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PRIMATE PHYSICAL ACTIVITY FOLLOWING EXPOSURE TO A SINGLE 4600-R--ETC(U)
AUG 76 C G FRANZ, L CLARK, J W CABLE

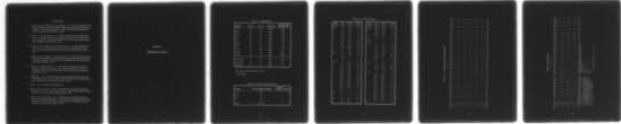
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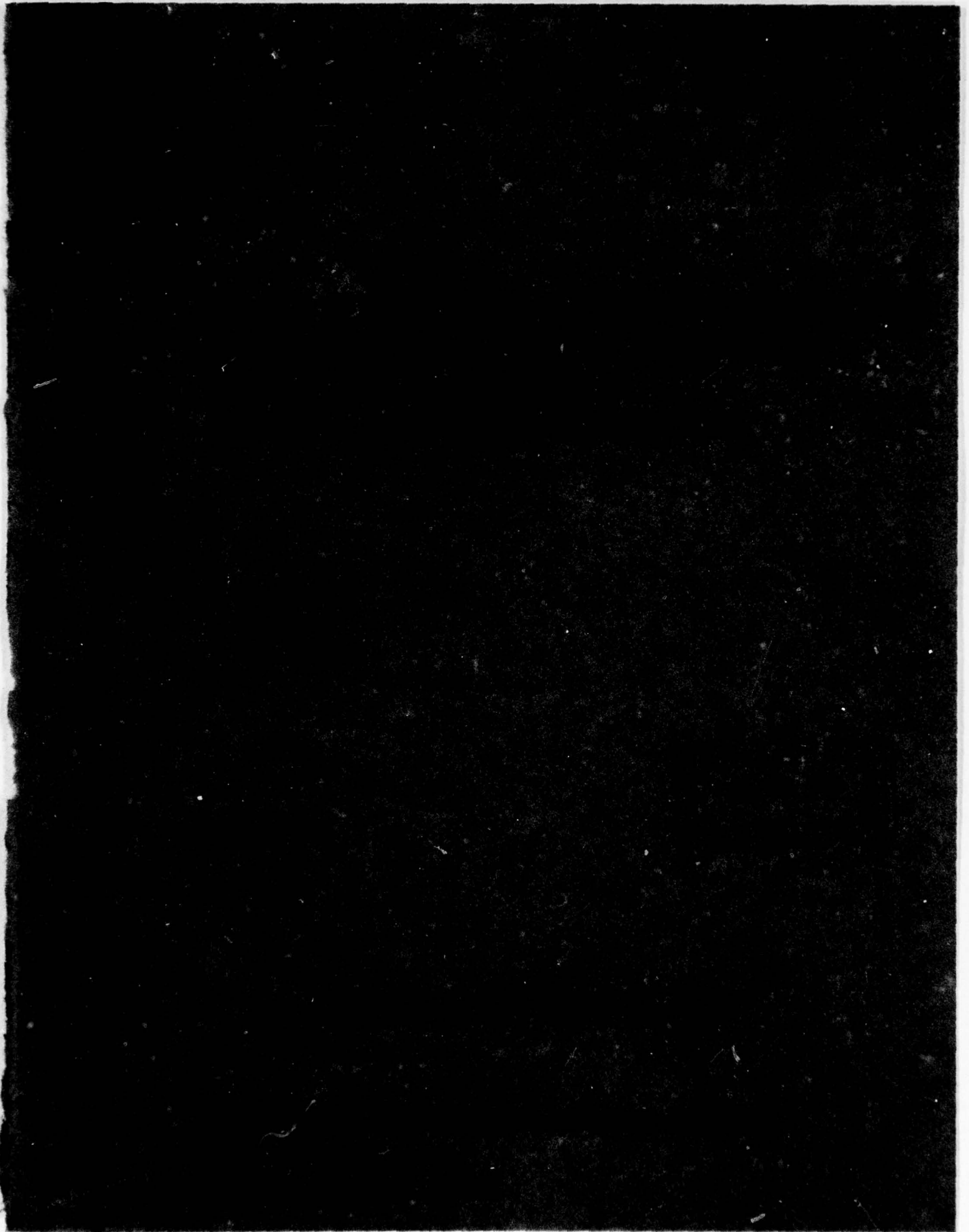


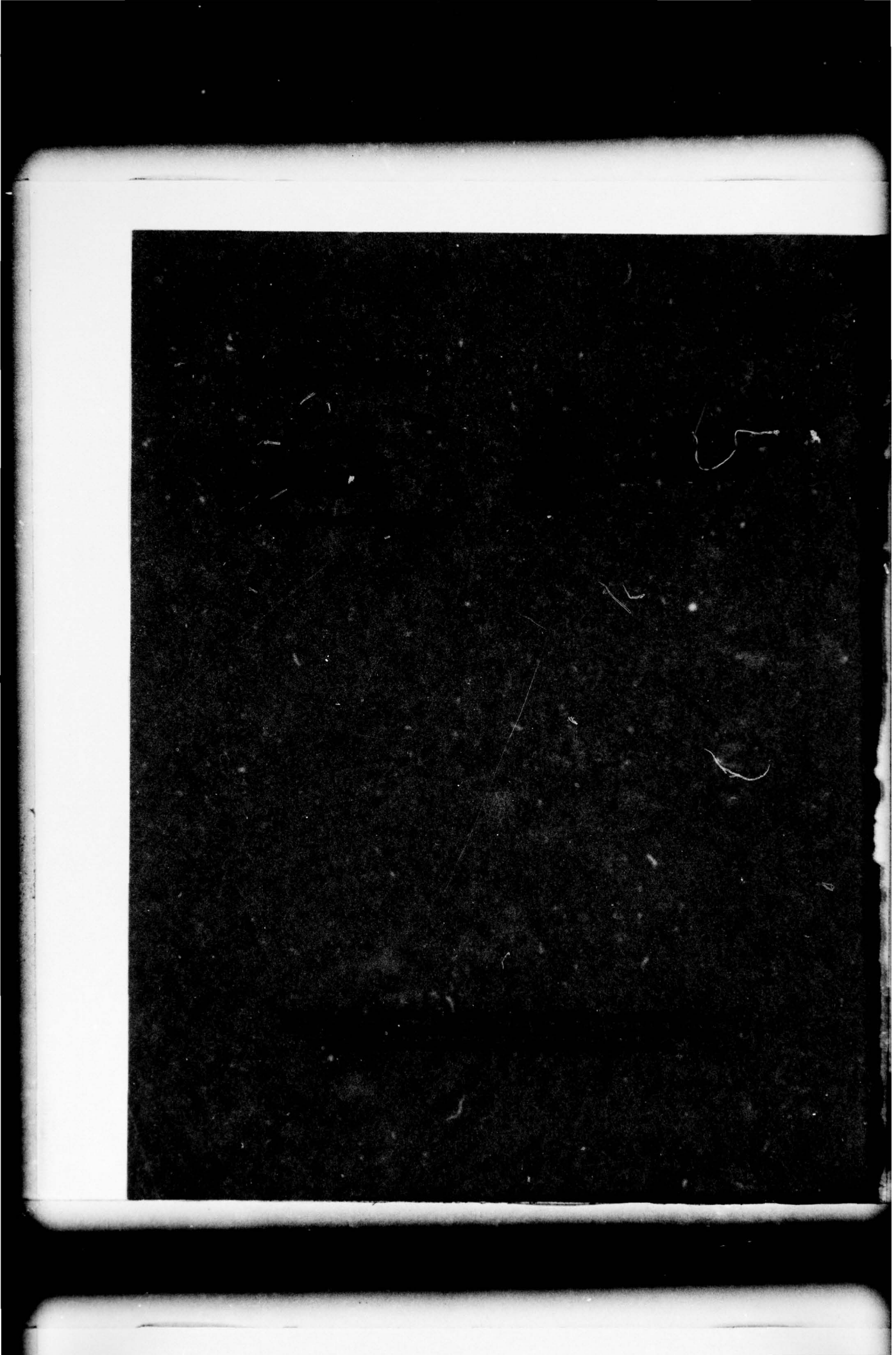
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20. ABSTRACT (continued)

minutes postexposure; (2) an apparent recovery from incapacitation with only 30 percent of the animals incapacitated between 45 and 70 minutes postexposure; (3) a steady increase in the number of animals exhibiting incapacitation until 60 percent were incapacitated between 105 minutes and the end of the test period 6 hours postexposure. At 24 hours postexposure, 90 percent of the animals were incapacitated. Group mean performance for animals, when not incapacitated, was 58 ± 9 percent of base line throughout the 6-hour test period. Survival time of the group ranged from 7 to 132 hours with a mean of 37 hours. Earlier work has suggested that there are differences in the postirradiation response of restrained animals and unrestrained physically active animals. This observation is of considerable interest to the military services which have many missions that require movement or physical activity for combat effectiveness. This study addresses this militarily relevant question.

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SUMMARY
(Nontechnical)

The majority of studies investigating primate behavior following exposure to high doses of ionizing radiation have used animals confined to restraint chairs and trained to perform a learned task requiring little physical movement. The objective of this study is to determine the effects of high neutron ($n/\gamma = 3$) radiation on the performance of a physical activity task. This paper reports the effects of a 4600-rad pulse ($n/\gamma = 3$, pulse width = 50 msec) on the performance capability of 10 male rhesus monkeys trained to operate a physical activity wheel as a nonmotorized treadmill.

The pattern of postexposure incapacitation was: (1) an early onset of incapacitation with 80 percent of the animals being incapacitated within 8 minutes postexposure; (2) an apparent recovery from incapacitation with only 30 percent of the animals incapacitated between 45 and 70 minutes postexposure; (3) a steady increase in the number of animals exhibiting incapacitation until 60 percent were incapacitated between 105 minutes and the end of the test period 6 hours postexposure. At 24 hours postexposure, 90 percent of the animals were incapacitated. Group mean performance for animals, when not incapacitated, was 58 ± 9 percent of base line throughout the 6-hour test period. Survival time of the group ranged from 7 to 132 hours with a mean of 37 hours.

PREFACE

The authors wish to acknowledge the outstanding technical assistance provided by C. H. Avila, J. E. Crawford, Jr. and P. E. Heinig, Jr.

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INTRODUCTION

The majority of studies investigating primate behavior following exposure to high doses of ionizing radiation have used animals confined to restraint chairs and trained to perform a learned task requiring little physical movement.^{4,8} Three AFRRI studies^{1,5,9} evaluating the effects of ionizing radiation on the overall performance of unrestrained animals exposed to a radiation field with a neutron-gamma ratio of 0.4 showed that performance on a task requiring physical activity (traversal of a 3 x 6 foot chamber) was more severely degraded following irradiation than performance on a task requiring little physical movement. A fourth study² that separated the physical activity task from the cognitive task showed that performance of a physical activity task was more affected than performance of a cognitive task. In addition, Thorp and Young found that neutrons are less effective than gamma radiation in producing incapacitation in an animal performing a cognitive task.⁸

The objective of this study is to determine the effects of high neutron ($n/\gamma = 3$) radiation on animals performing a physical activity task. This report is an evaluation of the ability of rhesus monkeys to perform a physical activity task following exposure to 4600 rads ($n/\gamma = 3$, pulse width = 50 msec).

METHODS

Ten male monkeys (Macaca mulatta) averaging 45 months of age and weighing an average of 5.7 kg were studied. Individual age, weight, dose, and survival information are given in Appendix A (Table A-1). All animals were fasted for 18 hours prior to base-line and postexposure testing. The animals were housed in a primate colony room and transported in a Plexiglas box to a non-motorized activity wheel.³

Each animal was exercised for 2 hours per day for 8 weeks to condition it to the point where an alternating 10-minute run, 5-minute rest cycle could be maintained for 6 hours without serious fatigue. Running behavior was maintained by a shock-motivated free-operant reinforcement schedule with visual and

auditory cues during the activity sessions (Table 1). A tone and light began approximately 30 seconds before the wheel became free to rotate. An animal could indefinitely avoid a brief electrical shock by rotating the wheel at or above a rate of 1 mph. If the rotation rate exceeded 5 mph at any time, a motorized brake automatically increased the drag on the wheel until the rotation rate dropped below 5 mph. During rest periods, there were no visual or auditory cues and the brake held the wheel in a fixed position.

Table 1. Visual and Auditory Cues to Acceptable Performance and the Criterion for the Onset of Brief Shocks

	mph	Tone (BPM)	Lights	Shock
Shock zone	0-1	90	green	.4-sec pulse* every 1.3 sec
Shock avoidance danger zone	1-3	90	green	none
Shock avoidance safe zone	3-5	60	white	none
Overspeed zone	5 and up	30	red	none†

* .4-sec pulse once every minute during incapacitation

† Brake moves to on position

Following 8 weeks of training, each animal was base-line tested for 2 hours in the reactor exposure room and 4 hours in the training room. Five days (normal training schedule) later, each animal was transported in a Plexiglas box to the exposure room for a 10-minute pretest to detect any significant changes in the animal's performance. If pretest performance was 80 to 120 percent of performance achieved during the first 10 minutes of the base-line test the animal was placed in a squeeze box and exposed to a single whole-body dose of mixed gamma-neutron radiation (pulse width = 50 msec; $n/\gamma = 3.1$). The radiation

exposure was monitored with miniature ionization chambers. This exposure was multiplied by an experimentally derived factor of 0.77 to obtain the midline tissue dose (MTD).⁷

Five seconds after exposure, the animal was released from the squeeze box into the activity wheel and tested immediately. Initial postirradiation testing lasted 6 hours and followed the same regimen as the base-line test. The animals were then tested for 2 hours each day until death. During training, base-line and postexposure testing, the animals were visually monitored by closed circuit television⁶ for changes in their physical condition and for emesis.

The rate of rotation and number of revolutions were permanently recorded on a strip chart. Each animal's performance on the postexposure test was analyzed for each 10-minute session to determine the number of incapacitations, the amount of time each animal was incapacitated and his performance level when not incapacitated. An animal was considered to be incapacitated when he did not perform for a period of 1 minute and was considered to have recovered when he performed continuously regardless of the speed for 1 minute. The level of performance was determined by comparing postirradiation performance with base-line performance.

RESULTS

Within 3.7 to 7.5 minutes postexposure ($\bar{x} = 5.1$) incapacitation occurred in 80 percent of the animals. Recovery from early incapacitation occurred in all cases by 45 minutes postexposure. Exact times of onset and recovery and the duration of all incapacitations are listed in Appendix A (Table A-3). During the first 2 hours postirradiation, the percent of the group incapacitated (Figure 1a) at any time during a 10-minute activity session dropped from 80 percent in the first 10 minutes to 30 percent between 45 and 70 minutes then rose steadily to 60 percent between 105 and 115 minutes postexposure. Between 2 and 6 hours postirradiation, 50 to 70 percent of the group were incapacitated at some time during every 10-minute session. Ninety percent of the animals were

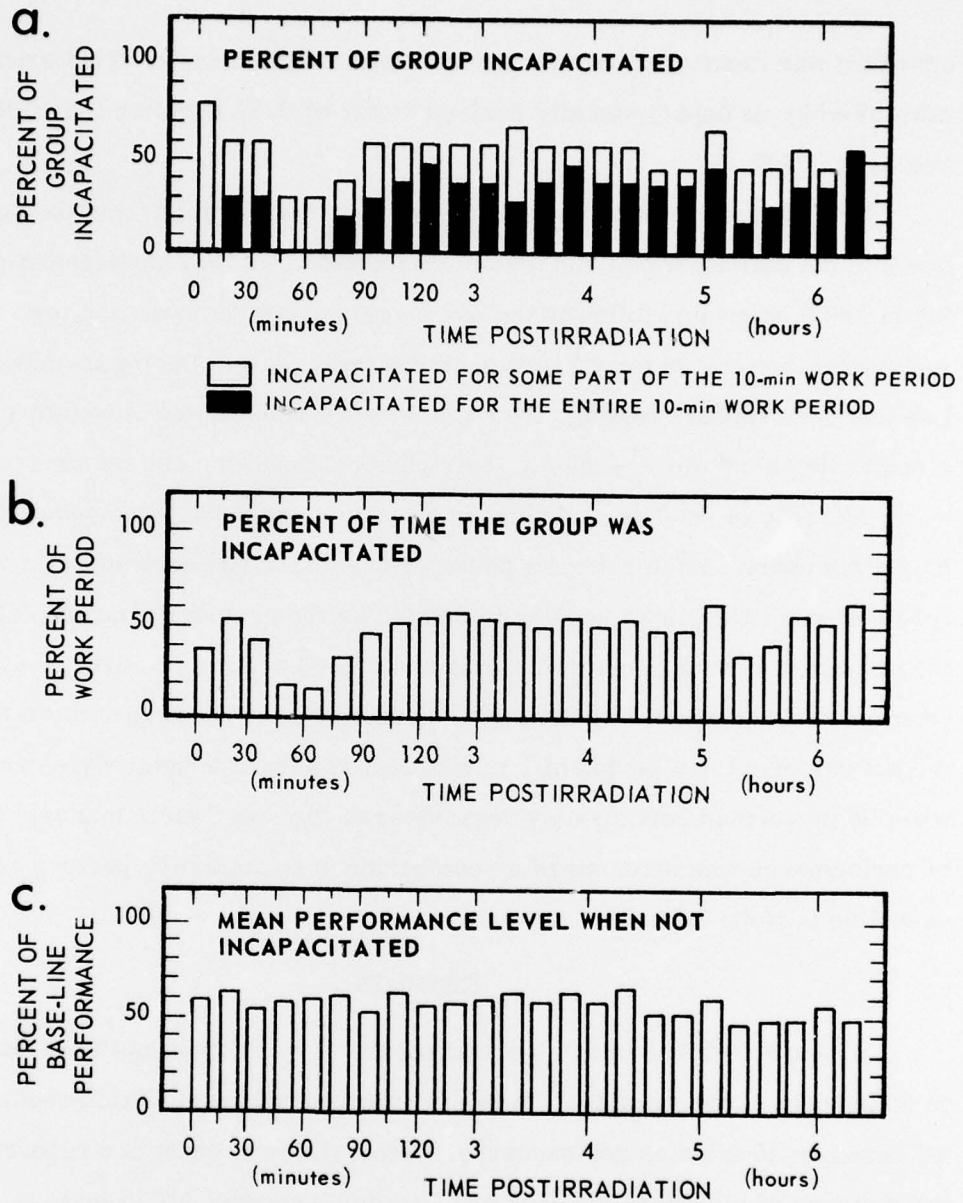


Figure 1. a. Percent of group incapacitated for 1 to 10 minutes during a work period. b. Percent of total available time the group lost to incapacitation for each work period. c. Mean performance level when not incapacitated for each 10-minute work period. (Raw data in Appendix, Table A-4.)

incapacitated when tested 24 hours postirradiation. Some animals were incapacitated for an entire 10-minute work period (Figure 1a). Thirty percent of the animals were incapacitated for complete work periods between 15 and 40 minutes postirradiation. At 45 to 70 minutes postexposure, some incapacitation occurred, but none lasted for the entire work period. From 75 minutes postexposure to the end of the 6-hour test, 20 to 60 percent of the group remained incapacitated.

An alternative to examining the incidence of incapacitation is to consider the percentage of time the group was incapacitated. For any specific 10-minute work period the percent of time the group was incapacitated (Figure 1b) was computed by summing the durations of all incapacitations and dividing by the total available work time. The group was incapacitated 37 percent of the work period 0-10 minutes postirradiation and 52 percent of the work period 15-25 minutes postirradiation. The percent of time incapacitated decreased to a low of ~16 percent between 45 and 70 minutes postirradiation, then increased to 50 percent at 105-115 minutes postexposure. The percent of time the group was incapacitated remained at ~50 percent for the rest of the 6-hour test.

To evaluate postirradiation performance decrement the rate of wheel rotation postirradiation (RPM_{PI}) was compared to base-line RPM_B for each 10-minute work period ($\frac{RPM_{PI}}{RPM_B}$). Animals incapacitated for an entire work period were deleted from the group. The performance of animals incapacitated for part of the 10 minutes was computed only for that portion of the time that the animal was not incapacitated. The group mean performance level (Figure 1c) was 58 ± 9 percent of base line for the 6-hour test period.

Four animals vomited postexposure, three at ~45 minutes and one at ~60 minutes postirradiation (Appendix, Table A-2). Survival times ranged from 7 to 132 hours with a mean survival time of 37 hours (Appendix, Table A-1).

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Appendix A

Detailed Data on Animals

Table A-1. Animal Data

ANIMAL #	AGE (Mo.)	WT (kg)	MTD (Rads)*	POST IRRADIATION SURVIVAL (Hrs)
HI-5	42	6.1	4730	36.0
E-35	NA†	4.9	4600	36.0
F2-14	NA	5.9	4625	14.5
22	26	4.4	4800	28.5
E-38	42	5.7	4600	36.0
C-4-6	52	5.9	4570	7.0
C45	72	7.0	4600	16.0
C-4-4	48	6.9	4600	29.0
K-338	35	4.4	4665	36.0
A-4-38	42	5.3	4496	132.0
Upper Limit	72	7.0	4800	132.0
Group Mean	45	5.7	4628	37.7
Lower Limit	26	4.4	4496	7.0

*MTD (Rads = Midline tissue dose in rads)

†Not available

Table A-2. Postirradiation Emesis

ANIMAL #	TIME POSTIRRADIATION (MINUTES)	NUMBER OF EPISODES OF VOMITING
22	44	1
C4-5	44	1
C4-4	40	1
	46	1
K3-38	60 to 62	6

Table A-3. Incapacitations

Animal number	Onset (min)	Recovery (min)	Duration (min)	Animal number	Onset (min)	Recovery (min)	Duration (min)	
HI-5	4.0	22.1	18.1	E-38 (contd)	114.2	126.0	11.8	
	23.6	32.5	8.9		127.7	129.2	1.5	
	38.1	46.8	8.8		133.6	134.6	1.0	
	52.4	55.4	3.0		144.3	150.0	6.1	
	66.3	67.4	1.0		161.9	191.0	29.1	
	69.6	76.3	8.3	C-4-6	85.4	-	-	
	92.7	109.7	15.1	C-4-5				
	111.9	160.4	48.5	C-4-4	7.5	10.7	3.2	
	172.2	185.0	12.8		15.7	25.1	9.4	
	188.8	200.0	11.2		31.4	34.6	3.2	
	342.3	352.0	9.7		79.9	87.9	8.0	
	E-35	3.7	46.8	43.2		98.9	104.7	5.8
		47.8	62.2	14.3		109.6	121.7	12.1
63.3		65.5	2.2		134.0	311.5	177.5	
66.5		-	-		315.6	-	-	
F-2-14	4.1	48.8	44.7	K-3-38	5.9	20.6	14.7	
	50.2	53.9	3.7		37.1	40.6	3.4	
	68.7	156.3	87.7		180.0	298.0	118.0	
	157.3	169.1	11.8		326.0	375.0	49.0	
	171.8	172.8	1.0	A-4-38	7.0	9.2	2.2	
	173.8	174.8	1.0		192.2	193.8	1.6	
	176.9	186.3	9.4		207.4	210.1	2.7	
	187.3	190.3	3.0		221.5	223.6	2.1	
	191.8	217.0	26.2		239.3	240.3	1.0	
	221.0	239.0	18.0		241.8	242.9	1.1	
	278.0	294.5	16.5		251.8	318.2	66.4	
	296.0	297.8	1.8		272.3	278.7	6.3	
	311.4	312.4	1.0		287.3	293.0	5.3	
	357.0	-	-		302.6	311.0	8.4	
22	5.1	6.1	1.0	321.4	332.8	11.7		
	7.3	8.3	1.0	335.8	349.8	4.0		
E-38	3.7	47.7	43.4	351.0	368.3	17.3		
	98.2	99.2	1.0	371.6	374.6	3.0		
	107.0	108.1	1.1					

Table A-4. Performance and Incapacitation

ANIMAL NO.	Time Postirradiation																								
	0-	15-	30-	45-	60-	75-	90-	105-	120-	135-	150-	165-	180-	195-	210-	225-	240-	255-	270-	285-	300-	315-	330-	345-	
Rev BASE ¹	204	203	137	184	178	176	165	188	122	154	137	133	124	119	117	124	121	130	123	114	114	121	127	118	118
Rev IRRAD ²	40	16(12)	42(11)	80(5)	75(10)	83	9(31)	42(27)	28(13)	29(13)	29(15)	53	66	63	65	65	50	45	57	46	51	22(17)	37	40	40
% of work period Incap ³	60	85	44	30	25	0	83	78	100	62	32	62	0	0	0	0	0	0	13	0	0	0	48	0	0
% of BL performance ⁴	50	53	38	61	59	47	29	100	0	47	31	58	43	55	54	52	41	35	53	40	45	35	31	34	34
Rev BASE ¹	144	144	147	119	134	140	142	135	147	132	145	140	143	150	140	130	127	127	128	128	133	128	129	131	131
Rev IRRAD ²	36	(6)	(6)	9(3)	22(8)	(4)	(17)	(3)	(19)	(7)	(9)	(1)	(4)	(3)	(4)	(7)	(1)	(4)	(4)	(0)	(3)	(1)	(4)	(3)	(3)
% of work period Incap ³	63	100	100	90	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
% of BL performance ⁴	68	0	0	60	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rev BASE ¹	194	180	162	150	156	166	155	151	181	159	161	154	146	140	144	140	142	137	135	134	133	133	129	131	131
Rev IRRAD ²	33	(4)	(4)	38	30	(20)	(14)	(21)	(22)	(13)	11(7)	34(11)	25(10)	(22)	14(14)	23(6)	37	31	(19)	39	50	38	42	(23)	(23)
% of work period Incap ³	63	100	100	50	46	100	100	100	100	100	90	31	56	100	60	80	0	0	100	18	10	0	0	0	100
% of BL performance ⁴	46	0	0	50	35	0	0	0	0	0	70	32	57	0	25	80	26	23	0	35	42	29	33	0	0
Rev BASE ¹	225	192	169	170	159	151	148	148	153	128	117	123	125	123	122	129	134	131	126	127	123	125	121	122	122
Rev IRRAD ²	82	133	113	114	114	116	118	109	96	37	96	99	90	96	92	93	93	87	91	95	90	91	91	86	86
% of work period Incap ³	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% of BL performance ⁴	45	69	66	67	71	76	79	73	63	76	84	77	72	78	75	72	70	66	72	29	73	72	75	70	70
Rev BASE ¹	276	250	212	185	190	205	204	211	263	300	316	259	256	258	227	241	282	251	228	228	229	227	237	235	235
Rev IRRAD ²	51	(35)	(62)	113	115	105	101(6)	46(30)	69	16(34)	(29)	52	96	100	102	97	96	93	35	80	62	62	81	73	73
% of work period Incap ³	63	100	100	0	0	0	10	21	25	90	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% of BL performance ⁴	49	0	0	61	61	51	44	28	35	56	0	20	38	39	45	40	34	37	15	74	27	27	34	31	31
Rev BASE ¹	242	220	211	197	184	167	165	159	142	134	128	129	129	127	130	127	133	123	117	118	118	126	117	111	111
Rev IRRAD ²	104	131	112	95	100	26(33)	(36)	(27)	(41)	(24)	(32)	(21)	(20)	(24)	(26)	(29)	(21)	(23)	(19)	(11)	(13)	(4)	(13)	(4)	(4)
% of work period Incap ³	0	0	0	0	0	0	34	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
% of BL performance ⁴	43	60	53	48	54	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A-4 (continued)

ANIMAL NO.	Time Postirradiation																							
	0-10	15-25	30-40	45-55	60-70	75-85	90-100	105-115	120-130	135-145	150-160	165-175	180-190	195-205	210-220	225-235	240-250	255-265	270-280	285-295	300-310	315-325	330-340	345-355
Rev. BASE ¹	142	157	181	182	190	172	172	164	162	165	148	146	144	141	140	148	141	142	144	140	136	132	136	131
Rev. IRRAD ²	125	117	124	120	112	112	118	113	104	95	101	99	101	99	100	100	96	101	101	101	102	108	112	89
C-4-5 % of work period incap ³	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% of BL performance ⁴	88	75	69	66	59	65	69	69	64	57	68	68	70	70	71	68	68	71	70	72	75	82	82	68
Rev. BASE ¹	206	215	208	206	197	194	192	187	178	183	164	164	158	141	144	142	157	150	152	153	137	145	151	143
Rev. IRRAD ²	78(9)	18(27)	71(16)	131	122	40(41)	40(23)	44(8)	37(7)	20(3)	35(40)	31(31)	31(31)	23(39)	33(40)	40(40)	39(26)	26(26)	34(34)	34(34)	37(37)	26(26)	25(22)	22(22)
C-4-4 % of work period incap ³	32	89	32	0	0	80	50	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
% of BL performance ⁴	56	82	50	64	62	115	42	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0
Rev. BASE ¹	161	148	108	166	176	184	180	175	153	155	161	160	160	146	139	138	134	137	136	139	129	112	119	129
Rev. IRRAD ²	71(12)	43(26)	56(10)	62	66	89	78	77	64	60	46	49	47	0	18	13	13	13	13	13	44	45	88	100
K-3-38 % of work period incap ³	43	44	34	0	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100
% of BL performance ⁴	88	52	44	37	38	48	41	44	42	38	29	120	0	0	0	0	0	0	0	0	38	57	0	0
Rev. BASE ¹	218	222	209	192	191	186	184	173	171	167	170	157	147	144	144	144	153	148	148	157	160	156	149	144
Rev. IRRAD ²	85(5)	110	120	120	129	115	117	114	135	123	119	87	78	57	94	80(9)	47(9)	57(17)	24(37)	41(33)	23(29)	15(25)	17(32)	23
A-4-38 % of work period incap ³	22	0	0	0	0	0	0	0	0	0	0	0	17	27	21	22	32	63	58	84	50	63	84	88
% of BL performance ⁴	53	50	57	63	68	62	64	66	79	74	70	66	73	84	83	84	84	84	93	100	52	38	63	92

1 Each revolution represents 11.9 feet of travel. To convert revolutions per minute to miles per hour divide the revolutions by the minutes and multiply by .136.

2 Revolutions in parentheses occurred during a period of incapacitation. An animal was considered to be incapacitated when he did not perform at all for a period of one minute, and was considered to have recovered when he performed for a minimum of 10 minutes. Some revolutions of the wheel were recorded during periods of incapacitation. These revolutions were deleted from the performance level when not incapacitated. If one wishes to compute overall performance level for the ten minutes without respect to incapacitation the numbers in parentheses should be added.

3 Work periods were ten minutes, therefore $(\text{min. incap.}) \times 100 =$ percent of time incapacitated.

4 Performance level was computed for that portion of the postirradiation work period during which the animal was not incapacitated. Calculated % of baseline for each work period.

$$\frac{\text{Rev(postirrad)}}{10 \text{ (min. Incap.)}} = \text{RPM}_1$$

$$\frac{\text{Rev(baseline)}}{10 \text{ min}} = \text{RPM}_2$$

$$\frac{\text{RPM}_1}{\text{RPM}_2} = \text{Performance level}$$

$$\text{RPM}_1 = \text{Revolution per minute postirradiation}$$

$$\text{RPM}_2 = \text{Revolution per minute during preirradiation (baseline) testing.}$$