TELEMETRY AS A METHOD FOR MEASURING THE IMPACT OF HOUSING CONDITIONS ON RATS' WELFARE

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Abstract

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Various tools have been developed over previous years to study the welfare of laboratory animals. These include preference tests, which are commonly used to evaluate housing environments. Preference tests, however, have some pitfalls: they supply information only on the animals' present preferences, and they allow the animal the choice only between the options offered. Other methods based upon the collection of clinico-chemical data require handling of the animals, which can be stressful in itself. An alternative may be to use telemetry to measure the changes in physiological parameters caused by different environmental conditions. The aim of this study was to use telemetry to evaluate the short-term impact of housing conditions on rodents. We monitored heart rate, blood pressure and body temperature in rats kept on three different types of flooring — bedding, grid floors and plastic floors. The study revealed significant differences in systolic and diastolic blood pressure, heart rate and body temperature between rats housed in the three conditions, indicating that both grid floors and plastic floors are more stressful for the animals than bedding. The observed differences did not diminish over the two-week observation period. The grid-floor housing induced elevations in blood pressure and heart rate. Blood pressure remained elevated even when the animals were returned to standard bedding, whereas the heart rate declined back to its original value immediately in response to this shift. This study shows that telemetry is a very effective tool but that it needs integrating with other methods; in addition, a greater understanding of the biological significance of the changes in cardiovascular parameters is required before the hypothesis that these changes represent an indication of distress can be accepted.

Keywords: *animal welfare, heart rate, housing conditions, rats, systolic blood pressure, telemetry*

Introduction

The publication in 1959 of the book *The Principles of Humane Experimental Technique* (Russell & Burch 1959) resulted in a great many attempts to monitor and improve laboratory animal welfare. Various tools have been developed to enable the quantification of welfare — for example, behavioural tests such as preference tests (Baumans *et al* 1987; Blom 1993; Dawkins 1983), preference-strength tests (Manser *et al* 1998) and open-field tests (Dahlborn *et al* 1996; Walsh & Cummins 1976), and evaluative tests of physiological parameters such as corticosterone levels (Friend 1980; Haemisch *et al* 1994; Livezey *et al* 1985), body temperatures (Satinoff 1998) and growth rates (Eskola & Kaliste-Korhonen 1998). The commonly used preference tests have some pitfalls: they supply information only on the animals' present preferences, and they allow the animal the choice only between the options offered. Other evaluative methods that are based upon clinico-chemical data require handling procedures, such as moving the animals from their home cage to a test cage or restraining them for collection of samples, which may be stressful. A good alternative, therefore, may be to use telemetry to register changes in physiological parameters caused by the different environmental conditions of the test animals.

Telemetry is based upon the insertion of a transmitter into the animal. The modern transmitters for use in rats are typically placed in the abdomen and a lead positioned in the aorta. The transmitter sends radio signals to a receiver plate beneath the animal's cage. The data are subsequently collected and stored on a computer and then managed by the computer software. Compared with traditional methods, telemetry enables a huge volume of physiological data to be collected at very short intervals throughout the entire 24 h period, allowing the observation of changes that occur as a result of the animal's perception of its present situation. Physiological parameters that are of interest for the assessment of welfare include heart rate, blood pressure and body temperature (Meerlo *et al* 1997; van den Buuse 1994). These parameters are not influenced by the animal's motivational state, whereas they are highly sensitive to emotional reactions such as stress and fear.

The effects of, and preferences for, different types of bedding and flooring have been investigated in traditional physiological and behavioural studies. In preference tests, rats have been shown to prefer cages with bedding to cages with a grid floor (Blom 1993); in particular, they prefer resting on bedding rather than on wire mesh (Manser *et al* 1995). During their active period, the choice of flooring is less distinct (Manser *et al* 1995). Previous exposure of the rats to a specific type of bedding does not seem to influence their preference for flooring-type (Blom 1993; Manser *et al* 1995). In clinico-chemical studies, major differences in serum corticosterone levels were seen when rats housed on bedding were compared with rats housed on grid floors (Eskola & Kaliste-Korhonen 1998).

The aim of the present study was to investigate whether telemetry is a useful method for measuring the impact on rats of different housing conditions. Specifically, the impact of different types of flooring was chosen, as several previous studies have investigated the effects of different floorings on physiological and behavioural measures of animal welfare. To evaluate the use of telemetry as a tool for measuring different impacts on the animals, the results from the present study will be compared with the results of these previous studies, to determine whether telemetry can indicate the same impacts on welfare.

Materials and methods

Eight female Mol:SPRD rats aged 12–18 months (M&B Ltd, Ll Skensved, Denmark) and weighing 270–340 g were used. For insertion of the transmitter, performed at least six months before the start of the study (as the rats were also part of another study), each rat was anaesthetised with isoflurane (Forene®, Abbott, UK). The abdomen of the rat was opened with a 3–5 cm long incision. All organs and fat were pushed aside, uncovering the aorta. A lead was inserted 1.5 cm into the aorta and then sealed in the aorta using surgical glue (Histoacryl®, Simonsen & Weel, Albertslund, Denmark). The transmitter (TL11M2-C50-PXT, Data Sciences International, St Paul, Minnessotta, USA) was then placed in the abdomen, fixed with three stitches to the muscular wall, and the laparatomy closed using sutures (Ethicon® Sterile Silk Suture, 3/0 and 4/0, Simonsen & Weel, Albertslund, Denmark). For 2–3 days after the operation, the rats were subcutaneously administered 0.05–0.1 mg kg^{-1} Temgesic® (Schering-Plough Animal Health, Denmark) and 5 mg kg^{-1} Rimadyl Vet® (Vericore Ltd, UK) for post-operative analgesia. From arrival at the laboratory until the beginning of the study, the rats were pair-housed in type-III cages (Tecniplast, Gazzada, Italy) with aspen-chip bedding (Tapvei, Kortteinen, Finland). Eight pairs of rats were used, each pair comprising a rat with an inserted transmitter and a rat with no transmitter as a social companion. The rats were fed Altromin 1324 (Brogaarden, Gentofte, Denmark) and water was available *ad libitum*. Lights were on from 0600h to 1800h with no twilight periods, and the air was changed 8–15 times per hour. The room temperature was 21°C and the humidity was 50%.

Study 1

Throughout a period of continuous monitoring, the rats were housed on three different types of flooring. Each rat was used as its own control. Study 1 was used as a pilot study to reveal the different effects of the housing conditions and to find the most suitable parameters for further use. First, the rats were housed for two days on aspen-chip bedding; following this, they were housed for three days on a metal grid inlet above the cage floor (Tecniplast, Italy); and finally they were housed for three days on a specially designed plastic inlet (Ritoform®, RIAS, Denmark). Throughout this period, systolic and diastolic blood pressure, heart rate and body temperature data were collected continuously.

As the bedding represents the animals' normal housing condition, the two days for which they were housed on bedding were regarded as control values. The animals were then recorded for three days on grids and for three days on plastic floors, as these were the test conditions and represented unusual flooring for the animals.

Data from the second 24 h period of each type of housing were chosen for statistical analysis. This period was divided into day (0600h–1800h) and night (0600h–1800h). The day period was divided into 24 periods (D1–D24) with each value being the mean of a 30 min interval. Similarly, the night period was divided into 24 periods (N1–N24).

Study 2

For a three-week period (days 1–21), four rats were housed on bedding and four rats were housed on grid floors. After three weeks, the flooring conditions were switched (days 22–33), so that rats that had initially been housed on grids were now housed on bedding, and vice versa. Throughout the study, data for systolic blood pressure and heart rate were collected during the daytime on days 1 and 2, days 11 and 12, days 22 and 23, and days 32 and 33. The days were divided into 19 periods lasting 30 min each, D1–D4 (0600h–0800h) and D5–D20 (1000h–1730h). The period from 0800h–1000h was used for the daily care of the animals.

Statistical analysis

The data from all of the periods (D and N) were tested independently using SAS (Procedure Mixed) with a Diggle model, which is a general linear model (SAS Institute, US). The parameters used were 'housing' (ie the housing conditions) and 'time' (ie D and N). In addition, the effect of interaction was tested. As the same rats were used for all three housing conditions, they were tested as the subject in the model.

Before using the model the data were tested by plotting the predicted values against the residuals. Additionally, for study 1 the three housing conditions were tested pair-wise using least-square means (LSMeans) for the four physiological parameters for both day and night, in order to indicate differences between the housing conditions. The null hypothesis was that there was no effect of housing on the physiological parameters, and the alternative hypothesis was that an effect would be observable.

Results

Study 1

Figures 1 and 2 show the diurnal patterns for systolic and diastolic blood pressure, heart rate and body temperature for the three different types of flooring for the first 46 h. A difference between day and night values is clearly observable. Systolic blood pressure and heart rate were significantly lower during both day and night when the rats were housed on bedding compared to grids or plastic floors.

Table 1 shows the *F*- and *P*-values from the overall statistical model. For both the day and the night periods, the effect of housing conditions on all four parameters was significant ($P < 0.0001$). The *F*-values for the day periods were much higher than those for the night periods. Table 1 also shows the mean values for the four parameters for both day and night, as well as the *P*-values for the pair-wise tests between LSMean values for the three housing conditions. There was a significant interaction between heart rate and temperature for both day and night. In addition, there was a significant effect of time for all the parameters for both day and night.

Table 1 Statistical analysis from the second of two 24 h periods showing the effect of three different floor-types (bedding, grid and plastic) on four physiological parameters (systolic and diastolic blood pressure, heart rate and body temperature) in female Mol:SPRD rats.

Parameter	Time	*F*-value for housing	*P*-value for housing	LSMean		SE LSMean	*P*-value Difference between LSMeans	
Systolic blood pressure	Day	91.88	0.0001	Bedding	118.61	5.31	Bedding vs grid	0.0001
				Grid	125.52		Bedding vs plastic	0.0001
				Plastic	123.07		Grid vs plastic	0.0001
	Night	31.35	0.0001	Bedding	124.37	5.60	Bedding vs grid	0.0001
				Grid	127.64		Bedding vs plastic	0.0001
				Plastic	128.35		Grid vs plastic	0.1858
Diastolic blood pressure	Day	11.99	0.0001	Bedding	83.67	3.90	Bedding vs grid	0.0001
				Grid	85.73		Bedding vs plastic	0.0070
				Plastic	84.81		Grid vs plastic	0.0294
	Night	7.73	0.0005	Bedding	89.63	4.12	Bedding vs grid	0.0042
				Grid	88.41		Bedding vs plastic	0.3698
				Plastic	90.01		Grid vs plastic	0.0002
Heart rate	Day	108.10	0.0001	Bedding	323.27	10.42	Bedding vs grid	0.0001
				Grid	344.84		Bedding vs plastic	0.0001
				Plastic	347.10		Grid vs plastic	0.2073
	Night	27.37	0.0001	Bedding	378.00	11.57	Bedding vs grid	0.0001
				Grid	385.86		Bedding vs plastic	0.0001
				Plastic	392.41		Grid vs plastic	0.0008
Body temperature	Day	111.58	0.0001	Bedding	37.90	0.10	Bedding vs grid	0.0001
				Grid	37.93		Bedding vs plastic	0.0001
				Plastic	37.84		Grid vs plastic	0.0001
	Night	90.77	0.0001	Bedding	37.93	0.10	Bedding vs grid	0.1145
				Grid	37.94		Bedding vs plastic	0.0001
				Plastic	37.83		Grid vs plastic	0.0001

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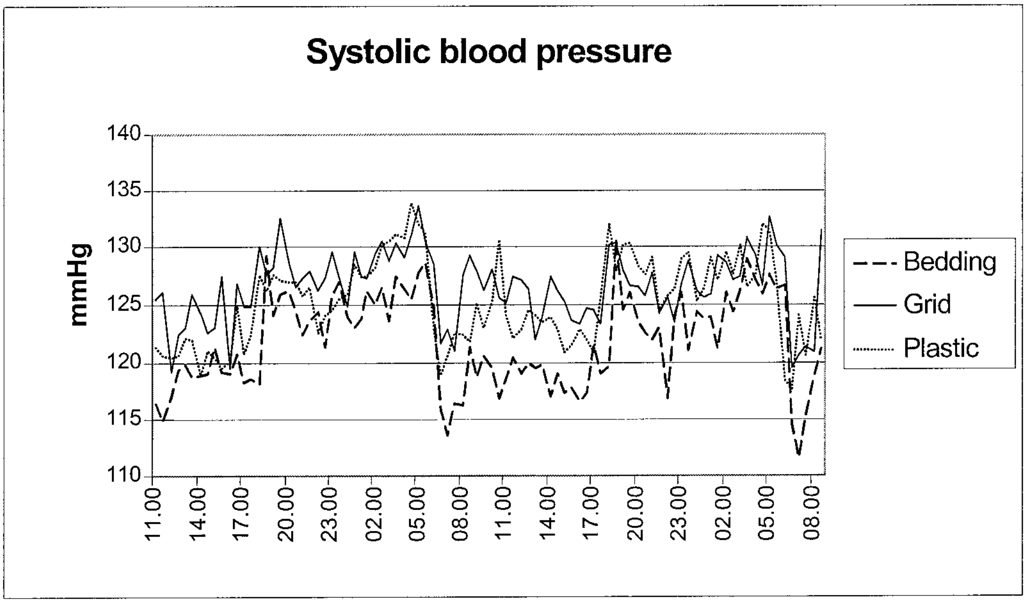


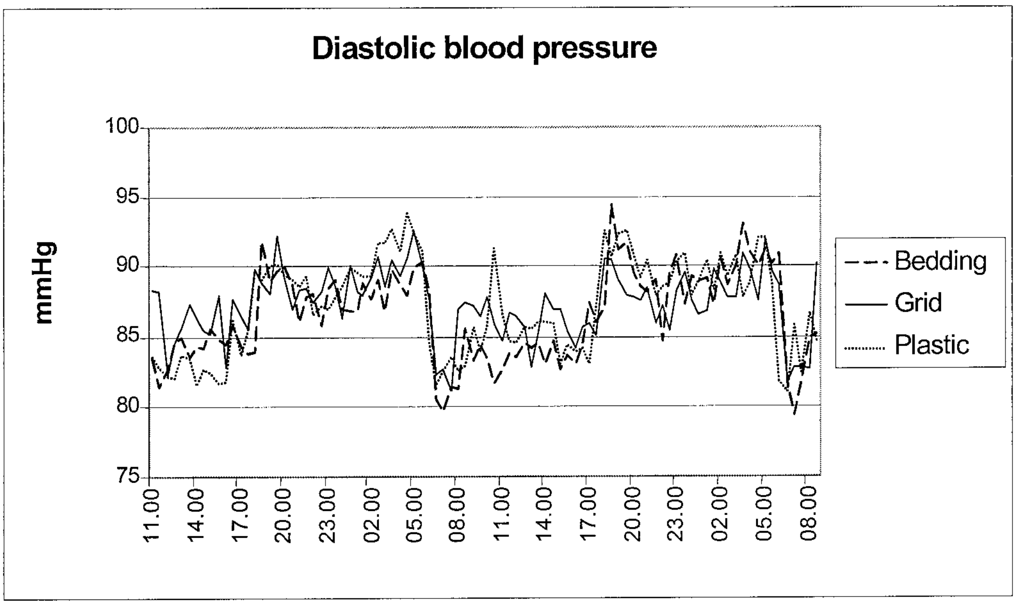
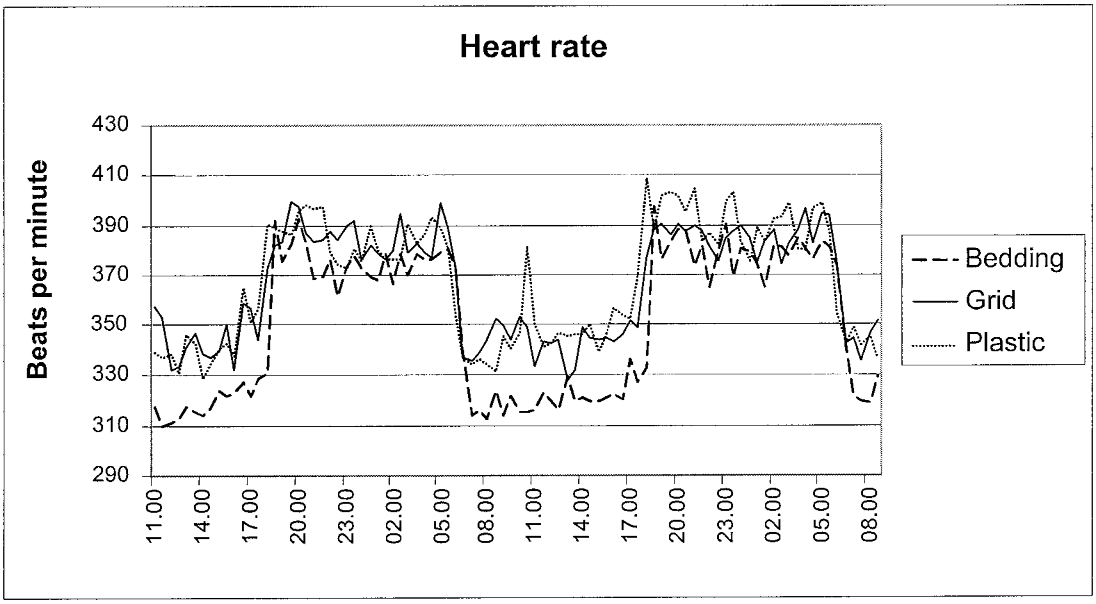


Figure 1 **Systolic and diastolic blood pressures of female Mol:SPRD rats housed on three different types of flooring (bedding, grid and plastic) during a 46 h period.**



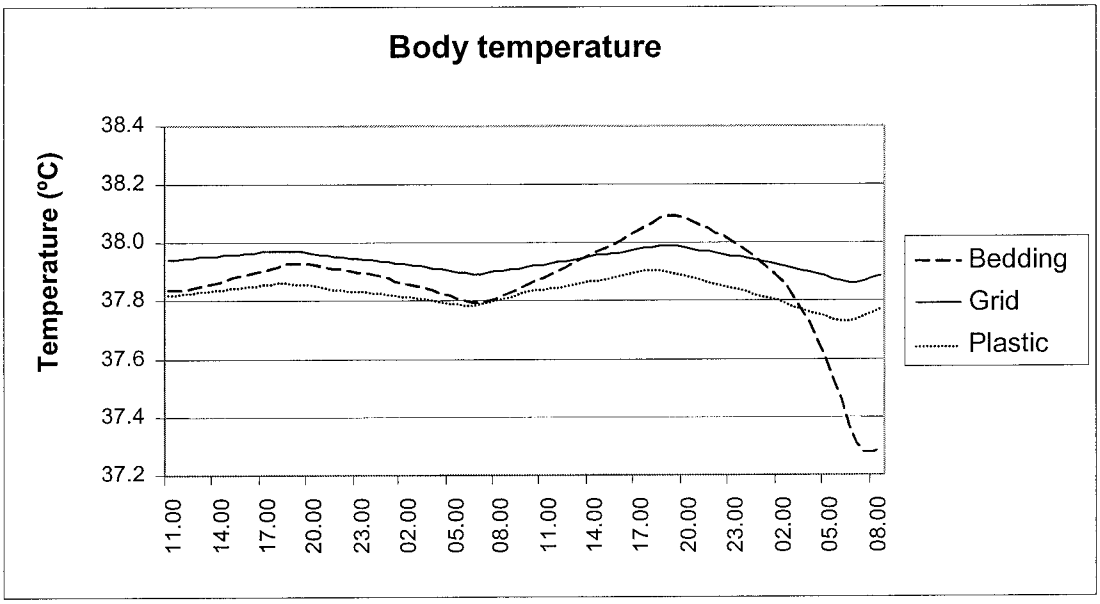


Figure 2 **Heart rate and body temperature of female Mol:SPRD rats housed on three different types of flooring (bedding, grid and plastic) during a 46 h period.**

Study 2

Study 2 confirms the results from study 1: significant increases in systolic blood pressure and heart rate were observed when the animals were housed on grid floors compared with bedding (Table 2, Figure 3). No significant changes in systolic blood pressure or heart rate developed between days 1–2 and days 11–12 for any of the floor conditions ($P > 0.05$).

Figure 3 and Table 2 show that when the rats are shifted from bedding to grid floors, an increase in both systolic blood pressure and heart rate is observed, similar to the observations in study 1 (see Figures 1 and 2). Conversely, shifting from grid floors to bedding induced a decrease in the heart rate; however, the systolic blood pressure remained elevated in these rats.

Table 2 Statistical analysis of two physiological daytime parameters (systolic blood pressure and heart rate) from female Mol:SPRD rats switched from bedding to grid floors and vice versa after 21 days.

Parameters	Comparison	Previous housing	*F*-value	*P*-value	LSMean	
Systolic blood pressure	Bedding vs grid	Both on bedding	30.31	0.0001	Bedding	114.8
					Grid	126.1
	Bedding vs grid	Bedding group previously on grid; grid group on bedding	0.00	0.9639	Bedding	122.4
					Grid	122.3
	Bedding → grid	—	219.08	0.0001	Bedding	114.8
					Grid	122.3
	Grid → bedding	—	93.63	0.0001	Bedding	122.4
					Grid	126.1
Heart rate	Bedding vs grid	Both on bedding	35.28	0.0001	Bedding	333.0
					Grid	358.4
	Bedding vs grid	Bedding group previously on grid; grid group on bedding	94.03	0.0001	Bedding	327.8
					Grid	364.3
	Bedding → grid	—	386.97	0.0001	Bedding	333.0
					Grid	364.3
	Grid → bedding	—	370.07	0.0001	Bedding	327.8
					Grid	358.4

Discussion

The results from our study complement those of earlier studies comparing different flooring for rats. The results clearly show that, using telemetry, it is possible to register the different impacts on animals when they are challenged with different situations.

Our study may be interpreted as showing that housing rats on bedding is less stressful than housing them on either plastic or grid flooring, because the rats showed elevated blood pressure and heart rate when housed on grids (Tables 1 and 2). This is analogous to findings from preference studies, which show that rats prefer bedding to grid flooring (Blom 1993; Manser *et al* 1995). Study 2 shows that the physiological effects of shifting the rats from bedding to grid floors are more than just novelty effects, as the heart rate drops again when the rats are shifted back from grid floors to bedding. However, it is important to emphasise that the telemetric data alone cannot be used to draw the conclusion that housing on grid floors is stressful, although this may be supported by the conclusions of previous preference studies (Blom 1993). Welfare assessment needs to be based upon several studies that use various monitoring methods. In this study, factors other than stress may influence the telemetric results. For instance, the body temperature differences registered between the

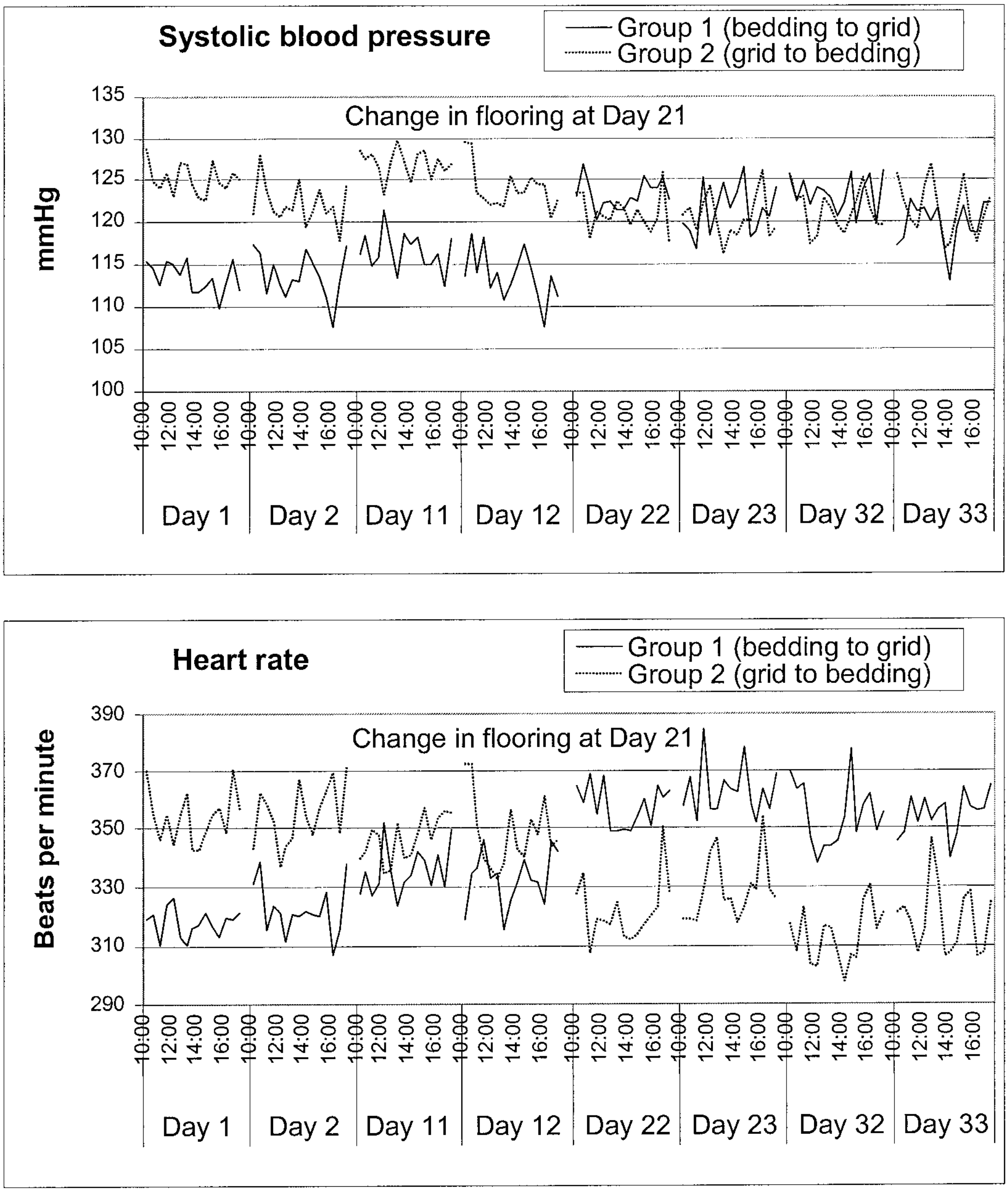


Figure 3 **Systolic blood pressure and heart rate in rats shifted on day 21 from bedding to grid floors, or vice versa. For each day the results shown derive from the period 1000h–1730h.**

different housing conditions (Figure 2) are more likely to result from their different insulation properties than from a stress reaction, as different flooring types show differences in the exchange of heat between the animals and their surroundings. The drop in temperature seen for the rats housed on bedding at the end of the second night-period is probably attributable to the sexual cycling of the female rats (Figure 2) and, therefore, totally unrelated to the different housing conditions.

The continued elevation of the systolic blood pressure in study 2 suggests that the physiological impact of housing on grids is complex and long-lasting. Continuously elevated systolic blood pressure is also seen in male rats defeated in social challenges with other male rats (Fokkema *et al* 1995). Daytime heart rate and daytime systolic blood pressure seem to be the most usable parameters, as the largest differences were observed in these variables. As the rat is a nocturnal animal (Batchelor 1994), the primary resting period is during the daytime. The results could, therefore, indicate that the rats are stressed when attempting to rest on flooring that they find unpleasant. This theory is supported by the fact that rats prefer resting on bedding to resting on wire mesh (Manser *et al* 1995).

As shown in Figures 1 and 2, blood pressure, heart rate and body temperature, in accordance with previous studies in both rats and rabbits (Batchelor 1994), follow a diurnal rhythm (van den Buuse 1994; van den Buuse & Malpas 1997). This has to be taken into account when analysing telemetric measurements. As can be seen from Figure 3, the impact of flooring on the physiological parameters remains stable over time, as no differences between the values at days 1–2 and at days 11–12 were observed.

Animal welfare implications

Our results show that telemetric measures are useful for registering the impact of different housing conditions on rats. Physiological reactions were clearly observable and were in accordance with observations from previous behavioural studies. Moreover, the results confirm previous results from preference studies and behavioural studies, and thereby indicate that telemetry is a useful method for measuring impacts on the animals' welfare. Systolic blood pressure and heart rate seem to be the most usable parameters, and daytime data give the clearest results. Our results do not indicate the occurrence of any adaptation to the flooring conditions over the two-week observation period. Our results, in combination with the results of previous preference studies of housing conditions (Blom 1993), indicate that grid floors are less attractive and more stressful for rats than bedding; however, further studies would be needed to confirm such a conclusion. These studies might include alternative monitoring methods, as well as the use of anxiolytic and stress-reducing drugs in combination with telemetry.

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