
Scrabbling							
Mirror directed (mean no per 30 min)	18.3	16.0	n/a	17.2	2.02	0.35	–
Barrier directed (mean no per 30 min)	n/a	22.6	23.8	21.3	5.85	n/a	0.73
Floor directed (median no per 30 min)	7.0	7.0	5.5	11.0	–	0.96	0.07
Ingestive behaviour							
Feeding on concentrate (mean min per 30 min)	6.5	4.3	5.1	5.7	1.62	0.17	0.62
Feeding on hay (mean no per 30 min)	11.7	5.4	6.1	11.0	2.30	0.02	0.06
Drinking (median no per 30 min)	0	2.5	0	0	–	0.03	0.95
Behaviour frequency							
Long and short duration							
1 behaviour per min	0.34	0.25	0.42	0.18	0.09	0.39	0.02
3+ behaviours per min	0.48	0.63	0.43	0.68	0.44	0.18	0.04
5+ behaviours per min	0.22	0.46	0.23	0.44	0.10	0.03	0.06
7+ behaviours per min	0.07	0.21	0.10	0.18	0.05	0.02	0.10

SED = standard error of difference between means for main effects

and sniffing at vertical surfaces, scrabbling at the mirror, the barrier, and floor — and more time feeding on hay than during the end period (Table 4). They also spent less time lying, sitting, alert, looking out of their cage, and feeding on concentrate, and exhibited both more long and short duration behaviours in the initial period. However, during the final period there was a stronger effect of the mirror in increasing sniffing of vertical surfaces. The presence of a conspecific resulted in a decrease in hay intake during the initial observations, but not during the final observation.

Experiment 2

More time was spent by the test rabbits close to the blank card than the soft toy or rabbit and more time near the mirror than near the rabbit (Table 5). There were no significant differences in the amount of time spent near the rabbit or soft toy ($P > 0.50$), rabbit or mirror ($0.10 > P > 0.05$), mirror or soft toy ($P > 0.10$), or mirror or blank card ($P > 0.10$). However, the blank card was significantly more attractive than either the soft toy ($P < 0.01$) or the rabbit ($P < 0.01$). The order of attractiveness was therefore blank card > mirror > soft toy > rabbit (these stimuli differ significantly using the Student's *t*-test).

Discussion

The increase in sniffing of vertical boundaries when a conspecific or mirror was present was due to a considerable interest displayed by the rabbit in the barrier or mirror respectively. The conspecific and mirror attracted the rabbit's attention both at the start of the week and at the end, and the mirror had a significantly greater effect than the conspecific in the end of week observation. This suggests that after one week the mirror was a more interesting stimulus to the rabbits than a conspecific, probably because a relationship with the conspecific had been established and conformed to the rabbit's expectations of a conspecific's behaviour; whereas the image in the mirror still did not perform the expected behaviour. The initial scrabbling at the mirror may have been due to investigation and the reduction in scrabbling over one week may have been due to the rabbit being unable to obtain confirmatory cues that the image is a conspecific. These cues are likely to be both olfactory and tactile, and the synchronised movement of the image in concert with that of the test rabbit may also have alerted the rabbit that this was not a normal conspecific. Sherwin (2004) has suggested that

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Table 3 Behaviour of rabbits with and without mirrors and conspecifics after one week of treatment. I = full isolation, P = partial isolation, –M = without mirror, +M = with mirror.

	Isolation		Mirror provision			*P*	
	I	P	–M	+M	SED	Isolation	Mirror
Body posture							
Lying (median min per 150 min)	58.9	40.5	41.2	58.2	10.47	0.10	0.13
Sitting (mean min per 150 min)	17.6	16.6	13.2	20.9	3.55	0.79	0.05
Ambulation (mean no per 150 min)	13.7	19.9	15.8	17.8	2.83	0.06	0.56
Alert (median no per 150 min)	2.0	2.0	2.0	3.5	–	0.74	0.38
Rearing (median no per 150 min)	0.0	6.0	1.0	2.5	–	0.02	0.52
Looking out of cage (mean no per 150 min)	15.9	13.2	19.9	9.2	3.33	0.43	0.01
Inside chamber (mean min per 150 min)	13.3	22.8	30.3	5.8	12.21	0.46	0.07
Investigatory behaviour							
Sniffing							
Vertical surfaces (mean no per 150 min)	7.6	21.2	8.9	19.8	2.81	<0.001	<0.01
Plain walls/grill (median no per 150 min)	1.5	1.0	0.5	1.5	–	0.30	0.23
Floor (mean no per 150 min)	6.4	7.2	6.2	7.4	1.50	0.63	0.42
Scrabbling							
Mirror directed (mean no per 150 min)	10.0	11.8	n/a	10.9	1.27	0.40	n/a
Barrier directed (mean no per 150 min)	n/a	16.6	15.2	18.0	2.73	n/a	0.83
Floor directed (median no per 150 min)	1.5	1.0	2.0	0.5	–	0.91	0.51
Ingestive behaviour							
Feeding on concentrate (mean min per 150 min)	35.4	41.1	38.3	38.5	5.49	0.32	0.93
Feeding on hay (mean no per 150 min)	19.9	22.3	17.9	24.3	5.46	0.67	0.23
Drinking (medium no per 150 min)	1.5	4.0	1.0	1.5	–	0.29	0.15
Behaviour frequency							
Long and short duration							
1 behaviour per min	0.67	0.62	0.67	0.62	0.05	0.29	0.29
3+ behaviours per min	0.23	0.28	0.23	0.28	0.018	0.03	0.04
5+ behaviours per min	0.49	0.53	0.48	0.54	0.01623	0.04	0.01
7+ behaviours per min	0.02	0.03	0.02	0.04	5×10^{-3}	0.36	0.01

SED = standard error of difference between means for main effects

mice piling up substrate against a mirror in preference tests may represent an attempt to bury the mirror, which was clearly aversive. It is possible that the scrabbling was an attempt to bury the image, but it more probably represents an attempt to reach the image by destroying the glass barrier, since it appears to be redirected digging behaviour.

Caged rabbits can increase their level of stimulation by looking out of the cage. The presence of a mirror decreased the frequency of this behaviour, suggesting that a mirror may make the cage a more stimulating environment. However, it is also possible that the reflections of rabbits apparently present in the cage may have increased stress. With their eyes on the sides of their head, it is possible that two reflections were visible for fully isolated rabbits and four for partially isolated rabbits.

The presence of the conspecific increased rearing, but not rearing onto the barrier, suggesting that the behaviour represented heightened awareness. Wild rabbits rear when they are scanning their surroundings (Lockley 1961), and caged rabbits use boxes and any height provided for the purpose of enrichment as lookout posts (Hansen & Berthelsen 2000).

The increase in time spent looking alert with mirror provision supports the hypothesis that rabbits initially found the mirror disturbing, and increased vigilance was required as it may have been perceived as a threat. Both a mirror and a conspecific increased the number of behaviours performed per minute. This may derive from greater restlessness or stimulation, and therefore the impact on welfare is difficult to determine. Reduced time spent sitting staring out of the cage when the mirror was present indicates that the latter may be more likely, but it could also be argued that there was a greater need for vigilance with the mirrors and the conspecific.

The order of attractiveness of stimuli in Experiment 2 indicates that the conspecific and soft toy stimuli were aversive to the rabbits. The conspecifics were considerably older and larger than the test rabbits and this is probably why they were avoided. All rabbits were group-reared, rather than individually reared, so it is unlikely that the novelty of

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Table 4 Differences in behaviour between the initial observation (Initial) and after one week (End). † There were no significant interactions between mirror provision, conspecific provision and time of observation.

	Initial	End	SED	Probabilities†		
				Time	Isolation × Time	Mirror × Time
Body posture						
Lying (median min per 150 min)	0.0	5.5	–	<0.001	–	–
Sitting (mean min per 150 min)	10.9	17.0	3.43	0.09	0.53	0.48
Ambulation (mean no per 150 min)	84.4	16.8	17.28	<0.01	0.11	0.50
Alert (median no per 150 min)	0	2.0	–	0.06	–	–
Rearing (median no per 150 min)	22.5	2.0	<0.01	–	–	–
Looking out of cage (mean no per 150 min)	12.7	14.5	6.75	<0.001	0.71	0.92
Investigatory behaviour						
Sniffing						
Vertical surfaces (mean no per 150 min)	102.2	14.3	13.44	<0.001	0.18	0.05
Plain walls/grill (mean no per 150 min)	35.6	1.8	5.43	<0.001	0.99	0.96
Floor (mean no per 150 min)	10.6	6.8	2.40	0.12	0.74	0.32
Scrabbling						
Mirror directed (mean no per 150 min)	85.6	10.9	7.00	<0.001	0.38	–
Barrier directed (mean no per 150 min)	110.0	16.6	23.75	<0.01	–	0.85
Floor directed (median no per 150 min)	7.0	1.5	–	0.01	–	–
Ingestive behaviour						
Feeding on concentrate (mean min per 150 min)	26.3	38.3	5.39	0.04	0.11	0.74
Feeding on hay (mean no per 150 min)	42.5	21.1	7.20	0.01	0.03	0.21
Drinking (median no per 150 min)	0	2.5	–	0.44	–	–
Behaviour frequency						
Long and short duration						
1 behaviour per min	0.30	0.64	0.0496	<0.001	0.76	0.07
3+ behaviours per min	0.55	0.25	0.06	<0.001	038	0.08
5+ behaviours per min	0.77	0.51	0.03	<0.001	0.26	0.28
7+ behaviours per min	0.14	0.03	0.0254	<0.001	0.02	0.18

SED = standard error of difference between means for main effects

Table 5 The difference in time (s per 3 min) spent close (within 50 cm) to two stimuli for rabbits offered a blank card, a mirror, a soft toy and a live rabbit as stimuli.

Stimulus 1	Stimulus 2	Time spent close to stimulus 2 minus time spent close to stimulus 1
Blank	Blank	–17.6
Blank	Mirror	–2.8
Blank	Toy	–68.9
Mirror	Toy	7.0
Rabbit	Toy	–3.0
Rabbit	Mirror	38.0
Rabbit	Blank	47.1
Summated results		
Blank	Any	39.6
Mirror	Any	9.4
Toy	Any	–21.6
Rabbit	Any	–27.0

another rabbit was aversive to the test rabbits, but the moving toy may also have been frightening because of its novelty. For example, chicks find moving pecking devices less attractive than static ones (Jones 2001). The results of the two experiments together suggest that rabbits do not respond to a mirror reflection in the same way as to a conspecific, which is probably due to the differences in sensory input and movement patterns of the mirror reflection.

Conclusions and animal welfare implications

Rabbits displayed considerable interest in the mirrors and did not become habituated to their presence during the course of the experiments. Initially, the mirrors also made them more alert: rabbits in cages with mirrors spent less time looking out of their cage and more time sitting in their living area. Rabbits performed more behaviours per minute with mirrors, which may indicate successful enrichment. Rabbits appeared to respond differently to the image in a

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mirror compared with a conspecific or even a moving toy. We conclude that the provision of mirrors in small rabbit cages offers some advantages to welfare, when assessed in terms of behavioural responses.

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