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Introduction

Noise in Animal Facilities: Why it Matters

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Environmental noise can alter endocrine, reproductive and cardiovascular function, disturb sleep/wake cycles, and can mask normal communication between animals. These outcomes indicate that noise in the animal facility might have wide-ranging affects on animals, making what laboratory animals hear of consequence for all those who use animals in research, not just the hearing researcher. Given the wide-ranging effects of noise on laboratory animals, routine monitoring of noise in animal facilities would provide important information on the nature and stability of the animal environment. This special issue will highlight the need for more thorough monitoring and will serve as an introduction to noise and its various effects on animals.

Environmental variables such as lighting, temperature, humidity, and airborne particles are given considerable attention in lab animal facilities. Measurements are routinely taken to monitor these variables, and rigorous records are maintained. However, the acoustic environment is often given relatively little consideration. When it comes to noise in the animal facility, routine measurements are generally not taken, records are generally not maintained, and remarkably little is known by those of us who care for and use lab animals about how noise impacts our animals. The relative disparity between the attention given to noise as compared with other significant environmental variables in the facility is disconcerting given strong evidence showing that environmental noise can significantly impact a variety of systems in lab animals and humans.[69] In fact, considerable evidence now suggests that animal facilities present a more problematic acoustic environment for lab animals than previously thought.[7,60] The current special issue, "Noise in the Animal Facility," will attempt to outline the problem and provide valuable background information for investigators, facility managers, veterinarians and other personnel.

Normal development and functioning of a healthy hearing system is necessary for the use of spoken language in humans and communication via vocalizations in other animals. Without a healthy hearing system during the critical first 36 mo of life, a child will not develop the central neural pathways required for communicating with speech. In the absence of an alternate form of non-aural form of language, such as American Sign Language, the individual will forever remain apart from others of its species. Historical cases in which a young child has been raised in the complete absence of any form of communication are poignant reminders of the key importance of language and communication for human beings. The loss of hearing later in life, after acquisition of spoken language, while not as dramatic as a child deprived of language from birth, nevertheless has significant social, emotional, and economic costs for the individual. Hearing impairment negatively impacts behavior with economic significance, such as driving a motor vehicle, as well as degrading quality of life by removing the experience of music, the simple sounds of nature, or the voice of a loved one.

The 2 most common causes of acquired hearing loss in humans are aging and acoustic trauma. The prevalence of age-related hearing loss increases from 15% in the population of "baby-boomers" between ages 45 and 64, to 35% of adults age 65 to 75 and 50% of people age 75 and older. The National Institute of Deafness and Communication Disorders estimates that 30 million Americans of all ages are exposed to hazardous sound levels on a regular basis. While 28 million Americans have some degree of permanent hearing loss, nearly one-third of this group—10 million people—have hearing loss that is related, at least in part, to noise damage. Noise-induced hearing loss is the most preventable form of sensory disability.

Much of our understanding of the pathology of hearing loss is derived from animal studies of the effects of acoustic trauma on the peripheral and central auditory pathways. An important, but at times overlooked, advantage of studying the effects of acoustic trauma on a particular species or strain of laboratory animals is the ability to exert experimental control over an individual animal's sound-exposure history. Knowledge of the sound conditions to which our experimental subjects are exposed is crucial if we are to accurately characterize the events and understand the mechanisms that result in damage to the auditory system.

In addition to its central role in communication, a major function of auditory systems is to maintain an appropriate level of arousal for an animal.[50] Noise serves as a very effective trigger for arousal. There could be a variety of reasons for this. For example, noise allows animals to hear predators (or prey) in complete darkness from a great distance. In addition, the auditory system responds faster than other sensory systems, and its neural circuitry supports the rapid activation that characterizes fight or flight responses. As a result of the critical role of noise in animal communication and survival, it should not be surprising that noise can induce a wide variety of changes in animals. Noise can induce changes in a number of organ systems, and can in that manner potentially impact nearly every area of biomedical/behavioral research. These changes have been reviewed in detail elsewhere but Table 1 provides a summary of some of the non-auditory changes induced by noise.

The goal of the present special issue on Noise in the Animal Facility is to provide an overview of the important considerations related to noise in animal facilities. The topics discussed in

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Table 1. Some of the non-auditory effects of noise in laboratory animals and humans (adapted from 69)

Systems	Results	Reference
Cardiovascular	↑ BP in cat, rat, rhesus monkey, and macaque monkey; ↑ HR in desert mule deer and rat	15,40,71,44,56,57
	↑ in vasoconstriction in rat, ↑ respiratory rates and ACTH in cat, no Δ in BP in rat	49,9,10,48
	↑ BP, HR, arteriosclerosis, ischemic heart disease, hypertension, coronary artery disease in humans	47,55,73,42,35,66,19, 27,23,58
Hormonal/	↑ norepinepherine, cortisol, cholesterol, and plasma corticosterone in rat,	6,37,22,21,70,4,11,43
Biochemical	↑ IgM levels, splenic NK levels, ↓ splenic lymphatic proliferation and peripheral phagocytic activity in rat	
	↑ levels of norepinepherine, adrenaline, noradrenaline, catecholamines, corticosteroids in humans	
Reproductive	↓ in estrus in rat, ↓ fertility rates and ↑ weight of ovaries in both rats and rabbits	30,75,24,25,54,18,51,60,53
	↑ suckling of young in tree shrew, ↓ milk production in both dairy cattle and tree shrew	
	↑ in fetal mortality and resorption of pups in rat, rabbit, chick and pig	
	irregular menstruations, ↓ in birth weight, intrauterine growth retardation, and ↑ in spontaneous abortions in humans	
Sleep	sleep deprivation, negative affect on immune system and healing, ↑ in adrenaline causing vasoconstriction, ↑ BP, and muscle tension, ↓ REM activity and shorter REM durations in humans	39,64,68
Behavior	↑ risk of overall functional loss notable in aged population, ↓ attention, performance, memory, dual-tasking, cognitive development, affects reading, problem solving, motivation, ↑ irritability and depressed mood in humans	5,32,1,3,62,63,12,13 14,72,38,20,59,17,33 16,22,41,19,28,34,26,66
Other	accelerates expression of lupus in a mouse model	2
	can cause audiogenic seizures	29,45
	↑ microvascular permeability/disruption of the intestinal lining in rat	46
	↑ in tail flick latency (indication of ↑ analgesia) in rat	61
	slower wound healing, ↓ in body weight but no difference in food intake in rat	74
	↓ body weight, ↑ in leukocytes, adrenal gland and liver size in rat and rabbit	31,52
	migraine headaches, peptic ulcer, and irritable bowl syndrome, ↑ neurovascular impairment in humans	58,67,36,8,65

ACTH, adrenocorticotropin hormone; BP, blood pressure; DCN, dorsal cochlear nucleus; HR, heart rate; IgM, immunoglobulin M; NK, natural killer; REM, Rapid Eye Movement.

this special issue range from the physics of sound to how sleep/wake cycles are altered by noise in the animal facility. Below is a summary of the invited overviews in this special issue.

1) Dr Larry Hughes, a psychophysicist, provides a brief tutorial on the physics of sound; how sound is generated and propagated through space, and how to measure sound in animal facilities. It is clear that one of the first steps that must be taken as we attempt to understand the impacts of noise on animals is to actually measure the noise present. Because much of what a rat or mouse hears is out of the range of the human ear, obtaining objective measures of noise, especially high-frequency sound in the facility, is particularly important. Without reliable measures of what sounds are present in animal facilities, we cannot begin to address the deeper issues of how these sounds impact laboratory animals.

2) Drs Henry and Rickye Heffner have been studying comparative hearing in different species of animals for over 35 y. They have managed to measure hearing abilities in dozens of mammalian species, from the Egyptian fruit bat to the elephant. Their Laboratory of Comparative Hearing at the University of Toledo provides as comprehensive a mammalian audiogram data bank as can be found anywhere. Heffners' chapter provides valuable information to the general reader about how hearing is measured and about the hearing ranges and sensitivities in a variety of commonly used lab animals, an often overlooked feature of noise in animal facilities.

3) Dr James Willott has been publishing articles on the factors affecting hearing and hearing loss in mice for over 40 y. He has also edited 2 widely referenced books about hearing in mice. Dr Willott provides valuable information about genetic and environmental factors that affect hearing in mice. For example, many investigators do not realize that some of the most commonly used lab animals suffer from genetic hearing loss (for example, DBA/2, C57/Bl6 and Balb/C inbred strains).

4) Dr Christine Portfors specializes in how high frequency sound is processed by the brain in mammals. Dr Portfors reminds us that lab animals communicate with one another and that this communication is a valuable part of their auditory environment. Because rat and mouse vocalizations/communications occur in the ultrasonic frequency range (>20,000 Hz), we humans cannot hear them. As a result, we know very little about what they communicate to one another. Dr Portfors renews the call for measuring ultrasounds in our animal facilities and provides fascinating new data suggesting that whether animals are housed with same-sex or opposite-sex cage mates will determine whether they emit vocalizations. This has implications not only for normal auditory development but also for a more careful examination of animal housing standards.

5) Dr Arnaud Rabat reviews the dramatic effects of environmental noise on the sleep-wake cycles of laboratory animals in a facility. Because of the widespread implications of altering the sleep cycle on immune function, memory, and other systems,

these data suggest that some of the non-auditory deficits seen after noise exposure might be the result of sleep cycle disturbances. Dr Rabat points out that much more work needs to be done in these areas and provides the valuable background information from which we can start.

6) Dr Mildred Randolph, Dr William Hill, and Dr Bruce Randolph remind us that if noise is a problem for animals, it is also likely a problem for human personnel who work there. They provide us with practical information and some key considerations on developing an occupational hearing conservation program for animal care personnel.

Several key points emerge from this special issue. Researchers and laboratory personnel should:

1) Make efforts to routinely monitor the full range of sounds present in the acoustic environment of the animal housing facility. Both chronic background noise levels and noise produced by common activities in the facility (handling, cage changes, wheels on carts) should be measured. As several articles in this special issue point out, it is not enough to just measure noise in the human hearing range because the most commonly used lab animals can hear activities at much higher frequencies.

2) Minimize excessive noise resulting from daily maintenance. Excessive noise in animal facilities produced by motors and cage washing machines should also be minimized using architectural and noise abatement techniques. However, sterilizing the acoustic environment through especially quiet rearing or the use of a white noise background masker can be problematic because deprivation of auditory input or rearing animals in a standard noise environment has either unknown or unwanted adverse consequences for organisms.

3) Recognize the effects of noise on the particular biological system being studied.

4) Know the hearing range and any unique hearing attributes (or dysfunctions) of the animal species/strain being used.

5) Recognize the need for more research on noise in animal facilities. Clearly, much remains to be learned about how noise can alter the biology and behavior of laboratory animals. By gaining a greater understanding of the noise in our lab animal facilities and the effects of those noises on animals, we might be able to further minimize unwanted variability in studies and ultimately reduce the number of animals needed in our research.

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