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ANIMAL BEHAVIOR AND ELECTROMAGNETIC ENERGY WAVES[1,2]

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SUMMARY • *Reports in the literature vary with respect to the effects of electromagnetic energy waves on animal behavior. Factors considered in this review include visible and invisible light, plus variations in duration, intensity, and quality of light exposure. Reproductive ability, sex ratio of newborn, animal activity, and length of life were reported to be altered. Investigators describing seemingly similar conditions reported wide variations in results. Well documented and controlled research is needed to accurately measure the effects of light upon animal behavior.*

Of the various kinds of electromagnetic energy waves in the universe, light is that portion within the range of human vision (8). Darkness is generally considered to be the portion of electromagnetic waves not detected by human vision or the absence of these waves.

Considerable research interest relates to effects of the electromagnetic energy wave spectrum in plants, laboratory animals, and people. Invisible electromagnetic waves may penetrate buildings and are referred to as general background radiation.

Interesting phenomena have been reported using the sensitive plant, *Mimosa pudica* (10). At sunset this plant folds its leaves tightly and the leaf branches hang in a downward position. Upon sunrise, the leaves unfold and return to their normal open position. Placing the sensitive plant in a dark closet does not alter the usual day and night leaf positions. Six sensitive plants were taken, at noon time, to the bottom of a mine 198 m below the earth's surface. Leaves and branches of all 6 plants immediately assumed their nighttime positions, not waiting for the sun to set. Incandescent bulbs illuminated the mine. This suggested that day-night responses of the sensitive plant result from some form of radiation capable of penetrating through the building material surrounding the dark closet at the surface of the earth, but not through to the bottom of the mine. Buds of the hoya vine, a nocturnal plant, open only during the nighttime regardless of whether or not they are placed in a dark closet at the surface of the earth during daytime.

Some species of laboratory animals were reported to be more active during nighttime when located in a 1-story frame building than in the basement area of a tall, solid masonry structure (10). Methods of measuring animal activity, room temperature, and other environmental variables were not discussed. Both plants and animals may react positively to nighttime radiation as well as to merely the absence of visible light during the dark nighttime period.

An experiment was designed to determine if electromagnetic energy waves were emitted from television sets (10). One-half of a large color television screen was covered with a 0.32 cm thickness of lead shielding and the other half was covered with black photographic paper. Two rats, approximately 3 months old, were placed in a cage directly in front of each area. The set was turned on, without audible sound, for 6 hr each week-

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day and 10 hr on Saturday and Sunday. No additional information was given. Rats protected only by the black photographic paper showed abnormal activities after 3–10 days and became progressively lethargic. After 30 days it was necessary to push them to make them move. The lead-shielded rats showed a mild degree of lethargy after a considerable period of time. Three replications of this experiment produced similar results according to the investigator.

Placing a color television set 4.6 m from a rat breeding colony with 2 ordinary building partitions between the television set and the animals disrupted the breeding program (10). Type of breeding program, number of animals involved, hours television set was on, and other environmental factors were not reported. Rats formerly averaging 8–12 young immediately dropped to 1 or 2, and many of these did not survive. After removing the television set, approximately 6 months time was required for reproduction to return to normal.

Much information is unknown regarding light and its effects concerning animal reproduction. Increasing lengths of daylight during spring months influences the breeding season of farm animals (12). Seasonal breeding patterns of many species may be caused by light stimulation of the pituitary plus the effect of external influences (1). Mouse production is higher in metal containers, which let in less light than translucent containers (4). Time of evulation and estrus in mice is controlled by the riurnal rhythm of light and darkness. Reversing the time of light and darkness reversed the time of ovulation and estrus (3). Voles require 15 or more hr of light for normal reproduction (16). Optimum reproduction in rats takes place with 13 hr of light and drops to 50% with 9 hr of light (16).

Intensity of light is also a factor affecting animal reproduction. Sexual cyclic responses in the ferret appeared dependent upon light intensity rather than light wavelength (7). Ferret sexual cycles were not accelerated when the optic nerves were cut prior to increasing light intensity (6).

The pineal gland has been described as an intricate and sensitive "biological clock", converting cyclic nervous energy generated by light in the environment into endocrine or hormonal information (17). Blinding male and female albino rats resulted in retarded development of reproductive organs. Blinding plus pinealectomizing did not retard reproductive organ development, which suggested a light reception-pineal-gonadothropic relationship (11). Similar results were obtained by blinding and pinealectomizing hamsters (5).

Human eyes can detect only a narrow band of electromagnetic waves and within the band there are great differences in sensitivity (8). Light in the spectra we normally see is in the wavelengths from 400–700 nm. Light waves under 400 nm are called ultraviolet waves and those over 700 nm are called infrared waves. Both ultraviolet and infrared waves are undetected by human vision. Only about 3% of all electromagnetic waves fall within the human vision light spectrum. The entire electromagnetic energy wave spectrum is illustrated in Fig 1.

Colors in the visible light spectrum include violet (400–450 nm), blue (450–500 nm),

Fig 1. ***The electromagnetic energy wave spectrum showing the 3% visible light spectrum (400 to 700 nm) shaded.***

Cosmic waves	0.00005 nm
Gamma waves (radiation)	0.0005 to 0.140 nm
X waves (X-ray)	0.01 to 10 nm
Ultraviolet waves	Under 400 nm
Infrared waves (heat)	Over 700 nm
Short-wave broadcasting	
Long-wave broadcasting	1 to 2,000 m
Alternating electric current	

green (500–550 nm), yellow (550–600 nm), orange (600–650 nm), and red (650–700 nm). Scotopic or rod vision is used for dim light, showing maximum sensitivity at 505 nm, or in the green color spectrum. Photopic or cone vision is used for daylight, showing maximum sensitivity at 560 nm, or in the yellow color spectrum (8).

Influence on animal behavior, caused by variation of the visible color spectrum, has been of research interest in recent years. Alteration of progeny sex ratio by colored lighting would be of desirable economic importance. Many environmental variables would be involved in research if the color of light bulbs in animal rooms produced important changes in animal behavior or sex ratio of offspring.

Light of different colors has been responsible for altering sexual cycles in ferrets (2). Fifty guppies in an aquarium, under blue fluorescent light for 9 hr daily, reportedly ceased all reproduction, while the same number under pink fluorescent light for 9 hr daily produced normal numbers of young; however, the sex ratio was altered with production of 80% females and 20% males (9). The male offspring were described as abnormally retarded in development of secondary sex characteristics. Laying hens and roosters, provided pink fluorescent light 12 hr daily, produced nearly all infertile eggs. Another flock, maintained under daylight white fluorescent light 12 hr daily, produced all fertile eggs. Number of birds and environmental conditions were not stated for either flock. Chinchillas housed outdoors, with natural light, produced 50% male and 50% female offspring. Moving the parent animals indoors and providing incandescent light, resulted in primarily male young. Changing to blue light resulted in virtually all female young. Environmental information was not reported; however, the investigator noted that temperature was not constant. Mouse breeding colonies that received natural light through a basement window produced 50% female and 50% male offspring (9). Under daylight white fluorescent light, the progeny sex ratio changed to 70% females and 30% males. With pink fluorescent light the sex ratio reversed to 30% females and 70% males. Pink light caused unthrifty young, shorter breeding lives, smaller litters, and shorter life than seen with natural or white light. These observations involved a colony of over 1,000 mice. Numbers of animals used in each test, day or night lighting, total hrs of lighting, and other husbandry practices were not discussed. It is not known from this report if the same animals or different animals of like quality were used for each test.

Other investigators, with controlled studies, did not produce variations of sex ratio in mouse breeding colonies using daylight, blue, or pink fluorescent lights (15). Lights were turned on automatically for 12 hr daily. The number of litters produced, number of mice born, and number weaned were affected most favorably by the daylight environment. Fourteen per cent of all females in the daylight group and 32% of all females in the blue light group died prior to 1 year of age. Specific causes of death for these animals were not reported. None of the animals in the pink light group died during the course of the investigation. These investigators concluded that normal environmental variations among laboratories during a 12 hr day had little effect on litter characteristics and no effect on sex ratios.

Normal and enucleated female albino mice, 6 months of age, were used to evaluate the effect of several visible colors in the electromagnetic spectrum on voluntary activity (13). Activity chambers consisted of 30.5 x 30.5 x 22.8 cm cubicles containing food, water, and an activity wheel. Two chambers were lighted with each color by 6 watt GE miniature fluorescent lights. Colors used were green, blue, red, yellow, daylight, or dark (no lighting). Each mouse was randomly assigned to a cubicle for 18 hr, rested under standard laboratory conditions 30 hr, and randomly assigned to a second chamber. After each animal spent 18 hr in each color environment, the experiment was replicated.

The number of revolutions of the activity wheel during the 18 hr activity period were recorded. Mean revolutions per hour fell into 3 color groups as follows: Group I (blue, green, and daylight), 19; Group II (yellow), 292; and Group III (red and dark), 758. Activity for each group differed significantly from the others, but colors within groups did not differ. Enucleated mice responded nearly identically to the 6 color environments. Receptors in the retina of the mouse eye are primarily rods. Rhodopsin is a deep red substance in the rods, absorbing all forms of visible light except that in the red spectrum. Red light appears as darkness to nocturnal animals; therefore, results from red light were similar to those in the dark environment. It was shown that activity in mice, and possibly other body functions, can be affected, by different color lighting environments.

Further experiments were completed to determine the influence of age, sex, and eye pigment on activity (14). Identical activity chambers and lighting were used as in the prior experiment. Albino female mice of 2 age groups (6 weeks and 6 months) and black mice of both sexes and age groups were used. Analysis of the results of this experiment indicated that 1) black and white mice markedly differ in activity; 2) differences were noted in response to different color environments; and 3) white females responded to colors differently than black females, with black females showing less response to environmental color changes. Black female mice were more active than male mice in both age groups. Activity response in albino and black mice of both sexes and age groups fell into 3 distinct groups showing significant differences between the groups: Group I (red and dark), exhibiting greatest activity; Group II (yellow), intermediate activity; and Group III (blue, green, and daylight), least activity. Albino mice showed greater response to environmental light changes than black mice. Possible explanations were a strain-influenced response difference or anatomical differences in the eye. Albino mouse eyes are devoid of pigmented epithelium, whereas eyes of black mice are well pigmented. Black male mice showed less activity at both 6 weeks and 6 months of age than either white or black females. Young male black mice were more active than old male black mice. It was evident from this investigation that significant differences in activity response resulted from various environmental light conditions influenced by the factors of age, sex, and eye pigment in mice.

Discussion

Individuals interested in using laboratory animals for research must be aware of lighting and its influences on animal behavior. Total effects of electromagnetic energy waves are unknown. Reports have included daytime and nighttime radiation (10), television disturbances (10), day length effects (3, 4, 12, 16), light intensity (6, 7), pineal gland-environment interactions (1, 5, 11, 17), and variations caused by different colors of the visible light spectrum (2, 9, 13, 14, 15).

Investigators have reported conflicting results in several areas. Well documented and controlled research in lighting and its influence on animal behavior is needed.

Investigators measuring the effects of light upon animals can only obtain meaningful results when all other environmental factors remain constant.

Sufficient evidence has been presented to make all breeders of laboratory animals aware of the problems encountered from environmental changes in lighting. Every effort should be made to keep lighting of the same color, intensity, and day length for laboratory animal breeding and housing, thus avoiding added environmental variables to investigations.

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