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Animal Stress Due to Noise and Vibration

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Abstract

Studies have conclusively shown that noise and vibration can adversely affect breeding in laboratory mice and other common research animals. The misperception of the main factors that cause startle and distress in these animals is largely due to our complete lack of awareness of the various phenomenon. Stressors, inaudible to lab personnel, influence the behavior of animals in a myriad of facets and directions. Thus, the design phase of an animal holding facility should recognize potential sources of animal stressors, and how integrating long-term monitoring strategies may maintain or maximize healthy pup yield and minimize behavior changes resulting from stress. The benefits of long-term monitoring include more than animal health, behavior and breeding, but also elevate the productivity of research studies and facility operations, with less down-time.

Key words: Vibration, Ultrasonics, Stress, Animal behavior, Breeding, Laboratory Design, Research Environments.

Стресс животных из-за шума и вибрации

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Аннотация

Исследования убедительно показали, что шум и вибрация могут негативно влиять на размножение лабораторных мышей и других распространенных исследовательских животных. Непонимание факторов, вызывающих испуг и страдания у этих животных, во многом объясняется нашим полным отсутствием восприятия этого явления. На этапе проектирования потенциального центра содержания животных следует распознавать потенциальные источники вибрации, слышимого звука или ультразвуковых нарушений и использовать долгосрочный мониторинг, чтобы максимально увеличить появление здорового потомства и свести к минимуму изменения в поведении животных. К преимуществам долгосрочного мониторинга также относятся более продуктивные исследования и эксплуатация оборудования, а также сокращение времени простоя.

Ключевые слова: *Вибрация, ультразвук, стресс, поведение животных, разведение, лабораторное проектирование, исследовательская среда***.**

Introduction

Studies have conclusively shown that audible stressors and vibration can adversely affect behavior and breeding in laboratory mice and the problem is reportedly widespread [1, 2]. New technologies, introduced constantly in the laboratory environment, emit high frequency signals either as a function of their operation or a byproduct of such. Investigators, facility managers, and other professionals working with laboratory mice in medical research facilities are aware that genetic research with transgenic mice colonies can be seriously impacted when breeding performance declines. Efforts to maximize healthy pup yield and minimize costs through sound breeding management practices must also include stress control. Stress has long been understood to be one impediment to successful breeding. Sudden

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bursts of noise or vibration causing startle are possibly more harmful than some sustained or continuous vibrations. Low frequency building vibrations and ultrasonic sounds are far below and above human detection, leading to the key misunderstanding of the effect of these signals on rodents and small animals.

1. Vibration as a Stressor

Vibrations in holding rooms are known to shake the animal racking and caging equipment. As stressors, vibration sources may be continuous or random. Continuous exposure to vibrations can impose fatigue, behavioral disorders and sleep deficiency [1-6]. Random vibration occurrences have been known to invoke panic in mice whereby they cannibalize their pups when low frequency vibrations are suddenly perceived coming from under their bedding possibly sensing an intruder is approaching.

Vibrations can originate from the exterior of the building via ground-borne transmission or from concrete pavements that bridge the foundation of the building to surrounding streets. Through the foundation, these vibrations travel up columns and load bearing walls to upper levels where damping may not sufficiently mitigate slab vibrations. Traffic, subways, rail lines, and nearby construction are typical culprits of ground-borne vibration. Vibrations can also originate from inside the labs. Cage ventilation systems mounted directly on racks have been shown to cause much vibration and noise. Other vibration sources common to labs are exhaust hoods, refrigeration, elevators, base building HVAC fans, and other motor driven equipment [7].

Building trends have tended towards the use of lighter weight structures for reasons of cost and environmentally responsible design; however, these trends have exacerbated the transmission of vibration throughout buildings [8].

As a design consideration, slab on grade is optimum for labs and holding rooms. For labs on upper levels, spans between beams and slab bay thicknesses should be designed to mitigate any risk of slab resonance resulting from known or predicted forcing frequencies. HVAC fans, exhaust hoods, elevators, refrigeration and other motor driven equipment should be installed with vibration isolation strategies, but may also emit very high frequency noise, above human hearing.

2. Ultrasonic Sound as a Stressor

Ultrasonic sound pollution is rarely considered to be a stressor as normal hearing adults cannot perceive sounds above 20 kHz (fig. 1). Animals of prey, mice, rats, and other rodents have developed ultrasonic vocalization as a defensive adaptation. Rodents use their ultrasonic vocalization for short range communication; vocalization of this type is ideal for communicating in underground burrows, finding breeding mates, and most importantly, communicating threats to one another without detection.

Mice hear between the frequencies of 1 kHz and 90 kHz (fig. 1). The frequency range where mice are the most sensitive to sounds is between 5 kHz and 50 kHz, and mice vocalize between 16 kHz and 35 kHz. As a comparison, the human hearing range is between 20-20,000 Hz. When ultrasonic sound in a lab intrudes in the vocalization range of mice, there is concern that the resulting stress may affect breeding [2, 9-11].

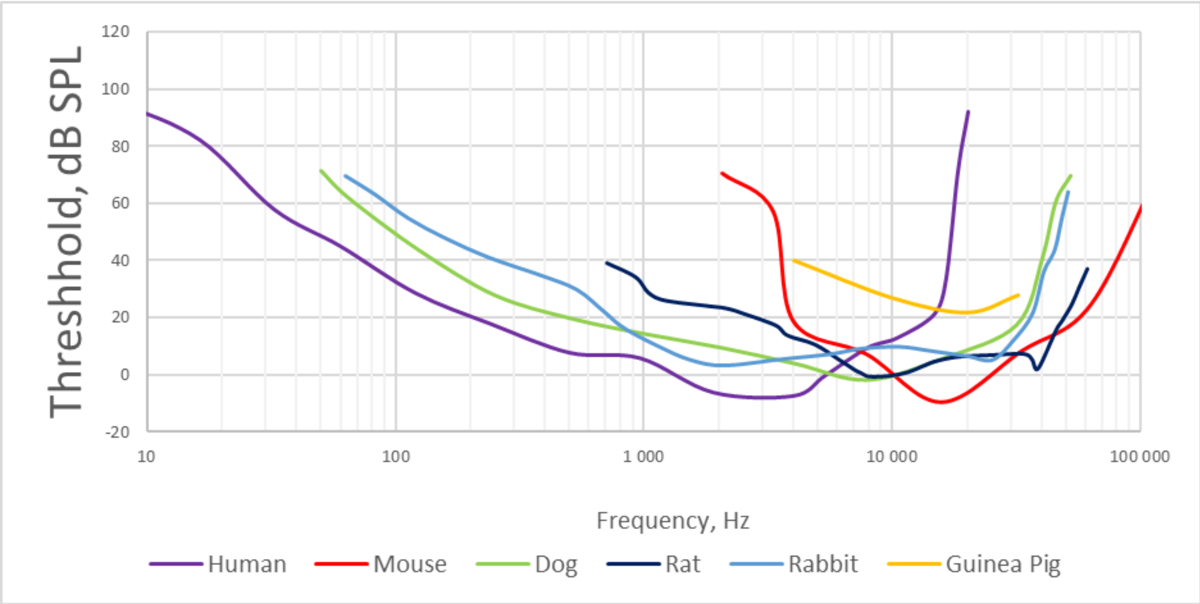

Fig. 1. Auditory thresholds for various mammals commonly found in research applications

The level of stress caused by ultrasonic sound may relate to the actual peak level above the ambient sound levels at these ultrasonic frequencies. As related to human hearing, a squeal can easily be perceived within ambient noise, but becomes a potentially unsettling distraction when the level of the squeal rises significantly above the ambient noise. It is not uncommon to measure ultrasonic noise 10 dB or more above the ultrasonic ambient sound in mice holding rooms. Stress also results from startle due to sudden onset or extended duration of a distraction noise. Humans generally adapt to ambient sounds (acclimation) but this has not been widely studied in rodents in the ultrasonic range from 20 kHz to 90 kHz.

There are many sources of ultrasonic sound in a lab environment including motors, fans, microprocessors and sensors [1, 10, 12]. Artifacts resulting from any size motor driven equipment, from small fans in computers to larger ventilation fans and exhaust hoods, commonly generate some level of ultrasonic sound due to friction from lack of lubrication, rubbing, scraping or skidding of rolling elements against a bearing raceway, mechanical flaws or a contaminated in the lubricant. Many sensors function by producing ultrasonic sound, such as motion detectors for automatic door openers or lighting on/off controls, particulate detection, fluid flow sensors as well as cell phones, monitors and CPUs [1, 10, 12].

As a design recommendation concerning ultrasonic noise pollution, where possible, locate all motors, fans, computers and sensors that employ ultrasonics outside of holding rooms and access hallways [1, 10, 12]. Testing to provide normal operating ultrasonic levels produced by systems and equipment can provide a baseline stressor risk assessment for all spaces where animals are held. Testing should include hallways outside holding and procedure rooms. Ultrasonic motion detectors located outside holding rooms can be heard by animals when holding doors are open.

3. Monitoring for Sound, Ultrasonics, and Vibration

There are many ways to detect and monitor levels of ultrasonic sound and low frequency vibrations. As discussed above, we as humans cannot detect very low frequency vibrations or any levels of ultrasonic sound, which is why conformance monitoring in labs is highly useful. Testing for conformance has become the de facto starting point for protecting animals against stress and sustaining breeding performance, thus removing stress-related behavioral change as a research variable.

A short-term monitoring survey of actual conditions and the testing of equipment provides a baseline. Long-term monitoring of labs, holding and procedure rooms provides continuous awareness to any change in the environment due to new building or research equipment, changes to procedures or personnel work habits; and construction activity interior or exterior to the building. As an example, maintenance to the ventilation systems and exhaust hoods, or general wear over time, can cause an increase in vibration and ultrasonic sound that would not be detected otherwise.

Data from continuous monitoring can be archived and retrieved and correlated with any problem laboratories may have with breeding in specific rooms. It is a highly useful tool for lab managers and personnel to have access to.

Conclusion

Changes in ultrasonic noise and structure-borne vibration appear intermittently and remain unnoticed by all lab personnel. Continuous monitoring provides alerts while data is archived for future review. The opportunity to correlate environmental changes to animal behavioral changes allows additional controls for research. Another advantage of long-term monitoring is proactive control of invisible stressors, avoiding error while increasing the animals' well-being as well as the quality of research.

References

1. Faith R., Miller S., The Need for Sound and Vibration Standards in U.S. Research Animal Rooms, Animal LAB NEWS, July/August, 2007 http://documents.allentowninc.com/ALN-sound%20and%20vibration%20Dr.%20faith%20SM%20-july-aug%202007.pdf

2. Glickman G., Bensing S., Carmanc R., Characterizing Ambient Noise and Vibration in Facilities Designed for Laboratory Animal Research, NOISE-CON 2011 Portland, Oregon, 2011 July 25-27 https://www.researchgate.net/publication/269105829

3. Guide for the care and use of laboratory animals, Eight Edition, National Research Council, Washington, D.C., 20116 pages 50, 142, 149 https://grants.nih.gov/grants/olaw/guide-for-the-care-and-use-of-laboratory-animals.pdf

4. Atanasov N.A., Sargent J.L., Parmigiani J.P., Palme R., Diggs H.E. Characterization of Train-Induced Vibration and its Effect on Fecal Corticosterone Metabolites in Mice, Journal of the American Association for Laboratory Animal Science Vol 54, No 6, 2015, Pages 737–744 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4671789

5. Reynolds R., Li Y., Garner A., Norton J. Vibration in mice: A review of comparative effects and use in translational research, Animal Model Exp Med. 2018;1:116–124. https://www.researchgate.net/publication/326673877_Vibration_in_mice_A_review_of_comparative_effects_and_use_in_translational_research

6. Papadimos C., Gorton A., Wowk R. Acoustic and vibration considerations for animal research facilities: planning through construction, ALN Magazine, (2010). https://www.laboratoryequipment.com/article/2010/06/acoustic-and-vibration-considerations-animal-research-facilities-planning-through

7. Neil D., McKay D. Canadian council on animal care guidelines on: laboratory animal facilities – characteristics, design and development, Canadian Council on Animal Care, 2003, ISBN 0-919087-41-8

https://www.ccac.ca/Documents/Standards/Guidelines/Facilities.pdf

8. Nguyen T., Gad E., Wilson J., Lythgo N., Haritos N. Evaluation of footfall induced vibration in building floor, Australian Earthquake Engineering Society 2011 Conference, 18-20 November, Barossa Valley, South Australia

https://www.researchgate.net/publication/264890682_Evaluation_of_footfall_induced_vibration_in_building_floor

9. Jafari Z., Faraji J., Mirza Agha B., Metz G.A.S., Kolb B.E., Mohajerani M.H. The Adverse Effects of Auditory Stress on Mouse Uterus Receptivity and Behaviour, Scientific Reports volume 7, Article number: 4720, 2017.

10. Zoontjens, L., Notes on the acoustical design of animal holding rooms within medical research facilities, Australian Acoustical Society: Proceedings of Acoustics 2012-Fremantle, 81.

https://www.acoustics.asn.au/conference_proceedings/AAS2012/papers/p81.pdf

11. Reynolds R.P., Kinard W.L., Degraff J.J., Leverage N., Norton J.N., Noise in a laboratory animal facility from the human and mouse perspectives, Journal of the American Association for the Laboratory Animal Science: JAALAS 49.5 (2010): 592-597. Print

12. Anderson M.D. Noise, vibration, and ultrasound design guide, CSTI RP 640., Rev. A, No. 33335-0-2000, 2010.

http://www2.mdanderson.org/depts/cpm/standards/supp_stds/MDACC_NoiseVibrationUltrasoundDG.pdf