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Original Research

Are Investigators Aware of Environmental Noise in Animal Facilities and That This Noise May Affect Experimental Data?

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Control of environmental factors, such as noise, in animal facilities is important to ensure that research animals respond consistently to experimental procedures and that experimental results are not confounded by outside influences. A survey of personnel involved with animal facilities (173 respondents) showed that almost all agreed with this statement. However, 48% thought that one or more environmental factors in their facilities could be stressing the animals, and a majority of respondents reported generation of audible noise from people (72% of respondents), fans (61%), and squeaky carts (56%). The presence of these noises was correlated with the perception of noise as a problem because of its psychologic and physiologic effects on the animals. The amount of time respondents spent in the facilities was strongly correlated with their perception of noise as a problem, with veterinarians spending the most time and perceiving the most problems, and professors and assistant/associate professors spending the least and perceiving the fewest. Therefore, they may lack key knowledge that can affect their research goals. In addition, because faculty are the least aware of noise as a potential problem but are primarily responsible for designing experiments, research involving animals may be confounded by noise as an unknown variable. This effect may lead to unnecessary numbers of animals being required to achieve statistical significance and possibly to erroneous interpretation of results. On the basis of the findings of this survey, we present recommendations for improving the environment, particularly for decreasing the noise level, in animal facilities.

Abbreviation: SPL, sound pressure level

In the United States, federal law mandates that institutional animal care and use committees monitor animal facilities within research institutions. To do this effectively, the members of these committees and other inspectors must be knowledgeable regarding the effects of environmental issues in research facilities. Although laboratory animals may not lack essential physical needs such as food and water, other environmental perturbations in animal facilities can contribute significantly to stress. For example, moving an animal to a new cage leads to increases in blood pressure, heart rate, and locomotor behavior.[11] Noise and vibration due to building construction have caused marked problems with behavioral studies in rats.[8] For example, one study in rats[18] showed that during construction, glucose absorption by the intestinal transporter GLUT2 was reduced. Noise from personnel activity in the animal facility leads to increased microvascular permeability and disruption of the intestinal epithelium in rats.[2,21,22] The banging of metal cages in animal rooms can produce sound levels of up to 73 dB sound pressure level (SPL) and results in a 100% to 200% increase in plasma corticosterone.[3] Therefore, noise can alter the physiology of an animal and introduce an uncontrolled experimental variable that may influence the validity of the experiment. As stated by Poole,[14] "To avoid confounding variables, experimental animals should have both normal physiology and behavior."

To complicate matters even further, the effects of noise levels on the inhabitants of laboratory animal facilities are determined partly by species and strain. Several inbred mouse strains often used in research experience a genetically determined, progressive hearing loss that can lead to further alterations in other parts of the body, as well as behavioral changes.[19] These mice will react differently from mice that are not hearing impaired when exposed to the same environmental noises. Occasionally, exposure to noise can improve certain functions. For example, rats exposed to noise of moderate intensity (70 dB SPL) showed fewer errors than did unexposed rats when navigating a complex maze.[15] However, louder noise (100 dB SPL) increases norepinephrine in the adrenal medulla.[9] The ways in which animals respond to different noises depends not only on the noise itself but also on the subjects.[20]

The latest edition of the *Guide for the Care and Use of Laboratory Animals*[12] recommends that noise control should be considered in facility design and operation. To the greatest extent possible, activities that might be noisy should be conducted in rooms or areas separate from those used for housing animals. In addition, the *Guide* suggests that excessive and intermittent noise can be minimized by training personnel in alternatives to practices that produce noise and by the use of cushioned castors and bumpers on carts, trucks, and racks. However, the degree to which these particular recommendations are followed is unknown.

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First, when animal facilities are inspected by the Association for Assessment and Accreditation of Laboratory Animal Care International, the site visitors do not measure noise levels in the facilities. Second, personnel activity may be minimized during scheduled site visits. In addition, the recommendations of the *Guide* for noise levels may not be adequate to protect research animals. Although the *Guide* specifies a value of 85 dB SPL as the maximum allowable noise level, noise intensities as low as 73 dB SPL can significantly increase the concentration of stress hormones in the plasma of rodents.[3,5]

A previous pilot study survey conducted by one of the present authors,[10] with 29 respondents of 49 persons surveyed, indicated that although stringent recommendations for research animal housing were published decades ago by Anthony[1] and Riley,[16] these instructions, particularly with regard to noise, frequently are ignored by managers of animal facilities in the United States. The pilot study, although small, demonstrated a lack of awareness among research investigators, animal care staff, and inspectors regarding the negative effects of noise on laboratory animals and the importance of reducing noise levels.

We therefore conducted a more extensive survey (173 respondents) to validate the pilot study with a larger data set and to distinguish between the attitudes and observations of different categories of animal facility users. In this second survey, the respondents were questioned about conditions in the facility in general and whether they believed that environmental conditions in the facility could affect the physiology of the animals. Their replies (Table 1) were sorted according to job title (Table 2) and qualifications (Table 3). Other issues addressed by the survey included potential problems, such as faulty ventilation, diseases in animals, and loss of breeding colonies, and how these problems affected research outcomes. In addition, questions were included to gain information about cage density, location of cages with respect to cage washers, and frequency of animal–human interactions. Typically the survey took between 15 and 20 min to complete. The complete survey, along with representative comments (both positive and negative) by respondents, is available from the corresponding author upon request.

Purpose of Survey

The first objective of the survey was to identify correlation between the job title of a respondent and the respondent's level of awareness of potentially negative environmental conditions in the animal facilities. A component of this first objective was to establish whether a respondent considers that problems with excessive noise exist. To assess the relevance of a respondent's perception of a noise problem to the animals, survey participants were also questioned about the behavior of their animals. The second objective of the survey was to identify correlation between the job title of a respondent and the respondent's level of awareness that environmental stress in animal facilities can affect the physiology and psychology of research animals and their responses to experimental protocols.

The results of the survey are presented in the form of statements relating to each of the 2 objectives. Each statement is supported by the number(s) of the pertinent survey question(s) from which the result was obtained. Statements referring to each specific personnel category were derived after analyzing the group as a whole, and exceptions occurred within categories.

Design of Survey

Personnel were categorized according to job title and qualifications according to the following choices: 1) Job titles: Professor, Assistant/Associate Professor, Veterinarian, Research Specialist, Laboratory Technician, Animal Technician; 2) Qualifications: PhD, MD, DVM, MS, BS, other.

To address the first objective (determining the correlation between a respondent's job title and his or her level of awareness of potentially negative environmental conditions in the animal facilities), respondents were asked how much time they spent in the facility per week and how frequently they entered the facility. They also were asked to rate their facility in terms of its spaciousness, quietness, and cleanliness and lack of odor and to indicate how often they encountered problems with disease, animal housing, loss of breeding colonies, noise (emanating from various sources), and ventilation. In addition, participants were asked to estimate the degree of personnel activity in the facility in terms of the number of times per day people entered and left the animal room(s) and the number of different people, on average, who encountered their animals in a given day. Regarding animal behavior, respondents were also asked to note the types of behaviors that were typical of their experimental animals and to assess the usual demeanor of their animals when being observed.

To address the second objective (determining the correlation between a respondent's job title and his or her awareness of the potential effect of environmental stress in animal facilities on the physiology and psychology of research animals), respondents were asked whether they thought that the factors they perceived as problems (if any) affected the outcomes of the research in which the animals were used. Next, the respondents were asked to what extent they agreed with statements suggesting that certain environmental conditions could produce physiologic changes (or stress responses) in the animals and whether they agreed that stress in research animals affects the outcome of the research. Finally, the respondents were asked whether any factor in their animal facility or the animal housing conditions might be contributing to stress in the animals.

The survey was designed short and simple to maximize the likelihood that recipients of the survey would respond. As a result, compromises regarding the number and depth of questions were necessary. For example, the questions relating to animal behavior do not include all types of behavior for all species. The questions in the survey reflect the fact that about 90% of research animals are rodents.[3] Despite the need to keep the survey short, some 'filler' questions were included to allay any suspicions of the respondents regarding our own opinions and biases and thus to encourage respondents to be forthcoming regarding their beliefs and attitudes. The survey questions that were used in the analysis are included in Table 1.

Survey Recipients

The survey was mailed to 75 members of the Scientists' Center for Animal Welfare, 65 members of the Society for the Neural Control of Movement, and 51 members of The Microcirculatory Society. Members of the various societies were selected according to the likelihood that they worked with research animals. The return rate for mailed surveys was 70%. In addition, the survey was posted on an Internet listserv, the Comparative Medicine list of the American Association for Laboratory Animal Science. However, few of the listserv subscribers replied, and so the bulk of the responses were derived from the mailed surveys.

Statistical Analysis

The survey data were entered question by question into an Excel (Microsoft, Redmond, WA) spreadsheet and converted to a Statistica for Windows (Circle Systems, Seattle, WA) spread-

Table 1. Responses to survey questions discussed in this article

Question no.	Summary of question text	Possible responses (no. respondents who selected the response)					
3	Respondent's job title	Professor (15)	Assistant/Associate Professor (34)	Veterinarian (24)	Research Specialist (14)	Laboratory Technician (19)	Animal Facility Technician (8)
		Other (57)					
4	Respondent's qualifications	PhD (53)	MS (13)	BS (40)	MD (5)	DVM (22)	Other (37)
5	Animals worked with	Cats/Dogs (50)	Rats/Mice (155)	Pigs/Monkeys (59)	Birds/Fish (34)	Other (77)	
8	Frequency at animal facility	Daily (79)	Almost daily (37)	Once weekly (34)	Once monthly (13)	Once every 6 months (0)	Never (0)
9	Time in facility each week	0–1 h (41)	2–4 h (33)	5+ h (91)			
11	Problems with animal housing	All the time (15)	Once monthly (25)	Once every 6 months (42)	Once yearly (35)	Never (49)	
11	Problems with noise	All the time (21)	Once monthly (20)	Once every 6 months (22)	Once yearly (31)	Never (73)	
12	Problems noted affected research?	Yes (71)	No (85)				
17	Entries into/ exits from animal room each day	Never (1)	Once daily (11)	Twice daily (32)	3–5 times daily (79)	6–10 times daily (21)	10+ times daily (23)
18	No. of people–animal interactions each week	None (0)	1 (4)	2 (37)	3 or 4 (103)	5–10 (26)	
20	Rate facility on good–bad continuum	Far left (61)	Left (69)	Center (33)	Right (3)	Far right (0)	
21	Noise-generators in facility	Fans and ventilators (105)	Doors (70)	People (123)	Carts (93)	Animals (52)	Cage washers (85)
22	Noise-generators in or near animal room	Ventilation fans (69)	Cage washers (39)	Fluorescent/ infrared lighting (86)	Oscilloscope (1)	Squeaky equipment (71)	Computing equipment (32)
		TV/video equipment (21)	Telephones (58)				
24	Behaviors typical of animals	Scratching (76)	Fighting (32)				
25	Environmental factors can contribute to physiologic changes in animals	Strongly agree (92)	Agree (69)	Don't know (6)	Disagree (2)	Strongly disagree (0)	
26	Environmental factors can be stressful to animals	Strongly agree (96)	Agree (65)	Don't know (5)	Disagree (3)	Strongly disagree (0)	
27	Artificial noise or sound in facility can contribute to physiologic changes in animals	Strongly agree (56)	Agree (64)	Don't know (36)	Disagree (13)	Strongly disagree (0)	
28	Artificial noise or sound in facility can be stressful to animals	Strongly agree (58)	Agree (71)	Don't know (27)	Disagree (10)	Strongly disagree (3)	
29	Laboratory animals are more likely to experience prolonged stress than are animals in the wild	Strongly agree (34)	Agree (57)	Don't know (34)	Disagree (35)	Strongly disagree (9)	
30	Stress in animals affects outcome of research	Strongly agree (69)	Agree (78)	Don't know (15)	Disagree (7)	Strongly disagree (0)	
31	Minor pain or stress causes physiologic changes in animals	Strongly agree (43)	Agree (87)	Don't know (27)	Disagree (9)	Strongly disagree (2)	
33	Rate general appearance of animals on calm–anxious continuum	Far left (64) (Calm)	Left (60)	Center (36)	Right (7)	Far right (2) (Anxious)	
34	Presence of stressor in animal facility	Yes (75)	No (81)				
35	Presence of stressor in animal housing conditions	Yes (63)	No (93)				

Table 2. Distribution of respondents with respect to job title

Title	No.
Professor	15
Assistant/Associate Professor	34
Veterinarian	24
Research Specialist	14
Laboratory Technician	19
Animal Technician	8
Other	57
Total	173

Table 3. Distribution of respondents with respect to qualifications

Degree	No.
PhD	53
MS	13
BS	40
MD	5
DVM	22
Other	37
Total	170

sheet for statistical analysis. Frequency tables were calculated, including means and percentages, for each question. Depending on the hypothesis examined, analyses of variance, chi-square tests, and correlation analyses were performed. For questions in which the answers consisted of a range of values (that is, 1 to 6), analysis was performed by one-way analysis of variance between groups. Those questions with binary responses (that is, yes or no) were analyzed using the chi-square test. Continuous variables were analyzed for correlations by use of the Pearson *r* correlation coefficient.

Results

The distributions of respondents with respect to job title and qualifications are shown in Tables 2 and 3, respectively. The following data address objective 1 (determining the correlation between a respondent's job title and his or her level of awareness of potentially negative environmental conditions in the animal facilities). The percentages of respondents who reported audible noise in their facility (question 21) generated by people (72%), fans (61%), squeaky carts (56%), and cage washers (49%) was significantly correlated with perceived problems with noise (questions 11 and 21; $P < 0.0005$, $P < 0.05$, $P < 0.007$, and $P < 0.05$, respectively). Job title and the number of noise sources reported were significantly correlated ($P < 0.00017$; questions 3 and 11; Table 4). Professors and assistant/associate professors reported fewer noise sources than did veterinarians and animal facility technicians. One possible reason for this difference is that professors and assistant/associate professors spend significantly less time in the animal facility ($P < 0.00001$) and go there less frequently ($P < 0.00001$; Figure 1) than do veterinarians and technical staff. Another possibility is that some professors and assistant/associate professors may fear that openly acknowledging that experimental conditions in their facility are suboptimal will devalue their published results. This concern could lead to 'social desirability' bias of the survey results and an underestimation of such problems.

Overall, 48% of respondents thought that one or more factors in their facility could cause stress to the animals, and the percentage varied significantly ($P < 0.05$) according to job title

Table 4. Average number of noise sources reported (maximum, 6) for each job title

Job Title	Average no. of noise sources reported	No. of respondents
Professor	1.93	15
Assistant/Associate Professor	2.20	34
Veterinarian	3.29	24
Research Specialist	3.79	14
Laboratory Technician	3.21	19
Animal Technician	4.38	8
Other	3.42	57

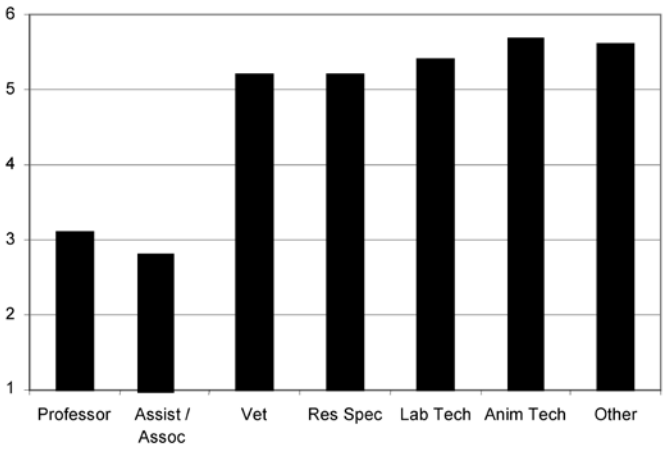

Figure 1. Histogram showing correlation of job title (Assist/Assoc, Assistant/Associate Professor; Vet, Veterinarian; Res Spec, Research Specialist; Lab Tech, Laboratory Technician; Anim Tech, Animal Facility Technician) with frequency of entry into animal facility (1, never; 2, once in 6 mo; 3, once a month; 4, almost every day; 5, daily).

(questions 3 and 34). Respondents' awareness of noise as a source for concern was similar to their awareness of the potential effect of other environmental variables. Professors and assistant/associate professors had less awareness that factors in the facility could stress their animals, whereas veterinarians and animal facility technicians showed greater awareness of environmental effects (Figure 2 A). A similar result was found regarding problems with animal housing (questions 3 and 35; $P < 0.05$; Figure 2 B). Positive answers to these questions did not necessarily mean that the respondent also believed that the problems would affect research outcomes. A relatively low percentage of faculty may perceive problems because they spend less time in the facility; the amount of time spent in the facility was significantly ($P < 0.05$) correlated with the probability that respondents perceive problems concerning noise (questions 8, 9, and 11). Therefore although 62% of respondents did not report problems with noise (126 of 167 responses to 11), some of these respondents were perhaps unaware of the noise problems because they rarely entered the facility or did not believe that the 'normal' background noise in their facility could present a problem.

The number of respondents who described their animals as having a calm demeanor (question 33) was negatively correlated with perceived problems with noise (question 11; $P < 0.000001$) and with animal facilities that were evaluated as more noisy (question 20; $P < 0.0005$). Respondents who rated their facilities as noisier (question 20) reported a higher frequency of 2 particular types of animal behaviors (question 24): scratching ($P < 0.005$) and fighting ($P < 0.008$). These behaviors may be associated with stress.[15] Significantly ($P < 0.05$) more of the

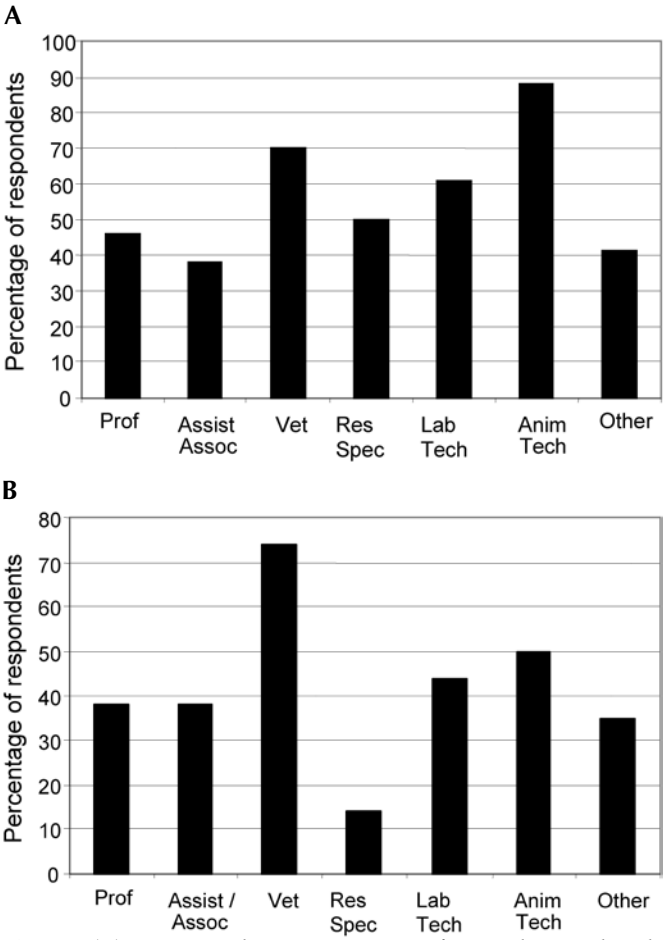

Figure 2. (A) Histogram showing percentage of respondents with each job title who believe environmental factors in their animal facilities cause stress to the animals that are housed there (question 34). (B) Histogram showing percentage of respondents with each job title who believe that housing factors are present that cause stress to the animals (question 35). Prof, Professor; Assist/Assoc, Assistant/Associate Professor; Vet, Veterinarian; Res Spec, Research Specialist; Lab Tech, Laboratory Technician; Anim Tech, Animal Facility Technician.

veterinarians (50%), laboratory technicians (53%) and research specialists (64%) reported scratching than did the professors (27%) and assistant/associate professors (21%; questions 3 and 24). Again, this result may be related to the amount of time people with each of the job titles spend in the animal facility, as the actual principal investigators observe their animals for the least amount of time. The percentage of respondents reporting scratching was significantly ($P < 0.05$) correlated with the number of different people, on average, who entered the animal room and encountered the animals each day (questions 3 and 24; 32% for 2 people, 40% for 3 to 4 people, and 69% for 5 to 10 people).

Regarding results of the survey pertinent to objective 2 (determining the correlation between a respondent's job title and his or her awareness of the potential effect of environmental stress in animal facilities on the physiology and psychology of research animals), there was no correlation between how frequently people entered the animal facility (Table 1, question 8), how much time they spent there (question 9), or whether they thought that the factors they perceived as problems (question 11) affected the research outcomes (question 12). About half of the people in each job title group answered 'Yes' to question 12, with the exception of laboratory technicians (16%; Table 5). In addition most respondents (regardless of job title; Table 6) agreed or strongly agreed that noise and housing conditions can affect animal physiology or cause stress (questions 25 to 28). In all cases, the veterinarians showed the strongest agreement. Similarly, job title did not significantly affect the belief that stress in research animals affects experimental outcomes (question 30) or that minor pain or stress affects animal physiology (question 31); most respondents agreed with the first statement and agreed with or did not know about the second (Table 6).

Table 5. Percentage of respondents of each job title who felt that problems with environmental factors (question 11) affected the outcome of research (question 12)

Job title	No. (%) of respondents who said problems affected research outcome
Professor	14 (43)
Assistant/Associate Professor	34 (50)
Veterinarian	22 (59)
Research Specialist	14 (57)
Laboratory Technician	19 (16)
Animal Facility Technician	6 (50)
Other	53 (45)

Discussion

An important finding of this survey is that although most respondents agreed in theory with the statement "stress in research animals affects experimental outcomes," as many as half of the participants did not think that the problems they encountered in their particular facility would affect research outcomes. This result is inconsistent with the number of noise sources in animal facilities reported in this survey (question 21). Such noise sources can adversely affect animal physiology.[2,21,22] A possible explanation for this dichotomy is that until fairly recently, little was known about the physiologic and psychologic effects of noise on animals (and even humans). Veterinarians and technical staff (Research Specialists, Laboratory Technicians, and Animal Facility Technicians) who answered the survey spend the most time in the animal facilities and reported the greatest number of problems and potential stressors. However, laboratory technicians, who often act as the link between faculty and husbandry technicians, are the least aware that environmental problems can affect research outcomes (Table 5). Because the research personnel are the least informed, important information about the environmental conditions in the facilities may not be communicated to professors and assistant/associate professors; therefore they may lack key information that is vital for accomplishing their research goals. Even as long ago as 1980, Brede[4] recognized the same problem regarding lack of communication between technical staff and academicians, although he had no data to support his claim.

Summary and Recommendations

In 1981, Riley[16] recommended that elimination of animal room vibrations and the high-pitched sounds of ventilation fans and noisy laboratory or building equipment was essential for low-stress animal housing. Peterson,[13] in 1980, recommended that care be taken to minimize the noise of cage washers and air conditioning ducts in animal facilities. Finally, the *Guide for the Care and Use of Laboratory Animals*[12] recommends that noise control should be considered in facility design and operation. Reasonable attempts should be made to control variables most likely to interfere with the work in progress.[7] For example, installation of readily available industrial and architectural acoustical panels can reduce noise levels in an animal facility

Table 6. Average scores of answers to questions 25 through 28

Job title	25	26	27	28	No. of respondents
Professor	1.69	1.46	2.00	2.00	13
Assist/Associate Professor	1.56	1.61	2.33	2.12	33
Veterinarian	1.30	1.25	1.58	1.71	24
Research Specialist	1.71	1.57	2.14	1.93	14
Laboratory Technician	1.56	1.50	2.00	2.05	18
Animal Facility Technician	1.38	1.63	1.88	2.00	8
Other	1.49	1.52	2.07	2.04	57

Scores: 1, strongly agree; 2, agree; 3, don't know; 4, disagree; 5, strongly disagree.

by as much as 15 dB.[6] Electronic noise-canceling equipment is now available, and the cost of this technology is becoming more reasonable. Animal research facilities are a prime site for the installation of such systems.

Principal investigators with research animal programs should receive data on environmental stressors, including noise, in the rooms in which their animals are housed, in much the same way as the results of tests for diseases are often disseminated. Continuous tracking of noteworthy changes in noise, temperature, air flow, and light intensities can be added to facility monitoring, enabling implementation of remedial actions within hours or days. Such records also can be made available during site visits.

Husbandry and laboratory technicians should be aware that noise sources they encounter (or produce) may affect animals and thus confound research outcomes. These personnel also must perform their duties quietly and report noisy incidents, either acute or chronic, to their supervisors and principal investigators. Even the jangling of keys can disturb rodents and produce variable alterations in their physiology. Riley,[16] who demonstrated that mice in conventional animal facilities had plasma corticosterone values more than 10 times greater than those of mice in special 'low-stress' housing, stated that "few technicians or research scientists are good judges of moderate stress." At present, little formal training is required for animal caretakers and animal technicians in universities in the United States as evidenced by the somewhat low level of necessary qualifications described in advertisements for these posts. Although the American Association for Laboratory Animal Science operates animal technician education programs, little (if any) emphasis is placed on the deleterious effects of noise on the validity of data obtained from experimental animals. Such information should be a required component of institutionally conducted training courses that are required prior to working with animals.

This survey has shown that faculty spend the least amount of time in the animal facilities and are not highly aware of potential environmental problems therein. Increased interaction between faculty and veterinarians might allow veterinarians to better inform investigators about factors that might be important to research outcomes.

In summary, a constant, reproducible environment in the typical university animal facility will help to minimize some of the physiologic variations of animals in those facilities. This improvement will benefit principal investigators and the scientific community in 2 ways. First, it may reduce the number of animals required for each experiment, a goal that is consistent with the "Three Rs" concept of Russell and Burch[17] and that is promoted by institutional animal care and use committees worldwide. Second, if facilities are built and operated in a manner to reduce noise levels to below their current status, the confounding effects of uncontrolled variables on experimental data will be minimized, thus improving the quality of the science practiced by principal investigators.

Acknowledgments

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