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MOTOR RESPONSES IN MOTHS TO LOW INTENSITY X-RAY EXPOSURE

by
J. C. Smith
D. J. Kimeldorf
E. L. Hunt

U.S. NAVAL RADIOLOGICAL DEFENSE LABORATORY

SAN FRANCISCO 24, CALIFORNIA

12ND. P7463

PHYSIOLOGY-PSYCHOLOGY BRANCH
D. J. Kimeldorf, Head

BIOLOGICAL AND MEDICAL SCIENCES DIVISION
E. L. Alpen, Head

ADMINISTRATIVE INFORMATION

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Eugene P. Cooper
Eugene P. Cooper
Scientific Director

E. B. Roth
E.B. Roth, CAPT USN
Commanding Officer and Director

ABSTRACT

A brief burst of x-rays elicited flight activity in the moth when placed in a darkened x-ray exposure room. Wing beat activity was recorded as an index of this behavior. Wing beat activity could be initiated in resting moths or amplitude augmented in active moths by x-ray dose rates of 0.01 - 1.5r/sec. with a latency of less than one second after onset of exposure.

NON-TECHNICAL SUMMARY

The Problem

The reactions of the nervous system to radiation are under investigation at this laboratory. It has been found that cardiac acceleration and arousal from sleep are prompt manifestations of neural reactions in the rodent to small doses of x-rays. In the present study, the reactions in a less complex species, the moth, have been investigated to provide further information regarding the reactivity of the neural system to low dose rates of x-rays.

The Findings

It was found that a brief burst of x-rays can elicit flight activity in the moth. Wing beat was recorded as an index of this behavior. Wing beat activity can be initiated in resting moths or augmented in active moths by very low x-ray dose rates (0.01 - 1.5r/sec). The reaction occurs promptly with the onset of exposure. This motor reaction to radiation occurs at dose rates below that reported for other species and provides a sensitive means of investigating neural reactivity to ionizing radiation.

DISCUSSION

Recent reports have cited observations of prompt deviations in behavior with the initiation of radiation exposure. In the rat, an arousal reaction from sleep was found to occur within seconds following the start of low intensity exposure (1). Also, an immediate disturbance in lever pressing behavior upon the onset of exposure has been reported when radiation was used as a conditioned stimulus (2). Hug (3) has identified some reflex-like reactions in marine invertebrates and insects which have involved tentacle retraction, shell closure, or migration from the exposure area with relatively low intensity radiation exposure. Born (4) observed a closure response of the snail mantle cavity similar to the snail tentacle response described by Hug. With high intensity beams prompt behavioral disturbances have been reported in several organisms including daphnids (5), turtles (6), mosquitoes (7) and fish (8).

Recent experiments in this Laboratory have indicated that the moth is remarkably sensitive to low intensity radiation exposure. In the initial observations it was found that a brief burst of x-rays

would elicit flight behavior in moths when placed in a darkened x-ray exposure room. This behavioral response is readily accessible and can be measured by observations of wing beat frequency. The present report describes this reaction and its sensitivity to radiation.

Moths from eight species of Noctudiae and one species of Arctiidae were used in the study. The moths were collected in the San Francisco area and tested within 24 hours after capture. X-rays were generated by a Westinghouse Maxitron X-ray machine, operated at 250 kvp, 25 ma, with a beam HVL of 2.3 mm. Cu. The exposure interval was controlled by a lead shutter operated manually from outside the x-ray room.

To record the wing beat, the moth was attached to a wire which was cemented to a ceramic crystal transducer (Electrovoice Model 53-3). Signal from the transducer was amplified so that vigorous flight movement resulted in a $\pm$ 10 mm deflection on a oscillographic recording. To attach the moth to the motion transducer the subject was anesthestized briefly with CO_2 and the scales were brushed from the dorsal exoskeleton of its thorax. The moth was then joined to the wire of the transducer with heated Tackiwax (CENCO).

In the test procedure, the animal preparation was mounted on a stand in the exposure room. The x-ray tube was turned on and the beam attenuated by the shutter. The moth was allowed to dark adapt for four minutes prior to the exposure tests. Each animal was tested

at least three times to dose rates of 0.33r/sec., 0.13r/sec., 0.10r/sec., and 0.07r/sec. The stimulus intensity at the site of action is presumed to be related to the dose rate. For close determination of the minimum effective exposure intensity additional dose rates were usually required. Differential dose rates were achieved by varying the distance from the subject to the source. The thimble chamber of a Philips dose-rate roentgen meter was placed adjacent to the moth to record the dose rate during exposure. The duration of the exposure varied from one to fifteen seconds and the time between exposures varied from several seconds to three minutes.

To demonstrate that the moth was reacting to the X-ray beam and not to shutter manipulation or some other stimulus, several types of controls were invoked. (1) Each animal was given several "sham" exposures in which all conditions were the same except that the power to the X-ray tube was turned off. (2) A tympanic nerve preparation, made according to method of Roeder (9), was used to test for the presence of auditory stimulation from high frequency sounds produced during the shutter operation and exposure. Any sounds which were within the moth's frequency and intensity range could be observed on an oscilloscope as spike potentials in the nerve preparation. (3) This control was provided to detect possible effects of the X-ray beam on the motion transducer or the lead wires, which might in turn evoke flight activity in the moth. For this

purpose, additional preparations were made with animals attached to wires which were fastened directly to the ring stand. Under dim red illumination and through a window from the control room, visual observations were made of the initiation of flight at the onset of the exposure to the X-ray beam.

Figure 1 shows the response of one moth (Agrotis ypsilon) to two exposures at a dose rate of 0.17r/sec. Each exposure was 2 seconds in duration. The first stimulus was presented when the animal was inactive and the second exposure was given during evoked flight. In each moth tested, the exposure to the X-ray beam initiated wing beat or caused a change in the amplitude of the beat during flight. The dose rate required to initiate this action varied from subject to subject. Table I gives the minimum rate to which each of the subjects responded. The response occurred early within the first second of exposure. If the moth was inactive, sometimes a suprathreshold intensity of X-rays did not elicit the flight pattern. The response to subsequent radiation exposures could be restored if the moth was first exposed to a brief flash of light.

The control tests indicate that the response of the moth is to the X-ray beam. When subjected to the "sham" trials the animals gave no evidence of initiation of the flight pattern. The record of spike potentials from the tympanic nerve preparation gave no indication of the presence of auditory stimuli during shutter operation and

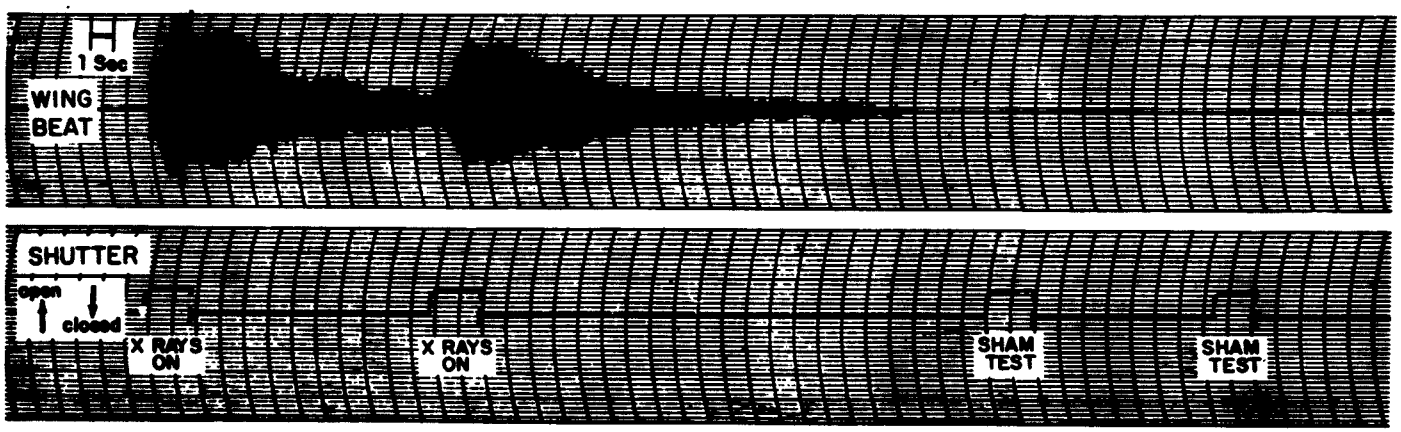

Fig.1 Initiation and augmentation of wing beat in a moth (Agrotis ypsilon) on exposure to X rays at 0.17r/sec. For the sham exposure test the shutter was opened but power to the X-ray tube was turned off.

Table I. X-ray dose rates effective in eliciting prompt motor activity for each specimen tested. All species are classified in the family Noctuidae except the last specimen (family Arctiidae).

SPECIES	MINIMUM EFFECTIVE DOSE RATE
Crymodes devastator (Brace)	0.50 r/sec.
Protorthodes rufula (Grote)	0.37 r/sec.
Agrotis ypsilon (Rottemberg)	0.01 r/sec.
Agrotis ypsilon (Rottemberg)	0.01 r/sec.
Agrotis ypsilon (Rottemberg)	0.12 r/sec.
Agrotis subterranea (Frabricuis)	0.20 r/sec.
Acronicta mormorota (Smith)	0.10 r/sec.
Catocala irene (Behr)	0.17 r/sec.
Catocala irene (Behr)	1.50 r/sec.
Prodenia praefica (Grote)	0.17 r/sec.
Mamestra configurata (Walker)	0.33 r/sec.
Halisidota maculata (Harris)	0.03 r/sec.

exposure. Animals not attached to the transducer were observed to exhibit vigorous flight movement at the onset of exposure, indicating that the response could not be attributed to radiation induced changes in the electrical detection system.

The complex motor reaction demonstrated in these moths occurs at a radiation intensity below that reported for any other organism. Several specimens exhibited responses to radiation intensities in the range of 0.01 - 0.12r/sec. The latency of reaction was less than one second on most records. The differences in effective dose rates among specimens may reflect differences in radiosensitivity among species, the variations in physiological state among specimens, and the level of excitation upon which radiation is imposed.

The control studies demonstrate that initiation of wing beat was not associated with the manipulatory procedures incidental to exposure. It is difficult to ascribe the response to radiation action on muscle fibers in view of the low exposure dose and the short latency. It is significant that the motor response could be obtained only when the specimen was dark adapted. Electroretinograms are being made on a large series of moths using both beta radiation plaques and x-rays as the source of stimulation. The preliminary data indicate that the threshold intensity for visual activation may be approximately equal to that required for initiation of wing beat in the moth. It is suggested that the induction of flight activity may be the behavioral consequence of visual stimulation through low intensity radiation.

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