

DNA 4147T

# IMMEDIATE EFFECTS OF 33 TO 180 RAD/ MIN <sup>60</sup>Co EXPOSURE ON PERFORMANCE AND BLOOD PRESSURE IN MONKEYS

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Education and Research  
P.O. Box 5890  
Albuquerque, New Mexico 87115

September 1976

Topical Report

CONTRACT No. DNA 001-74-C-0098

THIS WORK SPONSORED BY THE DEFENSE NUCLEAR AGENCY  
UNDER SUBTASK V99QAXMA191-04.

Prepared for  
Director  
DEFENSE NUCLEAR AGENCY  
Washington, D. C. 20305

HRF-0366

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1 REPORT NUMBER DNA 4147T	2 GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4 TITLE (and Subtitle) IMMEDIATE EFFECTS OF 33 TO 180 RAD/MIN <sup>60</sup> Co EXPOSURE ON PERFORMANCE AND BLOOD PRESSURE IN MONKEYS		5 TYPE OF REPORT & PERIOD COVERED Topical Report
7 AUTHOR(s) A. Bruner		6 PERFORMING ORG REPORT NUMBER
9 PERFORMING ORGANIZATION NAME AND ADDRESS Lovelace Foundation for Medical Education and Research, P. O. Box 5890, Albuquerque, New Mexico 87115		8 CONTRACT OR GRANT NUMBER(s) DNA 001-74-C-0098
11 CONTROLLING OFFICE NAME AND ADDRESS Director Defense Nuclear Agency Washington, D.C. 20305		10 PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Subtask V99QAXMA191-04
14 MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12 REPORT DATE September 1976
		13. NUMBER OF PAGES 72
		15 SECURITY CLASS (of this report) UNCLASSIFIED
		15a DECLASSIFICATION/DOWNGRADING SCHEDULE
16 DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17 DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18 SUPPLEMENTARY NOTES This work sponsored by the Defense Nuclear Agency under Subtask V99QAXMA191-04.		
19 KEY WORDS (Continue on reverse side if necessary and identify by block number) Dose Rate Performance Decrement Hypotension Monkeys Radiation Thresholds Early Transient Incapacitation		
20 ABSTRACT (Continue on reverse side if necessary and identify by block number) Four groups of monkeys received 1000 rads <sup>60</sup> Co at 33, 50, 75, or 180 rad/min wholebody irradiation while performing a delayed matching-to-sample task. Systematic dose rate effects were observed on performance and blood pressure within the initial 20 min postirradiation. The incidence and severity of performance decrement (PD) increased with higher dose rate. The percentage incidence of early PD was 7, 33, 33, and 81%		

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20. ABSTRACT (Continued)

respectively for the 33, 50, 75, and 180 rad/min groups, including those animals showing early transient incapacitation (ETI). The appearance of postirradiation hypotension was systematically delayed and its rate of fall prolonged as dose rate was lower. The hypotension likewise appeared less deep with lower dose rate exposure. Based on the calculated cumulative dose absorbed at the time of symptom appearance two coactive thresholds were proposed to exist: a total dose threshold of approximately 300 rads (midbody measurement), and a dose rate threshold of about 25 rad/min, for the induction of the early hypotension-PD/ETI syndrome. PD/ETI occurred only in the presence of hypotension, unusually following its nadir by 1 to 4 min. Moreover, an increasing strength of association between depth of hypotension and frequency of PD/ETI was demonstrated as the hypotension declined below 50% of baseline.

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## PREFACE

This work was performed as a Nuclear Weapons Effects Subtask entitled "Neurophysiological Basis of Primate Performance Decrement," funded by the Defense Nuclear Agency under Contract No. DNA-001-74-C-0098. The present data reveal radiation dose-rate effects on monkey performance and physiology relevant to an understanding of the basis of radiation-induced early primate performance decrement and incapacitation.

The author wishes to express his gratitude to the following individuals who assisted in many phases of this research: V. Bogo, E. A. Henderson, A. N. Gallegos, E. C. Kimmel, M. Sproul, C. D. Campbell, and S. F. Jennings.

This research was conducted according to the principles enunciated in the "Guide for Laboratory Animal Facilities and Care," prepared by the National Academy of Sciences, National Research Council.

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## INTRODUCTION

An earlier report from this laboratory demonstrated the dependence upon  $^{60}\text{Co}$  exposure dose rate of postirradiation hypotension and performance decrement.<sup>1</sup> As dose rate increased over the range from 50 to 180 rad/min, hypotension appeared earlier and its rate of development was more rapid. Likewise, with higher dose rate there was a greater incidence and severity of behavioral impairments as disclosed by our delayed matching-to-sample, shock-avoidance task.

Because the initial postexposure appearance of both hypotension and performance decrement occurred systematically later as dose rate was lower, we proposed the existence of a cumulative dose threshold for the elicitation of this early syndrome. The minimum effective total dose was estimated as being approximately 300 rad midbody. Additionally, a dose rate prediction was derived from a model based on the data obtained at that time which predicted a near-zero incidence of the early syndrome at a dose rate of approximately 30 rad/min.

The purpose of the present study was to test the low dose rate prediction by exposing a new group of monkeys to 33 rad/min while monitoring their matching-to-sample performance and blood pressure.

## METHODS AND MATERIALS

### Subjects

The subjects of the present study were 18 male rhesus monkeys (Macaca mulatta), weighing between 2.5 and 3.0 kg, obtained from Primate Imports Corp. of New York. They were observed and treated as necessary for enteric diseases and tuberculin tested before entering training. Two to seven days prior to irradiation they were surgically implanted, under halothane anesthesia, with a femoral arterial catheter. The catheter, which extended into the abdominal aorta, was continuously infused with heparinized saline (3-10 units/ml/30 min) outside the test sessions.

### Apparatus

Each animal was seated through the work week in a plastic restraining chair, which included a head restraint to maintain orientation toward a stimulus-response panel facing the animal in the test and exposure cubicle. The panel consisted of five plastic, circular keys arranged so that four of the keys were in a horizontal row with the fifth one centered above them. (Only the center two keys of the row of four were used with the present subjects.) A slide projector transilluminated the keys from behind,

displaying the task stimuli, which were 55 multicolored drawings and patterns.

### Procedure

The animal was initially shaped by conventional operant conditioning procedures to escape and eventually avoid shock to the feet (6-10 mA, 0.5 sec) by pressing the plastic keys when illuminated. Over a several week training period the animal eventually achieved the matching task. Here the upper key was lighted with a sample stimulus selected from the array of 55. If the animal pressed the sample key in less than 5 sec, he avoided a shock, the sample extinguished, and up to a 10-sec delay period ensued before the two center keys in the lower row were illuminated, one displaying the same stimulus as had appeared on the sample key earlier, the other showing a different stimulus. Pressing the correct match key avoided a shock and initiated a 10-sec time-out period before the next trial. Complete details of the procedure and apparatus are available in Bruner et al.<sup>2,3</sup>

### Radiation Exposure

When daily matching-to-sample performance accuracies had stabilized at above 70-percent correct, each

animal was run 4 or more days under sham radiation conditions. The animals were food-deprived 16 hr prior to irradiation. Each monkey was irradiated dorsoventrally while performing the task after a 30-minute warm-up run. Dosimetry was determined with live and cadaver monkeys using high-sensitivity Lithium Fluoride thermoluminescent dosimeters. For 14 of the animals, the source-to-subject distance was adjusted to produce approximately 1000 rad at 33.33 rad/min midbody absorbed dose (which will be referred to as 33 rad/min for simplicity), taking into account decay of the  $^{60}\text{Co}$ . The remaining four monkeys received 1000 rad at 50 rad/min. Further details regarding our exposure and dosimetry techniques may be found in Bruner et al.<sup>2,3</sup>

Continuous remote polygraph recordings of blood pressure and heart rate were instituted approximately 30 min prior to beginning the exposure, and continued without interruption up to 60-min postexposure. The exposure duration was 30 min and 20 min for the 33 and 50 rad/min groups, respectively. All present references to post-exposure are with respect to time from the exposure's start. Therefore the initial 30-min postexposure period, during which some of the significant early effects occurred,

refers to the same 30-min period during which the exposure was administered at the 33 rad/min dose rate. Shortly after completion of the exposure the performance task was interrupted for a few minutes for the substitution of a new matching-to-sample slide tray and the determination of a blood pressure zero reference. The performance task was then restarted and continued for the remainder of the 60-min period. The average duration of the procedural interruption was 6 min.

#### Assessment of PD-ETI

Percentage correct matching scores as well as penalty scores were computed for each subject according to the methods described in the previous reports.<sup>1-3</sup> The percentage-correct measure is simply the number of correct-response trials divided by the total number of trials presented over a 20-min period. This simple measure scores both errors and omissions as incorrect responses. With the penalty measure, errors and omissions of different types were assigned differentially weighted penalties according to their relative frequency of occurrence prior to irradiation, such that match errors, sample and match omissions, and, especially, runs of errors and omissions were weighted in relation to their relative rarity during the

baseline sessions. These scores were summed over 20-min periods for pre- to postirradiation comparisons.

The particular penalty weighting values employed are tabulated in Appendix Table A-1, and an example of how the scoring was applied is shown for a previously run 180-rad/min monkey in Appendix Table A-2, both tables being reproduced from Bruner et al.<sup>2</sup>

If an animal failed to respond to six successive sample presentations, it was considered to have met our criterion of Early Transient Incapacitation (ETI), or more simply referred to as "Quit" here. During such Quit periods, following which the animal usually resumed pressing, the shock was disconnected, although the sample stimulus continued to cycle.

## RESULTS

### 33 Rad/Min Performance

The trial-by-trial responses made by each 33-rad/min monkey during the initial 60-min postexposure are presented in Appendix Tables A-3 through A-20 along with their penalty score determinations. The penalty scores derived therefrom were summed for each postexposure minute and these are presented in Table 1.

TABLE 1

INDIVIDUAL PENALTY SCORES OVER INITIAL 30 MINUTES POSTIRRADIATION  
FOR THE 33 RAD/MIN MONKEYS

Monkey No.	Minute																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
854	1	0	0	2	2	1	1	0	0	0	2	1	0	1	0	0	0	1	0	0	1	0	2	17	13	0	0	0	0	1
923	0	0	0	2	0	0	0	1	1	2	0	1	0	-----	1	0	0	0	0	0	1	0	1	0	1	0	0	1	0	1
877	0	1	0	0	0	0	0	0	1	0	0	2	0	1	0	0	0	0	0	2	4	0	0	1	0	1	0	1	1	0
898	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	1	1	0	1	0	1	1
834	2	1	0	0	1	0	1	1	0	2	1	0	0	0	1	0	1	1	0	2	0	1	0	1	2	0	1	1	0	2
804	2	0	1	0	1	0	0	1	0	2	0	0	0	0	0	1	0	1	2	1	3	0	1	0	0	0	1	0	2	2
849	0	0	1	1	0	1	0	1	1	0	0	0	0	0	1	0	2	0	1	0	1	0	1	3	0	0	3	2	0	0
868	0	4	0	0	0	1	0	1	0	2	1	2	1	0	0	1	0	1	1	0	0	0	0	1	0	0	0	0	1	2
906	0	2	0	0	0	0	1	1	2	0	0	2	1	1	0	1	1	1	1	1	0	0	-----	-----	-----	-----	1	0	0	0
820	0	0	1	4	5	4	0	2	0	1	2	1	0	0	1	1	0	2	2	1	1	1	2	1	0	0	1	5	4	1
821	0	0	1	1	0	2	7	0	1	1	1	0	0	2	1	0	1	4	0	1	0	1	0	0	2	-----	0	0	1	1
915	1	1	0	0	1	1	0	2	0	0	5	4	1	0	1	0	1	0	1	0	0	2	7	0	0	0	0	0	0	1
881	2	7	0	1	2	0	0	1	1	1	2	3	0	0	1	0	1	0	0	1	1	0	0	1	0	2	1	3	1	0
860	2	1	0	1	1	0	1	4	0	0	1	0	1	14	41	84	17	4	30	16	1	0	1	1	14	67	68	28	1	1

In Table 1, only one of the 14 monkeys showed a definite increase in penalty scores during the first 30-min postexposure. This was Monkey No. 860, which showed its performance decrement primarily in the form of failures to respond to several nonconsecutive sample or match stimulus presentations beginning at the 14<sup>th</sup> minute (Table A-16), or after absorption of approximately 467 rad. This monkey then resumed good matching performance at minutes 21-24 before showing a second 4-min period of impairment.

The only other suggestion of transient impairment during the initial 30 min was shown by No. 854's slightly elevated scores at minutes 24-25, resulting from one sample omission followed by a match error (Table A-3). This was not judged statistically significant, however, as will be explained later.

A scheduled interruption for changing slide trays after completing the exposure was carried out between 30-40 min after the exposure's start. This procedural interruption was performed only if the animal's performance appeared satisfactory based on on-line examination of the remote data printouts. In the case of Monkey No. 868, it was noticed at the 30<sup>th</sup> minute, just before the planned interruption, that the animal's performance appeared to be faltering, so the

slide change was delayed. After several incorrect match choices between minutes 30-33, the monkey failed to respond to a sample presentation (Table A-10). Then at minute 36, the animal ceased responding altogether, and could not be re-started either by the administration of shocks or by manual manipulation. Accordingly No. 868 received a penalty score of 150 for minute 36 due to meeting our quit (Q) criterion of 6 consecutive sample omissions, which we have defined as constituting incapacitation on this task.<sup>1-3</sup>

All other animals performed well after the procedural break except No. 849, which showed several errors and omissions over a 10-min period beginning at the 49th minute (Table A-9).

The severity of performance decrement (PD) was evaluated statistically by computing PD ratios as described in the earlier reports.<sup>1-3</sup> The PD ratio is analogous to a standard z score, and is obtained by dividing the difference between each 20-min postscore and the mean prescore by the standard deviation of the animal's prescore. The derived z score or PD ratio, as we call it, therefore represents the degree of change in performance following irradiation, adjusted for individual differences, and may be referred to a Normal Distribution Table for expected p values. For z =

3.0, for example,  $p = 0.0013$ , one-tailed.<sup>4</sup> We have adopted the convention of utilizing a PD ratio of 3.0 or greater as a criterion for identifying significant PD.

Table 2 presents the pre-post changes in performance penalty scores summed over 20-min blocks and the respective PD ratios for the 0-20, 10-30, and 40-60 min blocks post-exposure. The 20-40 and 30-50 min blocks were not calculated because they included the procedural interruptions for slide changing and blood pressure zero reference determinations. The animals are listed in Table 2 in order of increasing severity of PD according to the 0-20 min PD ratio magnitude.

The PD ratios using the penalty score sums, as shown in Table 2, disclose the significant decrement exhibited by Monkey No. 860 between 14- and 28-min postexposure as noted in Table 1 earlier. No other animals demonstrated significant behavioral impairment by this measure during the first two overlapping 20-min blocks comprising the initial 30-min post. A significant PD ratio was also obtained for the 40-60 min decrement shown by No. 849. The incapacitation of No. 868, having occurred during the 30-40 min period, was not incorporated into this selective analysis.

Table 3 presents pre-post changes in percentage correct matching choices in analogous format to the penalty

TABLE 2

CHANGES IN PENALTY SCORE SUMS OVER 30-MIN BLOCKS AND  
PD RATIOS FOR THE 33 RAD/MIN MONKEYS

Monkey No.	Preradiation			Postradiation					
	<u>n</u>	<u>s</u>	Mean	Sum 0-20 Min	PD Ratio	Sum 10-30 Min	PD Ratio	Sum 40-60 Min	PD Ratio
854	34	9.50	24.41	12	-1.31	42	1.85	19	-0.57
923	24	9.75	19.75	9	-1.06	8	-1.18	35	1.54
877	32	15.51	20.69	7	-0.88	13	-0.50	21	0.02
898	27	9.71	9.38	3	-0.66	8	-0.14	9	-0.04
834	27	4.55	16.81	14	-0.62	12	-1.06	15	-0.40
804	41	9.50	17.68	12	-0.57	13	-0.49	17	-0.07
849	31	15.63	17.71	9	-0.56	14	-0.24	286	17.16
868	29	7.36	16.21	15	-0.16	11	-0.71	Quit @ 36'	
906	33	7.07	14.24	15	0.11	13	-0.13	31	2.37
820	55	10.26	22.98	27	0.39	26	0.29	33	0.98
821	31	13.32	16.41	23	0.49	19	0.19	28	0.87
915	50	8.76	13.94	19	0.58	25	1.26	24	1.09
881	35	5.74	14.97	23	1.40	17	0.35	23	1.40
860	43	5.80	16.58	218	34.73	390	64.38	17	0.07

TABLE 3

CHANGES IN PERCENTAGE CORRECT OVER 20-MIN BLOCKS AND  
PD RATIOS FOR THE 33 RAD/MIN MONKEYS

Monkey No.	Preradiation			Postradiation					
	<u>n</u>	<u>s</u>	Mean	% Correct 0-20 Min	PD Ratio	% Correct 10-30 Min	PD Ratio	% Correct 40-60 Min	PD Ratio
854	34	5.53	73.26	84	-1.94	81	-1.40	79	-1.04
923	24	5.88	72.50	84	-1.96	86	-2.30	63	1.62
877	32	5.05	76.36	87	-2.11	77	-0.13	62	2.84
898	27	3.83	90.73	95	-1.11	85	1.50	84	1.76
834	27	5.89	74.19	76	-0.31	78	-0.65	74	0.03
804	41	6.70	73.15	77	-0.57	75	-0.28	75	-0.28
849	31	8.54	78.10	82	-0.46	76	0.24	54	2.82
868	29	7.47	74.59	78	-0.46	80	-0.72	Quit @ 36'	
906	33	7.31	77.33	75	0.32	78	-0.09	63	1.96
820	55	6.67	69.11	64	0.77	72	-0.43	56	1.96
821	31	7.64	79.13	70	1.20	70	1.20	55	3.16
915	50	6.88	78.40	74	0.64	72	0.93	68	1.51
881	35	7.93	74.74	71	0.47	74	0.09	63	1.48
860	43	5.38	72.60	59	2.53	53	3.64	69	0.67

score analysis just described for the same postexposure periods. As we also found in the earlier dose-rate report,<sup>1</sup> the percentage correct measure failed to adequately disclose the severity or significance of decrement as detected by the penalty score method.

#### 50 Rad/Min Performance

Four monkeys received 50 rad/min in the present series in order to expand the N at this dose rate to 12, as 8 had been already run as reported in the earlier paper.<sup>1</sup> The individual penalty scores of all 12 50-rad/min monkeys over the first 20-min postexposure, which was also the exposure's duration for this group, are given in Table 4. The four new animals are Nos. 921, 894, 864, and 901. The procedural interruption occurred shortly after the exposure's completion and therefore no 20-30 min performance data were available. The trial-by-trial responses of the four new animals are presented in Appendix Tables A-17 through A-20.

Of the previous eight animals receiving 50 rad/min only two had shown performance impairment. These were Nos. 863 and 814, both of which met the quit criterion at 13 min post. Both recovered 3 min later and rapidly resumed normal performance. Of the four new 50-rad/min monkeys, none quit but two obtained PD ratios greater than 3.0, as shown in

TABLE 4  
INDIVIDUAL PENALTY SCORES OVER INITIAL 30 MINUTES POSTIRRADIATION  
FOR THE 50 RAD/MIN MONKEYS

Monkey No.	Minute																															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30		
829	1	0	0	0	1	0	1	0	1	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1
812	0	1	1	0	0	1	0	1	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
855	0	0	1	1	1	1	0	0	1	2	0	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	
921	1	3	1	1	0	2	0	1	0	0	1	1	0	1	0	0	1	3	1	0	0	2	0	0	0	0	0	0	0	0	0	
830	0	0	1	0	2	0	0	0	1	0	0	1	1	0	2	0	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	
825	1	2	0	0	1	0	1	0	2	0	2	0	2	0	0	1	1	5	4	0	0	2	0	0	0	0	0	0	0	0	1	
801	0	0	3	1	1	0	0	2	1	5	4	1	1	0	0	0	0	0	0	2	1	0	0	0	0	0	0	1	0	1		
894	1	0	0	0	0	0	0	2	0	2	0	30	0	0	1	1	3	0	0	1	0	0	0	0	0	0	0	0	1	1		
864	2	0	0	1	1	0	1	1	0	0	1	1	1	0	4	16	1	1	1	3	0	0	0	2	1	2	0	1	0	0		
901	1	1	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0	1	1	50	50	0	0	1	0	0	0	1	1			
863	0	1	0	2	0	1	0	0	2	5	29	25	150	0	0	26	0	1	0	0	1	0	0	0	0	0	0	1	1	0		
814	0	0	0	0	0	0	0	0	0	1	0	2	150	0	0	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0		

Table 5. No. 864 had been a very stable, good performer prior to irradiation, and consequently, had a very low standard deviation (Table 5). This animal's significant PD ratio of 3.31 resulted solely from the occurrence of a sample omission at minute 15 and a match omission at minute 16. Thus, its PD was considered mild. The other new animal showing a significant PD ratio, No. 901, failed to respond to two sample presentations at minute 20. Not shown in Table 4 is that this monkey also failed to press the next two successive samples, these being presented at the start of minute 21. Following these four consecutive sample omissions, No. 901 performed normally, making only one match error during the subsequent 4 min at which time the procedural interruption was carried out.

All the 50-rad/min animals were restarted on the performance task by 30-min postexposure. All performed normally thereafter except for No. 829 which made a few sample and match omissions at various times between 38 and 60 min post, and No. 801 which made six consecutive match errors just after the restart at minute 31.

Thus, the early PD shown by 4 of the 12 50-rad/min monkeys consisted of one mild and one moderate PD ratio and two quits. For each of these four, the impairment appeared

TABLE 5  
 CHANGES IN PERCENTAGE CORRECT AND IN PENALTY SCORES OVER THE  
 INITIAL 20 MINUTES POST EXPOSURE FOR THE 50 RAD/MIN MONKEYS<sup>a</sup>

Monkey	Percentage Correct					Penalty Score			
	Pre			Post Score	PD Ratio	Pre		Post Score	PD Ratio
	<u>n</u>	<u>s</u>	Mean		Pre-Post ÷ <u>s</u>	<u>s</u>	Mean		Post-Pre ÷ <u>s</u>
829	14	6.99	79.64	87	-1.05	4.05	11.29	7	-1.06
812	21	6.84	83.67	87	-0.49	3.80	8.71	7	-0.45
855	18	5.95	83.00	80	0.50	11.53	14.65	11	-0.32
921	40	6.66	75.52	72	0.53	14.02	18.45	17	-0.10
830	18	4.87	77.72	78	-0.06	2.94	12.83	13	0.06
825	19	4.34	78.11	72	1.41	6.64	15.42	22	0.99
801	20	6.73	81.22	71	1.52	5.65	14.45	21	1.16
894	27	6.11	82.15	78	0.68	13.89	15.33	41	1.85
864	33	4.55	71.45	71	.10	5.09	18.15	35	3.31
901	25	6.85	78.04	82	-.57	6.88	13.83	58	6.42
863	17	6.16	76.76	Q	-	7.24	15.25	Q	-
814	20	4.24	87.79	Q	-	2.68	5.79	Q	-

<sup>a</sup> Preradiation n indicates number of consecutive 20-min performance penalty scores obtained from the sham baseline runs. s is the standard deviation of the n preradiation scores. Negative PD ratios signify postradiation change in the direction of improvement. No PD ratios were calculated for the animals which quit (Q).

within 20-min postexposure and endured only 2-6 min (Table 4).

#### 75 and 180 Rad/Min Performance

In the previous dose-rate paper,<sup>1</sup> we reported that out of 12 animals exposed at a dose rate of 75 rad/min, two had ETI's and two showed PD ratios exceeding 3.0 within 20 min of the exposure's start. The two significant PD ratios were 6.53 and 17.01. The next highest ratio was 2.12 and all others were less than 1.0. The PD first appeared between 6- and 10-min postexposure and was over with by 16-min post for that group.

At a mean dose rate exposure of 180 rad/min,<sup>1</sup> we observed 8 out of 16 animals showing PD ratios greater than 3.0 plus 5 monkeys which showed early transient incapacitation (ETI, synonymous with Quits) within the first 20-min post. Two others had PD ratios between 2.0 and 3.0. Two of the incapacitated monkeys revived by 17-min post and resumed normal performance. Two of the other Quits resumed normal performance only after a break and manual stimulation about 40-min postexposure. The remaining monkey's incapacitation was permanent and death ensued within the hour. However, the observed severity of effects in this group was tempered somewhat by the fact that a few of the

animals were already debilitated prior to irradiation as a result of difficulties with their surgical implants as previously noted.<sup>2,3</sup>

#### Dose Rate Comparisons

To review, the incidence of performance decrement and/or ETI as a function of <sup>60</sup>Co dose rate is summarized in Table 6, in terms of the number of animals (and percentage) in each group obtaining PD ratios less than 2.0, greater than 2.0, greater than 3.0, or which quit. The dose-rate effect is readily evident in this table, although very little difference is discernible between the 50- and 75-rad/min groups.

A depiction indicating the PD ratios and the incidence data as a function of dose rate is presented in Figure 1. The percentage of animals in each dose-rate group having PD ratios greater than 3.0 or which quit (i.e., last column in Table 6) is plotted on the right-hand ordinate in Figure 1 as a function of dose rate (on a log scale). The individual animal's PD ratios are indicated on the left ordinate as are the frequencies of animals' having PD ratios exceeding 10 or ETI's. The latter represent categories rather than scores, therefore their location on the vertical reflects an ordinal rank but does not represent a

TABLE 6  
INCIDENCE OF PD/ETI ASSOCIATED WITH  $^{60}\text{Co}$  DOSE RATE

Dose Rate (rad/min)	Penalty PD Ratio			ETI	>2.0 + ETI	>3.0 + ETI
	<2.0	>2.0	>3.0			
33	13 (93%)	1 (7%)	1 (7%)	0 (0%)	1 (7%)	1 (7%)
50	8 (75%)	2 (17%)	2 (17%)	2 (17%)	4 (33%)	4 (33%)
75	7 (58%)	3 (25%)	2 (17%)	2 (17%)	5 (42%)	4 (33%)
180	1 (6%)	10 (63%)	8 (50%)	5 (31%)	15 (94%)	13 (81%)

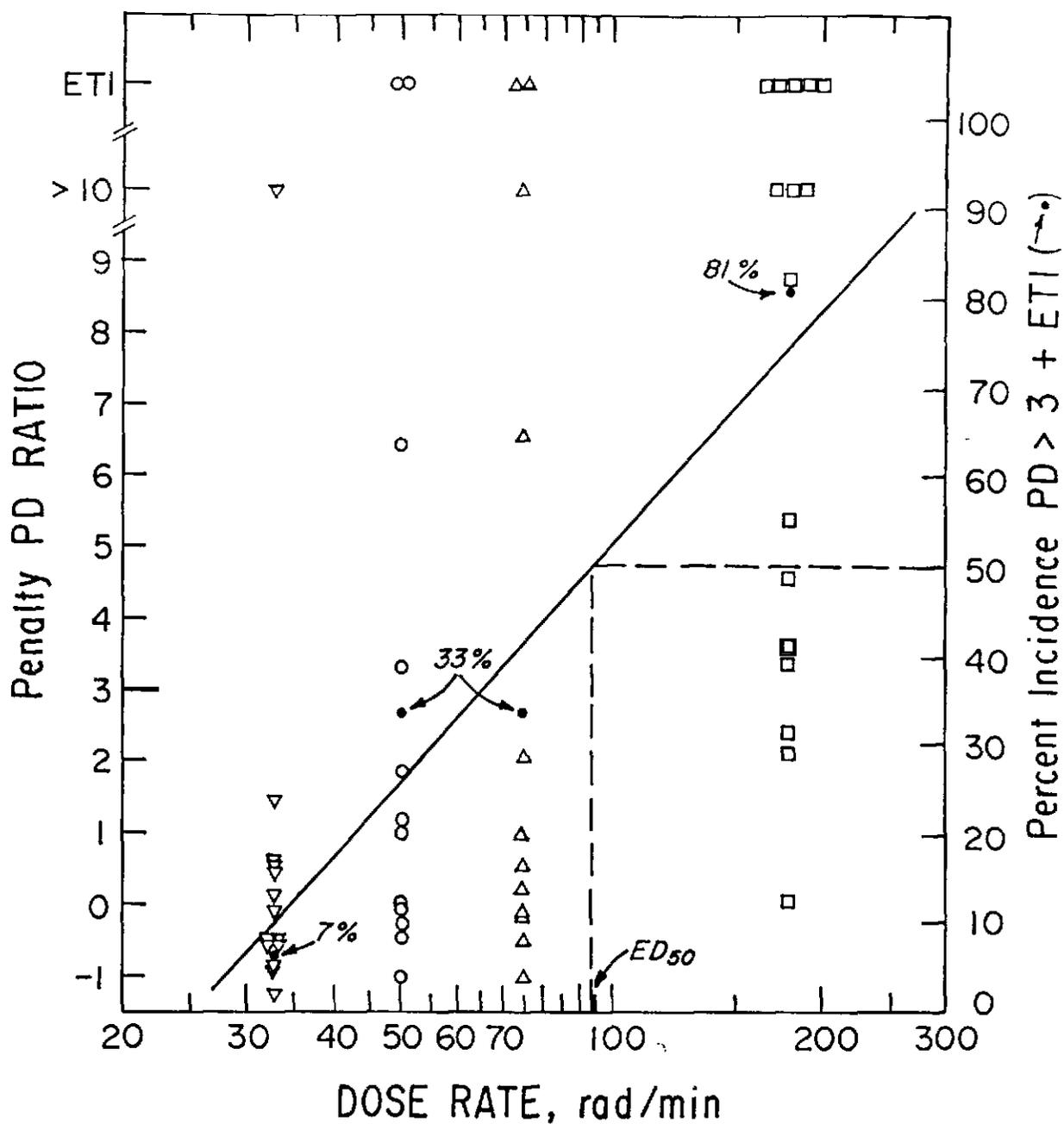


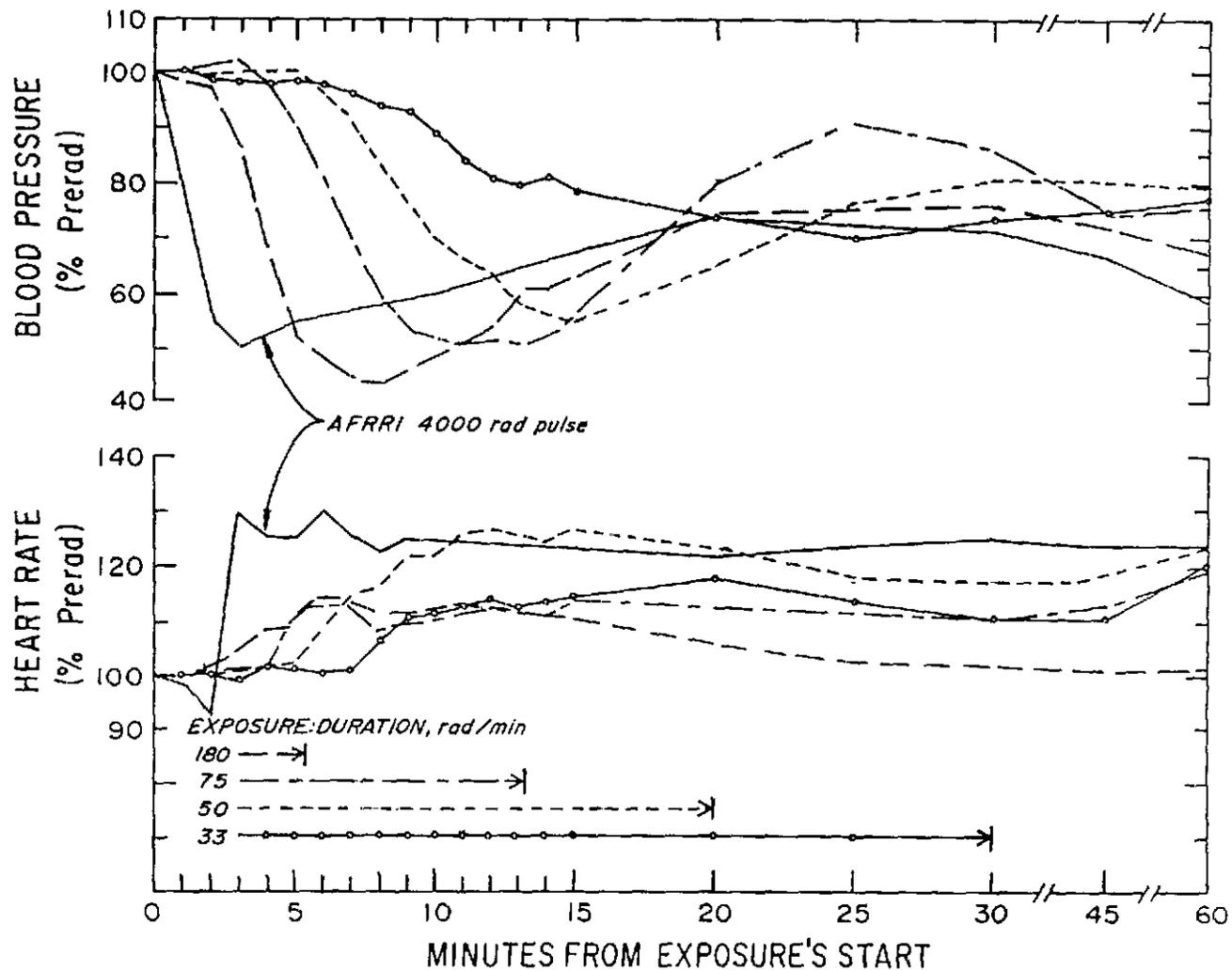
Figure 1. Penalty Score PD Ratios During Initial 20-Min Post-exposure (Left Ordinate, Open Symbols) and Percent Incidence of Animals Having PD Ratios Greater Than 3.0 or an ETI (Right Ordinate, Arrows). The Straight Line was Fit by Eye (see text). Median Effective Dose Rate Indicated is 94 rad/min.

scaled distance. A straight line has been drawn in by eye to fit the four group incidence points on the right ordinate. The line's position was chosen to imply that the 33 rad/min incidence point might have been underestimated because one animal not included in this analysis quit at 36-min post (No. 868), and as well to imply an overestimate by the 180 rad/min point because some of those animals may have been predisposed to PD/ETI due to surgical implant injury.

The locations of the PD ratios against the left ordinate in Figure 1 do not relate quantitatively to the function drawn for the incidence points. The depiction of the PD ratios here was to show: (a) that within-group variability appeared to increase with dose rate even among the subjects performing within normal limits; and (b) that the animals tended to dichotomize into those affected and those unaffected by exposure, as opposed to revealing a graded response on the PD ratio measure. Only for the highest dose rate group was an intermediate degree of decrement apparent.

#### Blood Pressure

Figure 2 presents mean percentage blood pressure (BP) and heart rate (HR) postirradiation relative to preradiation baseline for 12 of the present 14 33-rad/min animals (the



Figures 2. Mean Percentage Blood Pressure (BP) and Heart Rate (HR) Relative to Preirradiation Baseline for the Four Present  $^{60}\text{Co}$  Dose-Rate Groups and for a Group Exposed to a 4000-Rad Pulse at the AFRRI Laboratories.<sup>3</sup>

BP recordings were unreliable for two), superimposed upon a figure presented in our prior dose-rate report<sup>1</sup> showing the postradiation responses of the previously run 50-, 75-, and 180-rad/min <sup>60</sup>Co groups, plus a pulsed gamma-neutron group of nonperforming monkeys from the AFRRI laboratories.<sup>5</sup> Additionally, in this figure, the 50-rad/min group data has been updated to incorporate the 4 new animals' responses, yielding an N of 12 in each of the 5 group curves shown where useable BP data were available. The raw data for mean BP and HR of each of the 12 33-rad/min animals and the 4 new 50-rad/min animals are presented in Appendix Tables A-21 and A-22

In the previous report it was noted that the three <sup>60</sup>Co groups and the 4000-rad pulsed group all showed similar degrees of hypotension.<sup>1</sup> The average depth of hypotension was about 50% and every animal in the <sup>60</sup>Co groups exhibited some hypotension. Of the four new 50-rad/min monkeys, however, one did not show a BP drop. Likewise, in the new group of 12 33-rad/min monkeys, one showed no discernible early hypotensive response.

The chief difference among dose-rate groups noted in the earlier findings is borne out strikingly in the present comparison; namely, that the onset of hypotension occurred later and its rate of fall was slower as dose rate was lower. As before, the <sup>60</sup>Co groups' data indicate that

the first signs of developing hypotension appeared after cumulative absorption of approximately 300 rad, which will be examined in more detail below.

The prominent new trend demonstrated by the 33-rad/min group is that their mean BP curve showed no pronounced phasic dip and recovery as did the higher dose-rate groups. The 33-rad/min group's mean BP exhibited instead a gradual decline (beginning most clearly after about 9 min post) to its lowest point at 25 min post and rose only slightly thereafter. Many individual 33-rad/min animals did reveal distinguishably U-shaped BP curves, however, as is evident in the raw data of the Appendix, but as their hypotensive dips were relatively shallow, varied in time phase, and spanned long durations, they were masked in the averaged curve shown.

The timing and extent of the blood pressure changes are compared in more detail over dose-rate groups in Table 7. The table's first column indicates that the first noticeable drop in BP occurred significantly later as dose rate was lower. The second column indicates the approximate cumulative dose absorbed at the time of the first drop. The three lower dose-rate  $^{60}\text{Co}$  groups revealed similar mean cumulative absorbed doses of approximately 300 rad at the onset of hypotension, supporting our earlier conclusion of a minimum

TABLE 7

## TIMING AND EXTENT OF POSTIRRADIATION BLOOD PRESSURE CHANGES\*

Dose-Rate Group	(1) BP Drop Start	(2) Cum. Dose	(3) Lowest BP%	(4) Time of Low BP%	(5) Fall Time	(6) Time of Recov.	(7) Recov. BP%	(8) Min. to Recov.
<u>AFRRI 4000 Rad Pulse:</u>	0	4000	50	3	3	20	75	17
<u>Rad/Min <sup>60</sup>Co:</u>								
180 (n=12)	2.83 <sup>ab</sup> (0.94)	509	37.58 <sup>a</sup> (11.96)	7.08 <sup>a</sup> (2.35)	4.25 <sup>ab</sup> (1.76)	21.83 <sup>a</sup> (4.76)	83.99 (13.00)	14.67 <sup>a</sup> (5.63)
75 (n=12)	4.42 <sup>ab</sup> (1.08)	332	43.58 (14.43)	11.75 <sup>a</sup> (1.60)	7.33 <sup>a</sup> (1.23)	22.00 <sup>b</sup> (3.08)	88.89 (7.60)	10.25 <sup>a</sup> (3.84)
50 (n=11)	6.73 <sup>a</sup> (2.05)	336	42.42 (13.83)	14.27 <sup>a</sup> (2.87)	7.45 <sup>b</sup> (3.86)	24.91 <sup>c</sup> (4.48)	83.15 (8.63)	10.64 (4.46)
33 (n=11)	9.25 <sup>a</sup> (4.00)	308	50.88 <sup>a</sup> (15.15)	20.90 <sup>a</sup> (5.90)	11.10 <sup>a</sup> (4.77)	31.70 <sup>abc</sup> (4.03)	79.07 (16.98)	11.33 (5.94)

\* Within a column, group means bearing the same superscript were significantly different by t-tests ( $p < .05$ ), not including the AFRRI group. Standard deviations are shown in parentheses. One animal in each of the 33 and 50 rad/min groups showed no BP changes and therefore could not be included in the analyses provided in this table.

effective total dose, or threshold, for the induction of the hypotensive response.<sup>1</sup> As mentioned in the earlier report, the higher cumulative dose shown for the 180-rad/min group was probably an overestimate resulting from the poorer timing resolution associated with the higher dose rate delivery, yielding an inflated "threshold" for them.

Column three of Table 7 gives the lowest percentage BP observed for each animal after exposure averaged for each group. This mean differs from the group curves of Figure 2 which showed BP averaged for each minute postirradiation. Column three reflects a rough trend for the depth of hypotension to be greater as a function of higher dose rate. Due to the considerable individual variability, however, only the 33- and 180-rad/min groups are significantly different on this measure. The lowest BP percentage of 50 shown for the AFRR1 group is probably not comparable in this regard because that figure is not the mean of each animal's lowest BP (which data were not available), but rather was the group mean at the third minute postirradiation. In all likelihood, the AFRR1 mean lowest BP percentage shown by individual animals was at least as low as our 180-rad/min group since the AFRR1 monkeys received 4000 rad.

The time of observation of the lowest BP for each animal is averaged for each group in Column 4 of Table 7.

This time postirradiation is significantly delayed with lower dose rate. The mean time required for BP to fall from its initial drop to the lowest point is given in Column 5 (which in effect is Column 4 minus Column 1). The BP fall time was briefer as dose rate was higher, as was suggested by the steeper slopes of the curves for the higher dose-rate groups in Figure 2.

The average number of minutes postexposure by which BP recovered to a stable level--or in some cases, to a peak level followed by a slight decline--is presented in Column 6 of Table 7. A trend is indicated for the time of recovery to occur later as dose rate was lower, but this is influenced by the displacement in time of the onset of hypotension and the ensuing recovery cycle. The BP percentages to which the several groups recovered at the times just noted in Column 6 are given in Column 7. These values are very similar at approximately 80% of preradiation baseline for all groups. The minutes to recovery in Column 8 reflect the mean time between the point of deepest hypotension to the point of recovery or stabilization (i.e., Column 6 minus Column 4). These means are also very similar.

This analysis indicates generally that the phasic hypotensive response occurred earlier, developed more rapidly and its depth was more severe as a function of higher dose-

rate exposure. The duration of recovery did not vary much over groups, however, as the time to BP stabilization elapsing from either the onset (Column 1) or deepest point (Column 4) to the time of recovery (Column 6) was between 18 and 22 min for all  $^{60}\text{Co}$  groups.

#### Heart Rate

Heart rate (HR) increased after 8-9 min post for the 33-rad/min group, which represents a somewhat delayed response relative to the higher dose-rate groups based on a comparison of the curves of Figure 2. About the same higher, stable HR was achieved by the 33-rad/min group as the other groups at the final observations. No orderly relations between HR change and dose rate were noticeable besides the delayed appearance of tachycardia with lower dose rate, which corresponds to the delayed onset of hypotension observed with lower dose rate.

#### Association Between BP and PD/ETI

Every animal which showed significant early PD/ETI likewise showed concurrent hypotension, irrespective of dose-rate group. The mean percentage BP recorded during the minute when penalty score increases were first clearly noticed was 36.89 (s.d. = 14.13) for the 18 animals showing PD/ETI for

which useable BP data were available (four and two BP records were unuseable for the 180- and 33-rad/min groups, respectively). In other words, 84% (the percentage included by the mean + 1 s.d. in a normal distribution) of the PD animals had undergone drops in BP to 51% or less of baseline (mean + s.d. = 36.89 + 14.13 = 51%), at the time of PD onset. In 13 of the 18 cases the nadir of hypotension preceded the onset of PD by 1-4 min, and in most cases, by 2 min. In the other five cases, the lowest BP point and PD onset occurred during the same minute. In all cases, the BP had already started falling at least 1 min prior to the initial penalty score increase.

A chi square 2 x 2 contingency analysis of the association between depth of postradiation hypotension and PD/ETI was carried out and is presented in Table 8. The chi-square technique was deemed appropriate because of the tendency for radiation-induced PD/ETI to be categorically present or absent rather than varying continuously in degree from absent to ETI.<sup>2</sup> For example, the penalty PD ratios associated with no decrement cannot be interpreted as quantitatively describing the qualitative goodness of the unaffected performance. For this reason, the classification of significant PD when the PD ratio exceeded 3.0, or when an ETI occurred, was

TABLE 8

$\chi^2$  CONTINGENCY ANALYSES DETERMINING THE ASSOCIATION BETWEEN DEPTH OF HYPOTENSION AND FREQUENCY OF PD/ETI

33	50
$\Sigma$	
75	180

Quadrant Layout of Groups

SUMMARY

%BP	$\chi^2$	C
55	3.47 <sup>†</sup>	.26
50	4.04 <sup>‡</sup>	.28
45	9.14 <sup>*</sup>	.40
40	11.43 <sup>**</sup>	.44
35	16.81 <sup>**</sup>	.51
30	10.71 <sup>*</sup>	.43

† P > .05 < .10    \* P < .01  
 ‡ P < .05        \*\* P < .001

% BP	PD Ratio			
	<3	>3+ETI	<3	>3+ETI
>55	4	3 0	7	4 0
	10	1	18	2
≤55	3	0 0	5	2 1
	7	5 1	4	4 1
	20	17	12	16
	5	3 4	3	1 3
		8		8
>50	5	3 0	9	5 0
	13	2	23	4
≤50	4	1 1	6	3 1
	6	5 1	2	3 1
	17	16	7	14
	4	2 3	2	0 3
		8		6
>35	10	7 0	11	8 1
	28	6	30	11
≤35	8	3 1	8	3 2
	1	1 1	0	0 0
	2	12	0	0 0
	0	0 3	0	0 2
		5		4

a convenient criterion for the dichotomy required for contingency analysis.

In Table 8, six four-fold contingency analyses are presented to characterize the BP-PD/ETI interdependence. All animals of the four dose-rate groups having useable BP data ( $\underline{N} = 48$ ) were included. The quadrant layout at the left indicates the position of the respective groups within each of the six contingency tables. The frequency of monkeys in each group having PD ratios less than 3.0 vs those yielding ratios greater than 3.0 plus those which quit (ETI) during the first 20-min postexposure formed one dichotomy. The frequency exhibiting BP nadirs during the initial 20 min which were greater vs less than the indicated percentages of preradiation baseline formed the apposing dichotomy. The sum of the group frequencies is shown in the concentric box of each quadrant. The latter sums were used for the chi-square analyses. The individual group frequencies are presented for information only.

The summary at the left in Table 8 gives the chi-square values and contingency coefficients<sup>4</sup> for the six analyses  $\left[ \underline{C} = \chi^2 + (\underline{N} + \chi^2)^{\frac{1}{2}} \right]$ . It is evident that the strength of association between PD/ETI and BP was greatest ( $\underline{C} = .51$ ) when the animals were dichotomized according to

whether or not the lowest postexposure BP was less than or equal to 35% of baseline. The next strongest association was for the dichotomy at 40% BP ( $\underline{C} = .44$ ), while a slightly smaller  $\underline{C}$  obtained at 30%.

Dividing the animals at 55% BP failed to yield a significant  $\chi^2$ . Only one of the 18 animals showing significant PD (excluding those without BP data) exhibited early hypotension which, at its nadir, was above 55% of baseline. Only 2 of the 18 likewise exceeded 45% baseline BP. These and other such outcomes can be determined from the individual group frequencies shown in the corners of the quadrants in Table 8. It is apparent that a cutoff at 50% BP and below quickly engages the PD responders. Nevertheless a sizeable proportion of subjects undergoing BP drops of 50% or more did not demonstrate PD/ETI (17/33 = 52%).

#### Later Effects

Some signs of performance impairment became obvious for several of the animals between 30 and 60 min post-exposure. These cases involved both animals who showed and did not show PD prior to 30 min. The later decrements were observed for two monkeys in the 33-rad/min group, and for two, four, and four, respectively, in the 50-, 75-, and 180-rad/min groups. Such decrements were not associated with

further changes in BP, however, which had stabilized earlier. Such second or delayed decrements have been reported before,<sup>3,11</sup> and seem most readily ascribable to the motor impairment and distraction associated with concurrent emesis or retching episodes. Emesis has been shown to occur most regularly in monkeys between 30 and 60 min post-exposure with X-radiation in the present dose-rate range.<sup>6</sup> Our own monitoring of the animals at this time period via closed-circuit television has supported this conclusion.

## DISCUSSION

The present results establish the existence of a systematic relationship between <sup>60</sup>Co exposure dose rate and (a) the incidence and severity of PD/ETI and (b) the development of hypotension. With respect to the gradations of PD produced, the four dose rates administered appeared to encompass reasonably well the effective range over which differential PD effects may be discernible. Previous related studies have employed only dose rates of 200 rad/min or greater and have reported no dose-rate effects.<sup>2,7-9</sup>

The dose rate model developed from the present data (Fig. 1) implied a near-zero incidence of PD/ETI at 25 rad/min, and predicted a median effective dose rate at about 94 rad/min.

An upward extrapolation predicts that virtually all animals would exhibit significant PD/ETI at approximately 350 rad/min. It should be recognized that predictions such as the above are predicated upon the use of a complex performance task and sensitive scoring technique, as were presently utilized. Otherwise higher dose rate estimates would be proposed by analogy to our earlier finding that PD was detected by the present methods at substantially lower total doses than had previously been considered effective.<sup>2</sup>

The present results further support the previously espoused notion of a minimum effective, or threshold, cumulative total dose for the elicitation of the immediate post-irradiation syndrome.<sup>1,2</sup> The data now available from our lower dose rate groups allow the conclusion that the threshold cumulative dose of <sup>60</sup>Co is approximately 300 rad for the hypotensive response. This figure derived from the calculation of estimated midbody absorbed dose at the time of the first sign of developing hypotension postexposure. Considering that we might have included a response latency preceding the visible change in BP in the above calculation, the threshold dose might be even lower. Any response latency would be overlooked by the present method of administering the exposure beyond the onset of symptoms.

The two hypothesized thresholds, for total dose and dose rate, are proposed to operate jointly. That is, administration of a suprathreshold dose rate (e.g., 25+ rad/min) must be continued until the cumulative minimum (300+ rads) has been attained, according to the present interpretation of the data. This proposition, however, must await direct empirical test. The potential importance for the full development of deep hypotension and the subsequent occurrence of PD/ETI, of continuing the exposure past the 300 rad threshold, as has been our procedure, is unknown, but could be readily determined by limiting total dose below our standard 1000 rad. Earlier we estimated the total dose threshold for PD to be on the order of 500 rad.<sup>2</sup>

The relations between dose rate and hypotension were strikingly lawful among the present groups. The first signs of BP drop were systematically delayed with lower dose rate until approximately 300+ rad had been absorbed (calculated dose). The slope (rate of fall) of the BP drop was more gradual as dose rate was lower, and the BP nadir was shallower. The progressively shallower hypotensive dips may be explained by supposing that not only was the vascular response less precipitous as the radiation insult was administered more slowly, but also that any compensatory cardiovascular

adjustments responding to counter the developing hypotension would have more opportunity to offset it. Ultimately, therefore, at some sufficiently slow exposure the immediate, phasic hypotension described here should not be visible. Only the gradual, progressive hypotension regularly seen at a later time (e.g., hours) postirradiation in many species, at a variety of dose rates, would be recorded.<sup>10</sup>

Three forms of connection were demonstrated by the present results between postirradiation hypotension and PD/ETI. First, all monkeys showing PD/ETI demonstrated some hypotension. There have been no reports of radiation-induced PD/ETI in the absence of hypotension from other laboratories. Second, a close temporal contiguity was noted between the hypotensive nadir and the onset of the PD/ETI episode among those monkeys exhibiting measurable impairment. This has been a regularly observed coincidence.<sup>11</sup> Third, an increasing strength of association was revealed between depth of hypotension and frequency of PD/ETI as the nadir of hypotension declined below 50% of baseline. These associations, tempered by the observation that many hypotensive animals did not exhibit measurable PE/ETI, lead to the conclusion that hypotension is a necessary but not sufficient condition for the occurrence of PD/ETI.

In a concurrent report, we have emphasized the obvious point that "...hypotension constitutes only one component of a complex composite of cardiovascular sequelae to exposure."<sup>12</sup> The recording of only BP provides very little information as the status of the numerous other circulatory variables. Immediate postirradiation measurements of cardiac output and peripheral vascular resistance performed along with BP, in the contemporaneous report, were interpreted as supporting the inference that an impaired cerebral blood supply forms the physiological basis for the PD/ETI phenomena.<sup>12</sup>

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APPENDIX

Table A-1

PENALTY WEIGHTS ASSIGNED FOR ERRORS AND OMISSIONS  
USED IN CALCULATING THE PERFORMANCE PENALTY SCORE

Type	Run Length	Penalty Weights
<u>Match Error (ME):</u>	1 or 2	1 each ME
	3	4
	4	9
	5	16
	≥6	11 each ME
<u>Match Omission (MO):</u>	1	16
	≥2	25 each MO
<u>Sample Omission (SO):</u>	1	4
	2	25
	3	50
	4	75
	5	100
	6 (= Quit)	150
<u>Mixed (MX):</u>		25 each occurrence

TABLE A-2

INITIAL 20-MIN POSTIRRADIATION PENALTY SCORING

Monkey 684: Exposure dose = 1000 rad, rate = 179 rad/min, duration = 5.6 min, DMTS task, 4 match alternatives, 5-sec delay between sample and match

Minute	Trial	Sample	Match	Penalty	Minute	Trial	Sample	Match	Penalty
	1	+	-			36	+	+	
	2	+	-			37	+	+	
	3	+	-	4 (3 ME)	9	38	+	+	
1	4	+	+			39	+	+	
	5	+	+			40	+	+	
	6	+	+			41	+	+	
	7	+	+		10	42	+	+	
2	8	+	+			43	+	+	
	9	+	+			44	+	●	
	10	+	+		11	45	+	+	
3	11	+	+			46	+	+	
	12	+	+			47	+	+	
	13	+	+		12	48	+	-	1 (ME)
4	14	+	+			49	+	-	1 (ME)
	15	+	-			50	+	+	
	16	+	-			51	+	-	1 (ME)
	17	+	-	4 (3 ME)	13	52	+	+	
5	18	+	+			53	+	+	
	19	+	+			54	+	●	
	20	+	-			55	+	+	
	21	+	-		14	56	+	+	
6	22	+	-	4 (3 ME)		57	+	+	
				25 (MX)		58	+	+	
	23	SO		4 (SO)	15	59	+	+	
				25 (MX)		60	+	+	
	24	+	MO	16 (MO)		61	+	+	
				25 (MX)		62	+	+	
	25	SO			16	63	+	+	
	26	SO				64	+	+	
	27	SO				65	+	+	
	28	SO				66	+	+	
	29	SO		100 (5 SO)	17	67	+	+	
				25 (MX)		68	+	+	
	30	+	-	1 (ME)		69	+	+	
7				25 (MX)	18	70	+	-	1 (ME)
	31	SO		4 (SO)		71	+	-	1 (ME)
	32	+	+			72	+	+	
	33	+	+		19	73	+	+	
	34	+	+			74	+	+	
8	35	+	+		20	75	+	+	

PENALTY SUM = 267

**Legend:** Sample + = sample key press  
 Sample SO = no response to sample, omission (SO)  
 Match + = correct match choice  
 Match - = incorrect match choice, error (ME)  
 Match MO = no response to match stimuli, omission (MO)  
 MX = mixed; consecutive errors and omissions differing in type, shown by dashed lines

"Trial" indicates each sequential presentation of both sample and match stimuli, except where sample omissions occurred in which case "trial" indicates only that the sample was presented, as the match alternatives were not presented following a sample omission. Next to each penalty assignment in parenthesis is the number of typg(s) of error(s) and/or omission(s) constituting the score. See Table A-1 for the complete penalty score weighting assignments as a function of errors and omissions.

TABLE A-3

Monkey 854: Exposure dose = 1000 rad, rate = 33.33 rad/min,  
duration = 30 min, DMTS task, 2 match alternatives,  
5-sec delay between sample and match

Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty
	1	+	+											
	2	+	-	1 (ME)	18	65	+	+			127	+	+	
	3	+	+			66	+	-	1 (ME)		128	+	+	
1	4	+	+			67	+	+		43	129	+	+	
	5	+	+			68	+	+			130	+	+	
	6	+	+		19	70	+	+			131	+	-	
	7	+	+			71	+	+			132	+	-	4 (3 ME)
2	8	+	+			72	+	+			133	+	+	
	9	+	+		20	73	+	+		44	134	+	+	
	10	+	+			74	+	+			135	+	+	
3	11	+	+			75	+	+		45	136	+	+	
	12	+	+		21	76	+	-	1 (ME)		137	+	+	
	13	+	-	1 (ME)		77	+	+			138	+	+	
	14	+	-	1 (ME)		78	+	+			139	+	+	
4	15	+	+			79	+	+		46	140	+	+	
	16	+	+		22	80	+	+			141	+	+	
	17	+	+			81	+	-	1 (ME)		142	+	+	
	18	+	-	1 (ME)		82	+	+		47	143	+	+	
5	19	+	-	1 (ME)	23	83	+	-	1 (ME)		144	+	+	
	20	+	+			84	+	+			145	+	+	
	21	+	+			85	+	+			146	+	+	
	22	+	-	1 (ME)		86	+	+		48	147	+	+	
6	23	+	+		24	87	SO		4 (SO)		148	+	+	
	24	+	+						25 (MX)		149	+	+	
	25	+	+			88	+	-	1 (ME)		150	+	+	
	26	+	-	1 (ME)		89	+	+		49	151	+	+	
	27	+	+			90	+	+			152	+	+	
	28	+	+		25	91	+	+		50	153	+	-	1 (ME)
	29	+	+			92	+	+			154	+	+	
8	30	+	+			93	+	+		51	155	+	+	
	31	+	+			94	+	+			156	+	+	
	32	+	+		26	95	+	+			157	+	+	
9	33	+	+			96	+	+		52	158	+	+	
	34	+	+			97	+	+			159	+	+	
	35	+	+		27	98	+	+		53	160	+	+	
	36	+	+			99	+	-	1 (ME)		161	+	+	
10	37	+	+			100	+	+		54	162	+	+	
	38	+	-	1 (ME)		101	+	-	1 (ME)		163	+	+	
	39	+	-	1 (ME)	28	102	+	-	1 (ME)		164	+	-	1 (ME)
	40	+	+			103	+	+		55	165	+	+	
11	41	+	+			104	+	+			166	+	-	1 (ME)
	42	+	-	1 (ME)		105	+	+		56	167	+	+	
	43	+	+			106	+	+			168	+	+	
	44	+	+		29	107	+	+		57	169	+	+	
12	45	+	+			108	+	+			170	+	+	
	46	+	+			109	+	+		58	171	+	+	
	47	+	+			110	+	-	1 (ME)		172	+	+	
13	48	+	+		30	111	+	+		59	173	+	+	
	49	+	+			112	+	-	1 (ME)		174	+	-	1 (ME)
	50	+	+			113	+	+		60	175	+	+	
14	51	+	-	1 (ME)	31	114	+	+			176	+	+	
	52	+	+			8 MIN. BREAK					177	+	-	1 (ME)
	53	+	+			115	+	+		57	178	+	+	
	54	+	+			116	+	+			179	SO		4 (SO)
	55	+	+			117	+	-	1 (ME)		180	+	+	
15	56	+	+			118	+	+			181	+	+	
	57	+	+			119	+	+		58	182	+	+	
	58	+	+		40	120	+	+			183	+	+	
16	59	+	+			121	+	+			184	+	+	
	60	+	+			122	+	+		59	185	+	-	1 (ME)
	61	+	+		41	123	+	+			186	+	-	1 (ME)
17	62	+	+			124	+	-	1 (ME)		187	+	+	
	63	+	+			125	+	+			188	+	+	
	64	+	+		42	126	+	-	1 (ME)		189	+	+	
										60	190	+	-	1 (ME)
											191	+	-	1 (ME)

Penalty Sums for 20-Min Blocks

0-20 min = 12

20-40 min = 66.63\*

40-60 min = 19

10-30 min = 42

30-50 min = 13.82\*

\*Experimenter break, penalty sums extrapolated from available minutes

TABLE A-4

Monkey 923: Exposure dose = 1000 rad, rate = 33.33 rad/min,  
duration = 30 min, DMTS task, 2 match alternatives,  
10-sec delay between sample and match

Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty
	1	+	+							43	101	+	-	1 (ME)
	2	+	+		21	51	+	+			102	+	-	1 (ME)
1	3	+	+			52	+	+			103	+	+	
	4	+	+			53	+	+		44	104	+	-	1 (ME)
	5	+	+		22	54	+	+			105	+	+	
2	6	+	+			55	+	+		45	106	+	+	
	7	+	+			56	+	+			107	+	+	
	8	+	+		23	57	+	+			108	+	+	
3	9	+	+			58	+	-	1 (ME)	46	109	+	-	1 (ME)
	10	+	-	1 (ME)		59	+	+			110	+	+	
4	11	+	-	1 (ME)	24	60	+	+			111	+	+	
	12	+	+			61	+	+		47	112	+	+	
	13	+	+		25	62	+	+			113	+	-	1 (ME)
5	14	+	+			63	+	-	1 (ME)		114	+	+	
	15	+	+			64	+	+		48	115	+	-	
6	16	+	+		26	65	+	+			116	+	-	
	17	+	+			66	+	+			117	+	-	
	18	+	+			67	+	+			118	+	-	
	19	+	+		27	68	+	+		49	119	+	-	16 (5 ME)
7	20	+	+			69	+	+			120	+	+	
	21	+	-	1 (ME)		70	+	+			121	+	+	
	22	+	+		28	71	+	+		50	122	+	+	
8	23	+	+			72	+	-	1 (ME)		123	+	-	1 (ME)
	24	+	-	1 (ME)		73	+	+			124	+	+	
	25	+	+		29	74	+	+		51	125	+	+	
9	26	+	+			75	+	+			126	+	+	
	27	+	-	1 (ME)		76	+	-	1 (ME)	52	127	+	+	
	28	+	+		30	77	+	+			128	+	+	
10	29	+	-	1 (ME)		78	+	+			129	+	+	
	30	+	+		31	79	+	+		53	130	+	+	
	31	+	+			80	+	-	1 (ME)		131	+	-	1 (ME)
11	32	+	+			4 MIN. BREAK					132	+	+	
	33	+	+			81	+	-	1 (ME)	54	133	+	+	
12	34	+	-	1 (ME)	36	82	+	+			134	+	-	1 (ME)
	35	+	+			83	+	-	1 (ME)		135	+	+	
	36	+	+		37	84	+	+		55	136	+	+	
13	37	+	+			85	+	+			137	+	-	1 (ME)
	3 MIN. LOST*					38	86	+	+		138	+	+	
	38	+	+			87	+	+		56	139	+	+	
	39	+	+			88	+	+			140	+	-	1 (ME)
	40	+	+		39	89	+	+			141	+	+	
17	41	+	-	1 (ME)		90	+	+		57	142	+	+	
	42	+	+			91	+	+			143	+	+	
	43	+	+		40	92	+	+		58	144	+	-	
18	44	+	+			93	+	-	1 (ME)		145	+	-	
	45	+	+			94	+	+			146	+	+	4 (3 ME)
19	46	+	+		41	95	+	-	1 (ME)	59	147	+	+	
	47	+	+			96	+	-	1 (ME)		148	+	+	
	48	+	+		42	97	+	+			149	+	+	
20	49	+	+			98	+	+		60	150	+	+	
	50	+	-	1 (ME)		99	+	+						
						100	+	+						

Penalty Sums for 20-Min Blocks

0-20 min = 9.41\*      20-40 min = 10.00\*\*      40-60 min = 34.74\*  
10-30 min = 8.23\*      30-50 min = 35.28\*\*

\* Lost data, penalty sums extrapolated from available minutes.  
\*\* Experimenter break, penalty sums extrapolated from available minutes.

TABLE A-5

Monkey 877: Exposure dose = 1000 rad, rate = 33.33 rad/min, duration = 30 min, DMTS task, 2 match alternatives, 10-sec delay between sample and match

Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty
	1	+	+		20	52	+	+		42	102	+	-	1 (ME)
	2	+	+			53	+	-			103	+	+	
1	3	+	+			54	+	-			104	+	+	
	4	+	+		21	55	+	-	4 (3 ME)	43	105	+	+	
2	5	+	-	1 (ME)		56	+	+			106	+	+	
	6	+	+			57	+	+			107	+	-	1 (ME)
	7	+	+		22	58	+	+		44	108	+	+	
3	8	+	+			59	+	+			109	+	+	
	9	+	+		23	60	+	+		45	110	+	-	1 (ME)
4	10	+	+			61	+	+			111	+	+	
	11	+	+			62	+	-	1 (ME)	46	112	+	+	
	12	+	+		24	63	+	+			113	+	+	
5	13	+	+			64	+	+		47	114	+	+	
	14	+	+		25	65	+	+			115	+	+	
6	15	+	+			66	+	-	1 (ME)	48	116	+	-	1 (ME)
	16	+	+			67	+	+			117	+	+	
	17	+	+		26	68	+	+		49	118	+	+	
7	18	+	+			69	+	+			119	+	+	
	19	+	+		27	70	+	+		50	120	+	+	
8	20	+	+			71	+	+			121	+	+	
	21	+	-	1 (ME)		72	+	+			122	+	+	
	22	+	+		28	73	+	-	1 (ME)		123	+	-	
9	23	+	+			74	+	+		51	124	+	-	
	24	+	+			75	+	-	1 (ME)		125	+	-	4 (3 ME)
10	25	+	+		29	76	+	+			126	+	+	
	26	+	+			77	+	+		52	127	+	+	
	27	+	+		30	78	+	+			128	+	-	
11	28	+	+			79	+	+		53	129	+	-	
	29	+	-	1 (ME)		80	+	+			130	+	-	4 (3 ME)
	30	+	+		31	81	+	+		54	131	+	+	
12	31	+	-	1 (ME)		82	+	+			132	+	+	
	32	+	+			4 MIN. BREAK				55	133	+	+	
	33	+	+			83	+	+			134	+	+	
13	34	+	+			84	+	+		56	135	+	-	1 (ME)
	35	+	-	1 (ME)	36	85	+	+			136	+	+	
	36	+	+			86	+	-	1 (ME)	57	137	+	-	1 (ME)
14	37	+	+			87	+	-	1 (ME)		138	+	+	
	38	+	+		37	88	+	+		58	139	+	+	
15	39	+	+			89	+	+			140	+	+	
	40	+	+			90	+	-	1 (ME)	59	141	+	-	1 (ME)
16	41	+	+		38	91	+	+			142	+	+	
	42	+	+			92	+	+		57	143	+	-	1 (ME)
	43	+	+			93	+	+			144	+	+	
17	44	+	+		39	94	+	+		58	145	+	-	
	45	+	+			95	+	-	1 (ME)		146	+	-	
	46	+	+		40	96	+	+			147	+	-	4 (3 ME)
18	47	+	+			97	+	+		59	148	+	+	
	48	+	+			98	+	+			149	+	+	
19	49	+	+		41	99	+	+			150	+	+	
	50	+	-	1 (ME)		100	+	+		60	151	+	+	
	51	+	-	1 (ME)		101	+	-	1 (ME)					

Penalty Sums for 20-Min Blocks

0-20 min = 7                      20-40 min = 15\*                      40-60 min = 21  
 10-30 min = 13                      30-50 min = 14.69\*

\*Experimenter break, penalty sums extrapolated from available minutes.

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TABLE A-6

Monkey 898: Exposure dose = 1000 rad, rate = 33.33 rad/min,  
duration = 33 min, DMTS task, 2 match alternatives,  
10-sec delay between sample and match

Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty
	1	+	+		19	53	+	+		42	104	+	+	
	2	+	+			54	+	+			105	+	-	1 (ME)
1	3	+	+			55	+	+			106	+	+	
	4	+	+		20	56	+	+		43	107	+	+	
	5	+	+			57	+	+			108	+	+	
2	6	+	+			58	+	+			109	+	-	1 (ME)
	7	+	+		21	59	+	+		44	110	+	+	
	8	+	+			60	+	+			111	+	+	
3	9	+	+		22	61	+	+			112	+	+	
	10	+	+			62	+	-	1 (ME)	45	113	+	+	
	11	+	+		23	63	+	+			114	+	+	
4	12	+	+			64	+	-	1 (ME)		115	+	+	
	13	+	-	1 (ME)		65	+	+		46	116	+	-	1 (ME)
	14	+	+		24	66	+	+			117	+	+	
5	15	+	+			67	+	+			118	+	+	
	16	+	+			68	+	-	1 (ME)	47	119	+	-	1 (ME)
6	17	+	+		25	69	+	+			120	+	+	
	18	+	+			70	+	+			121	+	+	
7	19	+	+		26	71	+	+		48	122	+	+	
	20	+	+			72	+	+			123	+	+	
	21	+	+			73	+	+			124	+	-	1 (ME)
	22	+	+			74	+	-	1 (ME)	49	125	+	+	
8	23	+	+		27	75	+	+			126	+	-	1 (ME)
	24	+	+			76	+	+			127	+	+	
	25	+	+			77	+	+		50	128	+	+	
9	26	+	+		28	78	+	+			129	+	+	
	27	+	+			79	+	+		51	130	+	+	
10	28	+	+		29	80	+	-	1 (ME)		131	+	+	
	29	+	+			81	+	+			132	+	+	
	30	+	+			82	+	-	1 (ME)	52	133	+	+	
11	31	+	+		30	83	+	+			134	+	-	1 (ME)
	32	+	+			84	+	+			135	+	+	
	33	+	+			85	+	+		53	136	+	+	
12	34	+	+		31	86	+	+			137	+	+	
	35	+	+			87	+	+		54	138	+	+	
	36	+	+		32	88	+	+			139	+	+	
13	37	•	-	1 (ME)		4 MIN. BREAK				55	140	+	+	
	38	+	+			89	+	-	1 (ME)		141	+	+	
	39	+	+		37	90	+	+			142	+	+	
14	40	+	+			91	+	+			143	+	+	
	41	+	+			92	+	+		56	144	+	+	
	42	+	-	1 (ME)	38	93	+	+			145	+	+	
15	43	+	+			94	+	+			146	+	+	
	44	+	+			95	+	+		57	147	+	+	
16	45	+	+		39	96	+	+			148	+	+	
	46	+	+			97	+	+			149	+	-	1 (ME)
	47	+	+			98	+	+		58	150	+	+	
17	48	+	+		40	99	+	+			151	+	-	1 (ME)
	49	+	+			100	+	+			152	+	+	
	50	+	+			101	+	+		59	153	+	+	
18	51	+	+		41	102	+	+			154	+	+	
	52	+	+			103	+	+		60	155	+	+	

Penalty Sums for 20-Min Blocks

0-20 min = 3                      20-40 min = 8.75\*                      40-60 min = 9  
 10-30 min = 8                      30-50 min = 9\*  
 \*Experimenter break, penalty sums extrapolated from available minutes.

TABLE A-7

Monkey 834: Exposure dose = 1000 rad, rate = 33.33 rad/min, duration = 30 min, DMTS task, 2 match alternatives, 10-sec delay between sample and match

Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty
1	1	+	-	1 (ME)	19	54	+	+			106	+	+	
	2	+	+			55	+	+			107	+	+	
1	3	+	-	1 (ME)		56	+	+		42	108	+	-	1 (ME)
	4	+	+			57	+	+			109	+	+	
	5	+	+		20	58	+	+		43	110	+	+	
	6	+	-	1 (ME)		59	+	+			111	+	+	
2	7	+	+			60	+	+		44	112	+	+	
	8	+	+		21	61	+	+			113	+	+	
3	9	+	+			62	+	-	1 (ME)		114	+	+	
	10	+	+			63	+	+		45	115	+	-	1 (ME)
	11	+	+		22	64	+	+			116	+	-	1 (ME)
4	12	+	+			65	+	+			117	+	+	
	13	+	-	1 (ME)		66	+	+		46	118	+	-	1 (ME)
	14	+	+		23	67	+	+			119	+	+	
	15	+	+			68	+	+			120	+	+	
5	16	+	+		24	69	+	-	1 (ME)	47	121	+	+	
	17	+	+			70	+	-	1 (ME)		122	+	+	
	18	+	+			71	+	+			123	+	+	
6	19	+	+		25	72	+	-	1 (ME)	48	124	+	+	
	20	+	-	1 (ME)		73	+	+			125	+	+	
7	21	+	+			74	+	+			126	+	-	1 (ME)
	22	+	+		26	75	+	+		49	127	+	-	1 (ME)
8	23	+	-	1 (ME)		76	+	+			128	+	+	
	24	+	+			77	+	-	1 (ME)		129	+	+	
	25	+	+		27	78	+	+		50	130	+	+	
	26	+	+			79	+	+			131	+	+	
9	27	+	+			80	+	+			132	+	+	
	28	+	-	1 (ME)	28	81	+	-	1 (ME)	51	133	+	+	
	29	+	+			82	+	+			134	+	+	
10	30	+	-	1 (ME)		83	+	+		52	135	+	-	1 (ME)
	31	+	+		29	84	+	+			136	+	+	
11	32	+	-	1 (ME)		85	+	-	1 (ME)		137	+	+	
	33	+	+			86	+	-	1 (ME)	53	138	+	+	
	34	+	+		30	87	+	+			139	+	-	1 (ME)
12	35	+	+			88	+	+			140	+	+	
	36	+	+			89	+	-	1 (ME)	54	141	+	-	1 (ME)
13	37	+	+		31	90	+	+			142	+	-	1 (ME)
	38	+	+			5 MIN. BREAK					143	+	+	
	39	+	+			91	+	+			144	+	+	
14	40	+	+		37	92	+	+		55	145	+	-	1 (ME)
	41	+	+			93	+	-	1 (ME)		146	+	+	
	42	+	+			94	+	+			147	+	-	1 (ME)
15	43	+	-	1 (ME)		95	+	+		56	148	+	+	
	44	+	+		38	96	+	-	1 (ME)		149	+	+	
16	45	+	+			97	+	-	1 (ME)	57	150	+	+	
	46	+	+			98	+	+			151	+	+	
	47	+	+		39	99	+	+			152	+	+	
	48	+	-	1 (ME)		100	+	+		58	153	+	-	1 (ME)
17	49	+	+			101	+	+			154	+	+	
	50	+	-	1 (ME)	40	102	+	+			155	+	-	1 (ME)
	51	+	+			103	+	+		59	156	+	-	1 (ME)
18	52	+	+		41	104	+	+			157	+	+	
	53	+	+			105	+	+			158	+	+	
										60	159	+	+	

Penalty Sums for 20-Min Blocks

0-20 min = 14      20-40 min = 16\*      40-60 min = 15  
 10-30 min = 12      30-50 min = 12.21\*  
 \*Experimenter break, penalty sums extrapolated from available minutes.

TABLE A-8

Monkey 804: Exposure dose = 1000 rad, rate = 33.33 rad/min,  
duration = 30 min, DMTS task, 2 match alternatives,  
10-sec delay between sample and match

Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty
	1	+	+		19	49	+	-	1 (ME)		96	+	+	
	2	+	-	1 (ME)		50	+	+		43	97	+	+	
1	3	+	-	1 (ME)		51	+	+			98	+	-	1 (ME)
	4	+	+		20	52	+	-			99	+	+	
	5	+	+			53	+	-		44	100	+	-	1 (ME)
2	6	+	+		21	54	+	-	4 (3 ME)		101	+	+	
	7	+	-	1 (ME)		55	+	+		45	102	+	+	
	8	+	+		22	56	+	+			103	+	+	
3	9	+	+			57	+	+		46	104	+	+	
	10	+	+		23	58	+	-	1 (ME)		105	+	+	
4	11	+	+			59	+	+			106	+	-	1 (ME)
	12	+	+			60	+	+		47	107	+	+	
	13	+	-	1 (ME)		61	+	+			108	+	+	
5	14	+	+		24	62	+	+		48	109	+	+	
	15	+	+			63	+	+			110	+	+	
6	16	+	+			64	+	+		49	111	+	+	
	17	+	+		25	65	+	+			112	+	+	
	18	+	+			66	+	+		50	113	+	+	
7	19	+	+		26	67	+	+			114	+	+	
	20	+	+			68	+	+		51	115	+	+	
8	21	+	-	1 (ME)	27	69	+	-	1 (ME)		116	+	+	
	22	+	+			70	+	+			117	+	+	
9	23	+	+			71	+	+		52	118	SO		4 (SO)
	24	+	-	1 (ME)	28	72	+	+			119	+	+	
	25	+	-	1 (ME)		73	+	+			120	+	+	
10	26	+	+			74	+	-	1 (ME)		121	+	+	
	27	+	+		29	75	+	-	1 (ME)	53	122	+	+	
	28	+	+			76	+	+			123	+	-	1 (ME)
11	29	+	+			77	+	-	1 (ME)	54	124	+	+	
	30	+	+		30	78	+	-	1 (ME)		125	+	+	
	31	+	+			79	+	+			126	+	+	
12	32	+	+			80	+	+		55	127	+	-	
	33	+	+		31	81	+	+			128	+	-	
13	34	+	+			6 MIN. BREAK					129	+	-	4 (3 ME)
	35	+	+			82	+	+		56	130	+	+	
	36	+	+		38	83	+	+			131	+	-	1 (ME)
14	37	+	+			84	+	-	1 (ME)		132	+	+	
	38	+	+			85	+	+		57	133	+	+	
15	39	+	+		39	86	+	-	1 (ME)		134	+	+	
	40	+	+			87	+	+		58	135	+	+	
16	41	+	-	1 (ME)		88	+	+			136	+	+	
	42	+	+		40	89	+	+			137	+	+	
	43	+	+			90	+	-	1 (ME)	59	138	+	-	1 (ME)
17	44	+	+			91	+	+			139	+	+	
	45	+	-	1 (ME)	41	92	+	-	1 (ME)		140	+	+	
18	46	+	+			93	+	-	1 (ME)		141	+	+	
	47	+	+			94	+	+		60	142	+	+	
	48	+	-	1 (ME)	42	95	+	+			143	+	-	1 (ME)

Penalty Sums for 20-Min Blocks

0-20 min = 12.33      20-40 min = 16.71\*      40-60 min = 17  
10-30 min = 13      30-50 min = 11.69\*

\*Experimenter break, penalty sums extrapolated from available minutes.

TABLE A-9

Monkey 849: Exposure dose = 1000 rad, rate = 33.33 rad/min, duration = 30 min, DMTS task, 2 match alternatives, 10-sec delay between sample and match

Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty	
1	1	+	+		19	49	+	+		46	96	+	+		
	2	+	+			50	+	+			97	+	+		
	3	+	+			51	+	+			98	+	+		
2	4	+	+		20	52	+	+		47	99	+	+		
	5	+	+			53	+	-	1 (ME)		100	+	-	1 (ME)	
	6	+	+			54	+	+			101	+	+		
3	7	+	-	1 (ME)	21	55	+	+		48	102	+	-	1 (ME)	
	8	+	+			56	+	+			103	+	+		
	9	+	-	1 (ME)		57	+	+			104	+	+		
4	10	+	+		22	58	+	+		49	105	+	-	1 (ME)	
	11	+	+			59	+	-			106	+	MO	25 (MX)	
	12	+	+			60	+	-			16 (MO)				
5	13	+	+		23	61	+	-	4 (3 ME)	24	62	+	+	25 (MX)	
	14	+	+			63	+	+			107	SO		4 (SO)	
	15	+	-	1 (ME)		64	+	+			25 (MX)				
6	16	+	+		24	65	+	+		25	66	+	+	1 (ME)	
	17	+	+			67	+	-			108	+	-		
	18	+	+			68	+	-			109	+	+		
7	19	+	-	1 (ME)	25	69	+	-	4 (3 ME)	26	70	+	+		
	20	+	+			71	+	+	1 (ME)		110	+	+		
	21	+	+			72	+	+			111	+	+		
8	22	+	+		26	73	+	+		27	74	+	+		
	23	+	-	1 (ME)		75	+	+			112	SO		4 (SO)	
	24	+	+			76	+	+			113	+	+		
9	25	+	+		27	77	+	+		28	78	+	+		
	26	+	+			79	+	+			114	+	-	1 (ME)	
	27	+	+			80	+	+			25 (MX)				
10	28	+	+		28	81	+	-	1 (ME)	29	82	+	+	4 (SO)	
	29	+	+			83	+	+			25 (MX)				
	30	+	+			84	+	+			16 (MO)				
11	31	+	+		29	85	+	+		30	86	+	+	25 (MX)	
	32	+	+			87	+	-			116	+	MO	16 (MO)	
	33	+	+			88	+	-			25 (MX)				
12	34	+	+		30	89	+	-	9 (4 ME)	50	117	+	-	1 (ME)	
	35	+	+			90	+	+			118	+	+		
	36	+	+			91	+	-	1 (ME)		119	+	+	1 (ME)	
13	37	+	+		31	92	+	-	1 (ME)	51	120	+	-	1 (ME)	
	38	+	-	1 (ME)		93	+	+			121	+	MO	16 (MO)	
	39	+	+			94	+	+			122	+	+		
14	40	+	+		32	95	+	-	1 (ME)	52	123	+	+		
	41	+	+			7 MIN. BREAK	76	+	+			124	+	+	
	42	+	+			77	+	+			125	+	+		
15	43	+	-	1 (ME)	33	78	+	+		53	126	+	+		
	44	+	-	1 (ME)		79	+	+			127	+	-	1 (ME)	
	45	+	+			80	+	+			128	SO		25 (MX)	
16	46	+	+		34	81	+	-	1 (ME)	54	129	+	+	4 (SO)	
	47	+	+			82	+	+			130	+	+		
	48	+	-	1 (ME)		83	+	+			131	+	+		
17	49	+	+		35	84	+	+		55	132	+	-	1 (ME)	
	50	+	+			85	+	+			133	+	+		
	51	+	+			86	+	-			134	+	+		
18	52	+	+		36	87	+	-		56	126	+	+		
	53	+	+			88	+	-			127	+	-	1 (ME)	
	54	+	+			89	+	-	9 (4 ME)		128	SO		25 (MX)	
19	55	+	+		37	90	+	+		57	129	+	+	4 (SO)	
	56	+	+			91	+	-	1 (ME)		130	+	+		
	57	+	+			92	+	-	1 (ME)		131	+	+		
20	58	+	+		38	93	+	+		58	132	+	-	1 (ME)	
	59	+	+			94	+	+			133	+	+		
	60	+	+			95	+	-	1 (ME)		134	+	+		

Penalty Sums for 20-Min Blocks

0-20 min = 9  
10-30 min = 14

20-40 min = 16.92\*  
30-50 min = 172.30\*

40-60 min = 286

\*Experimenter break, penalty sums extrapolated from available blocks.

TABLE A-10

Monkey 868: Exposure dose = 1000 rad, rate = 33.33 rad/min,  
 duration = 30 min, DMST task, 2 match alternatives,  
 10-sec delay between sample and match

Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty	
1	1	+	+		13	36	+	-	1 (ME)	26	70	+	+		
	2	+	+			37	+	+			71	+	+		
	3	+	+			38	+	+			72	+	+		
2	4	+	+		14	39	+	+		27	73	+	+		
	5	SO		4 (SO)		40	+	+			74	+	+		
	6	+	+			41	+	+			28	75	+	+	
3	7	+	+		15	42	+	-	1 (ME)	29	76	+	+		
	8	+	+			43	+	+			77	+	+		
	9	+	+			44	+	+			78	+	-	1 (ME)	
4	10	+	+		16	45	+	+		30	79	+	+		
	11	+	+			46	+	+			80	+	-	1 (ME)	
	12	+	+			47	+	-	1 (ME)		81	+	-	1 (ME)	
5	13	+	+		17	48	+	+		31	82	+	+		
	14	+	-	1 (ME)		49	+	+			83	+	-	1 (ME)	
	15	+	+			50	+	+			84	+	+		
6	16	+	+		18	51	+	-	1 (ME)	32	85	+	-	1 (ME)	
	17	+	+			52	+	+			86	+	-	1 (ME)	
	18	+	+			53	+	+			87	+	+		
7	19	+	+		19	54	+	+		33	88	SO		4 (SO) 25 (MX)	
	20	+	-	1 (ME)		55	+	+			89	+	-		
	21	+	+			56	+	+			90	+	-		
8	22	+	+		20	57	+	+		34	91	+	-	4 (3 ME)	
	23	+	+			58	+	+			92	+	+		
	24	+	+			59	+	+			93	+	-	1 (ME)	
9	25	+	-	1 (ME)	21	60	+	+		35	94	+	+		
	26	+	+			61	+	+			95	+	+		
	27	+	-	1 (ME)		62	+	+			96	SO			
10	28	+	+		22	63	+	+		36	97	SO			
	29	+	+			64	+	+			98	SO			
	30	+	-	1 (ME)		65	+	-	1 (ME)		99	SO			
11	31	+	-	1 (ME)	23	66	+	+		100	SO				
	32	+	+			67	+	+			101	SO		150 (6 SO)	
	33	+	-	1 (ME)		68	+	+						Quit	
12	34	+	+		24	69	+	+					Did not		
	35	+	+										Resume		

0-20 min = 15

Penalty Sums for 20-Min Blocks  
 10-30 min = 11

20-40 min = 191 Quit

TABLE A-11

Monkey 906: Exposure dose = 66.7 rad, rate = 33.3 rad/min,  
 duration = 20 min, DMTS task, 2 match alternatives,  
 10-sec delay between sample and match

Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty	
1	1	+	+		20	57	+	+		43	112	+	+		
	2	+	+			58	+	+			113	+	+		
	3	+	+			59	+	-	1 (ME)		114	+	-	1 (ME)	
2	4	+	+		21	60	+	+		44	115	+	+		
	5	+	-	1 (ME)		61	+	+			116	+	+		
	6	+	-	1 (ME)		62	+	+			117	+	+		
3	7	+	+		22	63	+	+		45	118	+	-		
	8	+	+			64	+	+			119	+	-		
	9	+	+			5 MIN. BREAK			120		+	-	4 (3 ME)		
4	10	+	+		28	65	+	+		46	121	+	+		
	11	+	+			66	+	+			122	+	+		
	12	+	+			67	+	+			123	+	+		
5	13	+	+		29	68	+	-	1 (ME)	47	124	+	+		
	14	+	+			69	+	+			125	+	+	1 (ME)	
	15	+	+			70	+	+			126	+	+		
6	16	+	+		30	71	+	+		48	127	+	+		
	17	+	+			72	+	+			128	+	+		
	18	+	+			73	+	+			129	+	-	1 (ME)	
7	19	+	-	1 (ME)	31	74	+	+		49	130	+	+		
	20	+	+			75	+	+			131	+	-	1 (ME)	
	21	+	+			76	+	+			132	+	+		
8	22	+	+		32	77	+	-	1 (ME)	50	133	+	+		
	23	+	-	1 (ME)		78	+	+			134	+	+		
	24	+	+			79	+	+			135	+	-		
9	25	+	-	1 (ME)	33	80	+	+		51	136	+	-		
	26	+	+			81	+	+			137	+	-	4 (3 ME)	
	27	+	-	1 (ME)		82	+	+			138	+	+		
10	28	+	+		34	83	+	+		52	139	+	+		
	29	+	+			84	+	+			140	+	+		
	30	+	+			85	+	+			141	+	+		
11	31	+	+		35	86	+	-	1 (ME)	53	142	+	+		
	32	+	+			87	+	+			143	+	+		
	33	+	+			88	+	+			144	+	+		
12	34	+	-	1 (ME)	36	89	+	+		54	145	+	+		
	35	+	-	1 (ME)		90	+	+			146	+	+		
	36	+	+			91	+	-			147	+	+		
13	37	+	-	1 (ME)	37	92	+	-		55	148	+	-	1 (ME)	
	38	+	+			93	+	-			149	+	-	1 (ME)	
	39	+	+			94	+	-	9 (4 ME)		150	+	+		
14	40	+	+		38	95	+	+		56	151	+	+		
	41	+	-	1 (ME)		96	+	-	1 (ME)		152	+	-	1 (ME)	
	42	+	+			97	+	-	1 (ME)		153	+	-	1 (ME)	
15	43	+	+		39	98	+	+		57	154	+	+		
	44	+	+			99	+	+			155	+	+		
	45	+	+			100	+	-	1 (ME)		156	+	-	1 (ME)	
16	46	+	-	1 (ME)	40	101	+	+		58	157	+	-	1 (ME)	
	47	+	+			102	+	+			158	+	+		
	48	+	-	1 (ME)		103	+	+			159	+	+		
17	49	+	+		41	104	+	+		59	160	+	+		
	50	+	+			105	+	+			161	+	+		
	51	+	-	1 (ME)		106	+	-			162	+	+		
18	52	+	+		42	107	+	-		60	163	+	-		
	53	+	+			108	+	-			164	+	-		
	54	+	+			109	+	-	9 (1 ME)		165	+	-	1 (3 ME)	
19	55	+	-	1 (ME)		110	+	+			166	+	+		
	56	+	+			111	+	+			167	+	+		

Penalty Sums for 20-Min Blocks

0-20 min = 15                      20-40 min = 20.77\*                      40-60 min = 31  
 10-30 min = 13.33\*                      30-50 min = 35

\*Experimenter break, penalty sums extrapolated from available minutes.

TABLE A-12

Monkey 820: Exposure dose = 1000 rad, rate = 33.33 rad/min,  
duration = 30 min, DMTS task, 2 match alternatives,  
10-sec delay between sample and match

Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty
1	1	+	+		19	55	+	-	1 (ME)	42	108	+	-	1 (ME)
	2	+	+			56	+	+			109	+	+	
1	3	+	+			57	+	+			110	+	+	
	4	+	+		20	58	+	-	1 (ME)	43	111	+	-	1 (ME)
	5	+	+			59	+	+			112	+	-	1 (ME)
2	6	+	+			60	+	+			113	+	+	
	7	+	+		21	61	+	-	1 (ME)	44	114	+	-	1 (ME)
3	8	+	+			62	+	+			115	+	-	1 (ME)
	9	+	-			63	+	-	1 (ME)		116	+	+	
	10	+	-	4 (3 ME)	22	64	+	+		45	117	+	+	
	11	+	-			65	+	-	1 (ME)		118	+	+	
4	12	+	-	1 (ME)		66	+	+			119	+	+	
	13	+	+		23	67	+	-	1 (ME)	46	120	+	+	
	14	+	-			68	+	-	1 (ME)		121	+	-	
5	15	+	-			69	+	+			122	+	-	
	16	+	-		24	70	+	+		47	123	+	-	4 (3 ME)
	17	+	-	9 (4 ME)		71	+	+			124	+	+	
6	18	+	+			72	+	+			125	+	+	
	19	+	+		25	73	+	+		48	126	+	+	
	20	+	+			74	+	+			127	+	+	
7	21	+	+			75	+	+			128	+	+	
	22	+	-	1 (ME)	26	76	+	+		49	129	+	-	
	23	+	+			77	+	+			130	+	-	
8	24	+	-	1 (ME)	27	78	+	-	1 (ME)	50	131	+	-	4 (3 ME)
	25	+	+			79	+	+			132	+	+	
	26	+	+		28	80	+	-			133	+	+	
9	27	+	+			81	+	-		51	134	+	+	
	28	+	+			82	+	-			135	+	+	
10	29	+	-	1 (ME)		83	+	-	9 (4 ME)		136	+	+	
	30	+	-	1 (ME)		84	+	+		52	137	+	-	1 (ME)
	31	+	+		29	85	+	+			138	+	-	1 (ME)
11	32	+	-	1 (ME)		86	+	+			139	+	+	
	33	+	-	1 (ME)		87	+	-	1 (ME)	53	140	+	+	
	34	+	+		30	88	+	+			141	+	-	
12	35	+	+			89	+	+			142	+	-	
	36	+	+			90	+	+		54	143	+	-	4 (3 ME)
	37	+	+		31	91	+	+			144	+	+	
13	38	+	+			92	+	+		55	145	+	+	
	39	+	+			6 MIN. BREAK					146	+	-	
	40	+	+			93	+	+			147	+	-	
14	41	+	+			94	+	-	1 (ME)	56	148	+	-	4 (3 ME)
	42	+	+		38	95	+	+			149	+	+	
	43	+	-	1 (ME)		96	+	-	1 (ME)		150	+	+	
	44	+	+			97	+	+		57	151	+	-	
	45	+	+			98	+	-	1 (ME)		152	+	-	
16	46	+	-	1 (ME)	39	99	+	+			153	+	-	4 (3 ME)
	47	+	+			100	+	+			154	+	+	
	48	+	+			101	+	-		58	155	+	+	
17	49	+	+		40	102	+	-			156	+	+	
	50	+	+			103	+	-	4 (3 ME)	59	157	+	+	
	51	+	-	1 (ME)		104	+	+			158	+	+	
18	52	+	-	1 (ME)	41	105	+	+			159	+	-	1 (ME)
	53	+	+			106	+	+		60	160	+	-	1 (ME)
	54	+	-	1 (ME)		107	+	+						

Penalty Sums for 20-Min Blocks  
 0-20 min = 27      20-40 min = 20.86\*      40-60 min = 30.33  
 10-30 min = 26      30-50 min = 29.23\*  
 \*Experimenter break, penalty sums extrapolated from available minutes.

TABLE A-13

Monkey 821: Exposure dose = 840 rad, rate = 33.33 rad/min, duration = 25 min, DMTS task, 2 match alternatives, 10-sec delay between sample and match

Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty
1	1	+	+		19	54	+	+			109	+	+	
	2	+	+			55	+	+			110	+	-	1 (ME)
1	3	+	+		20	56	+	-	1 (ME)		111	+	-	1 (ME)
	4	+	+			57	+	+		44	112	+	+	
2	5	+	+			58	+	+			113	+	+	
	6	+	-	1 (ME)	21	59	+	+			114	+	+	
	7	+	+			60	+	-	1 (ME)	45	115	+	+	
3	8	+	+			61	+	+			116	+	-	1 (ME)
	9	+	+		22	62	+	+			117	+	+	
	10	+	+			63	+	+		46	118	+	-	1 (ME)
4	11	+	-	1 (ME)		64	+	+			119	+	-	1 (ME)
	12	+	+		23	65	+	+			120	+	+	
	13	+	+			66	+	+		47	121	+	+	
5	14	+	+		24	67	+	+			122	+	+	
	15	+	+			68	+	-	1 (ME)	48	123	+	-	1 (ME)
6	16	+	-			69	+	+			124	+	-	1 (ME)
	17	+	-		25	70	+	-	1 (ME)		125	+	+	
	18	+	-			71-77 (2' min. performance) deleted due to noise in room.				49	126	+	+	
7	19	+	-	9 (4 ME)		78	+	+			127	+	-	1 (ME)
	20	+	+		28	79	+	+			128	+	+	
	21	+	+			80	+	+			129	+	+	
8	22	+	+			81	+	-		50	130	+	-	1 (ME)
	23	+	-	1 (ME)	29	82	+	-			131	+	+	
	24	+	+			83	+	-	4 (3 ME)	51	132	+	+	
9	25	+	+			84	+	+			133	+	-	
	26	+	+			85	+	+			134	+	-	
	27	+	-	1 (ME)	30	86	+	+		52	135	+	-	4 (3 ME)
10	28	+	+			87	+	+			136	+	+	
	29	+	-	1 (ME)		88	+	+			137	+	-	1 (ME)
	30	+	+		30	86	+	+			138	+	+	
11	31	+	+			6 MIN BREAK				53	139	+	+	
	32	+	+			87	+	+			140	+	-	1 (ME)
	33	+	+			88	+	+			141	+	-	1 (ME)
12	34	+	+		37	90	+	+		54	142	+	+	
	35	+	+			91	+	-	1 (ME)		143	+	+	
13	36	+	+			92	+	+			144	+	-	1 (ME)
	37	+	-	1 (ME)	38	93	+	-	1 (ME)	55	145	+	+	
	38	+	-	1 (ME)		94	+	+			146	+	-	1 (ME)
14	39	+	+			95	+	+		56	147	+	+	
	40	+	-	1 (ME)		96	+	+			148	+	-	1 (ME)
	41	+	+		39	97	+	+			149	+	+	
15	42	+	+			98	+	+		57	150	+	-	1 (ME)
	43	+	+			99	+	+			151	+	+	
	44	+	+		40	100	+	-	1 (ME)		152	+	-	1 (ME)
16	45	+	+			101	+	+			153	+	-	1 (ME)
	46	+	+			102	+	-	1 (ME)	58	154	+	+	
	47	+	-	1 (ME)		103	+	+			155	+	-	1 (ME)
17	48	+	+		11	103	+	+			156	+	+	
	49	+	-			104	+	-	1 (ME)	59	157	+	-	1 (ME)
	50	+	-			105	+	+			158	+	-	1 (ME)
18	51	+	-	4 (3 ME)	42	106	+	+			159	+	+	
	52	+	+			107	+	+		60	160	+	+	
	53	+	+		43	108	+	-	1 (ME)					

Penalty Sums for 20-Min Blocks

0-20 min = 23                      20-40 min = 16.67\*\*                      40-60 min = 28  
 10-30 min = 18.89\*                      30-50 min = 21.43\*\*

\* Lost data, penalty sums extrapolated from available minutes.  
 \*\* Experimenter break, penalty sums extrapolated from available minutes.

TABLE A-14

Monkey 915: Exposure dose = 1000 rad, rate = 33.33 rad/min,  
duration = 30 min, DMTS task, 2 match alternatives,  
10-sec delay between sample and match

Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty	
	1	+	+			43	+	+			44	84	+	-	1 (ME)
	2	+	+			44	+	+				85	+	+	
1	3	+	-	1 (ME)		45	+	-	1 (ME)			86	+	+	
	4	+	+			46	+	+			45	87	+	+	
	5	+	+			47	+	+				88	+	+	
2	6	+	-	1 (ME)		48	+	+				89	+	+	
	7	+	+			49	+	+			46	90	+	-	1 (ME)
	8	+	+			50	+	-	1 (ME)			91	+	+	
3	9	+	+			51	+	+			47	92	+	+	
	10	+	+			52	+	+				93	+	+	
4	11	+	+			53	+	+			48	94	+	-	1 (ME)
	12	+	+			54	+	+				95	+	+	
	13	+	+			55	+	+			49	96	+	-	
5	14	+	-	1 (ME)		56	+	+				97	+	-	
	15	+	-	1 (ME)		57	+	+			50	98	+	-	4 (3 ME)
6	16	+	+			58	+	+				99	+	+	
	17	+	+			59	+	-			51	100	+	+	
	18	+	+			60	+	-				101	+	-	1 (ME)
7	19	+	+			61	+	-			52	102	+	+	
	20	+	-	1 (ME)		62	+	-	9 (4 ME)			103	+	-	1 (ME)
8	21	+	-	1 (ME)		63	+	+			53	104	+	+	
	22	+	+			64	+	+				105	+	+	
	23	+	+			65	+	+			54	106	+	+	
9	24	+	+			66	+	+				107	+	+	
	25	+	+			67	+	+			55	108	+	+	
	26	+	+			68	+	+				109	+	+	
10	27	+	+			69	+	+			56	110	+	+	
	28	+	+			70	+	+				111	+	+	
	29	+	-			71	+	+			57	112	+	+	
11	30	+	-			72	+	+				113	+	+	
	31	+	-			73	+	-	1 (ME)		58	114	+	+	
	32	+	-	9 (4 ME)		74	+	+				115	+	+	
12	33	+	+			75	+	-	1 (ME)		59	116	+	-	
	34	+	-	1 (ME)		76	+	+				117	+	-	
	35	+	+			77	+	+			57	118	+	-	
13	36	+	+			78	+	+				119	+	-	9 (4 ME)
	37	+	+			79	+	-	1 (ME)		58	120	+	+	
	38	+	+			80	+	+				121	+	-	1 (ME)
	39	+	-	1 (ME)		13 MIN. BREAK						122	+	+	
	40	+	+			81	+	+			59	123	+	+	
14	41	+	+			82	+	+				124	+	+	
	42	+	+			83	+	+			60	125	+	-	1 (ME)

Penalty Sums for 20-Min Blocks

0-20 min = 19  
10-30 min = 25

20-40 min = 24\*  
30-50 min = 20\*

40-60 min = 23.53\*

\*Experimenter break, penalty sums extrapolated from available minutes.

TABLE A-15

Monkey 881: Exposure dose = 1000 rad, rate 33.33 rad/min, duration = 30 min, DMTS task, 2 match alternatives, 10-sec delay between sample and match

Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty
	1	+	+			55	+	+			108	+	-	1 (ME)
	2	+	+		19	56	+	+		43	109	+	-	1 (ME)
	3	+	+			57	+	+			110	+	+	
1	4	+	-			58	+	+			111	+	-	1 (ME)
	5	+	-		20	59	+	-	1 (ME)	44	112	+	+	
	6	+	-			60	+	-	1 (ME)		113	+	-	1 (ME)
2	7	+	-	9 (4 ME)		61	+	+			114	+	+	
	8	+	+		21	62	+	+		45	115	+	-	1 (ME)
	9	+	+			63	+	+			116	+	-	1 (ME)
3	10	+	+			64	+	+			117	+	+	
	11	+	-	1 (ME)	22	65	+	+		46	118	+	+	
	12	+	+			66	+	+			119	+	-	
	13	+	+			67	+	+			120	+	-	
4	14	+	+		23	68	+	+		47	121	+	-	4 (3 ME)
	15	+	-	1 (ME)		69	+	+			122	+	+	
5	16	+	-	1 (ME)	24	70	+	-	1 (ME)		123	+	+	
	17	+	+			71	+	+		48	124	+	+	
	18	+	+			72	+	+			125	+	+	
6	19	+	+		25	73	+	+		49	126	+	+	
	20	+	+			74	+	-	1 (ME)		127	+	+	
	21	+	+			75	+	+			128	+	+	
7	22	+	+		26	76	+	-	1 (ME)		129	+	+	
	23	+	-	1 (ME)		77	+	+		50	130	+	-	1 (ME)
	24	+	+			78	+	+			131	+	-	1 (ME)
8	25	+	+		27	79	+	-	1 (ME)		132	+	+	
	26	+	-	1 (ME)		80	+	+		51	133	+	+	
	27	+	+			81	+	-			134	+	+	
9	28	+	+		28	82	+	-			135	+	+	
	29	+	+			83	+	-	4 (3 ME)	52	136	+	-	1 (ME)
10	30	+	-	1 (ME)		84	+	+			137	+	-	1 (ME)
	31	+	-	1 (ME)		85	+	+			138	+	+	
	32	+	+		29	86	+	+		53	139	+	-	1 (ME)
11	33	+	-			87	+	+			140	+	+	
	34	+	-		30	88	+	+			141	+	-	1 (ME)
	35	+	-	4 (3 ME)		89	+	-	1 (ME)	54	142	+	-	1 (ME)
	36	+	+			90	+	-	1 (ME)		143	+	+	
12	37	+	+		31	91	+	+			144	+	+	
	38	+	+			92	+	+		55	145	+	-	1 (ME)
	39	+	+			93	+	+			146	+	+	
13	40	+	+		32	94	+	+			147	+	+	
	41	+	+			6 MIN. BREAK				56	148	+	-	1 (ME)
14	42	+	+			95	+	-	1 (ME)		149	+	+	
	43	+	+			96	+	+			150	+	+	
	44	+	+		39	97	+	+		57	151	+	+	
15	45	+	-	1 (ME)		98	+	-	1 (ME)		152	+	+	
	46	+	+			99	+	+			153	+	+	
	47	+	+		40	100	+	-	1 (ME)	58	154	+	-	1 (ME)
16	48	+	+			101	+	-	1 (ME)		155	+	-	1 (ME)
	49	+	+			102	+	+			156	+	+	
17	50	+	-	1 (ME)		103	+	+		59	157	+	-	1 (ME)
	51	+	+		41	104	+	+			158	+	+	
	52	+	+			105	+	+			159	+	+	
18	53	+	+		42	106	+	+		60	160	+	+	
	54	+	+			107	+	+						

Penalty Sums for 20-Min Blocks

0-20 min = 23                      20-40 min = 16.50\*                      40-60 min = 23  
 10-30 min = 17                      30-50 min = 22.50\*

\*Experimenter break, penalty sums extrapolated from available minutes.

TABLE A-16

Monkey 860: Exposure dose = 1000 rad, rate = 33.33 rad/min, duration = 30 min, DMTS task, 2 match alternatives, 10-sec delay between sample and match

Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty
	1	+	-	1 (ME)		49	+	+			39	94	+	+
	2	+	+		17	50	SO		4 (SO)		95	+	+	
1	3	+	-	1 (ME)		51	+	+		40	96	+	-	1 (ME)
	4	+	-	1 (ME)		52	SO		4 (SO)		97	+	+	
	5	+	+		18	53	+	+		41	98	+	+	
	6	+	+			54	SO		4 (SO)		99	+	+	
2	7	+	+			55	+	-	25 (MX)		100	+	+	
	8	+	+			56	+	+	1 (ME)	42	101	+	+	
3	9	+	+			57	+	+			102	+	+	
	10	+	-	1 (ME)	19	58	+	+			103	+	+	
	11	+	+			59	+	MO	16 (MO)	43	104	+	+	
4	12	+	+		20	60	+	+			105	+	-	1 (ME)
	13	+	-	1 (ME)		61	+	+	1 (ME)	44	106	+	+	
5	14	+	+		21	62	+	+			107	+	-	1 (ME)
	15	+	+			63	+	+		45	108	+	+	
6	16	+	+		22	64	+	+			109	+	+	
	17	+	+			65	+	+		46	110	+	+	
	18	+	-	1 (ME)		66	+	+			111	+	+	
7	19	+	+		23	67	+	-	1 (ME)	47	112	+	+	
	20	+	-			68	+	-	1 (ME)		113	+	-	1 (ME)
	21	+	-			69	+	+			114	+	-	1 (ME)
8	22	+	+	4 (3 ME)	24	70	+	+			115	+	+	
	23	+	+			71	+	+		48	116	+	-	1 (ME)
	24	+	+			72	+	+			117	+	-	1 (ME)
9	25	+	+		25	73	+	-	1 (ME)	49	118	+	+	
	26	+	+			74	+	MO	16 (MO)		119	+	-	1 (ME)
	27	+	+			75	+	-	1 (ME)	50	120	+	+	
10	28	+	+			76	+	MO	16 (MO)		121	+	-	1 (ME)
	29	+	-	1 (ME)	26	77	+	-	1 (ME)		122	+	+	
	30	+	+			78	+	-	1 (ME)	51	123	+	+	
11	31	+	+			79	+	MO	16 (MO)		124	+	+	
	32	+	+			80	+	+			125	+	+	
12	33	+	+		27	81	+	+		52	126	+	+	
	34	+	+			82	+	+			127	+	-	1 (ME)
	35	+	+		28	83	+	-	1 (ME)	53	128	+	-	1 (ME)
13	36	+	-	1 (ME)		84	+	-	1 (ME)		129	+	+	
	37	+	+			85	+	+		54	130	+	+	
	38	+	+		29	86	+	+			131	+	-	1 (ME)
14	39	+	-	1 (ME)		87	+	+		55	132	+	+	
	40	SO		4 (SO)		88	+	+			133	+	+	
	41	+	+		30	89	+	+		56	134	+	+	
	42	SO				90	+	-	1 (ME)		135	+	+	
15	43	SO		25 (2 SO)		91	+	-	1 (ME)		136	+	-	1 (ME)
	44	+	+			92	+	+		57	137	+	+	
	45	SO		4 (SO)		93	+	+			138	+	+	
	46	+	-	1 (ME)	37	87	+	+		58	139	+	-	1 (ME)
	47	+	MO	16 (MO)		88	+	+			140	+	+	
	48	+	-	1 (ME)		89	+	+		59	141	+	+	
				25 (MX)		90	+	-	1 (ME)		142	+	+	
				1 (ME)	38	91	+	-	1 (ME)		143	+	-	
						92	+	+		59	144	+	-	
						93	+	+			145	+	-	4 (3 ME)
										60	146	+	+	

Penalty Sums for 20-Min Blocks

0-20 min = 218  
10-30 min = 390

20-40 min = 264.27\*  
30-50 min = 15.71\*

40-60 min = 17

\*Experimenter break, penalty sums extrapolated from available minutes.

TABLE A-17

Monkey 921: Exposure dose = 1000 rad, rate = 50 rad/min, duration = 20 min, DMTS task, 2 match alternatives, 10-sec delay between sample and match

Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty		
	1	+	+			50	+	-	1 (ME)		98	+	+			
	2	+	+			51	+	+			99	+	+			
1	3	+	-		19	52	+	+		43	100	+	+			
	4	+	-			53	+	+			101	+	+			
	5	+	-	4 (3 ME)	20	54	+	+		44	102	+	+			
2	6	+	+			55	+	+			103	+	+			
	7	+	+			56	+	+			104	+	+			
	8	+	+		21	57	+	+		45	105	+	+			
3	9	+	-	1 (ME)		58	+	-	1 (ME)		106	+	-	1 (ME)		
	10	+	-	1 (ME)		59	+	+			107	+	+			
	11	+	+		22	60	+	-	1 (ME)	46	108	+	-			
4	12	+	+		7 MIN. BREAK								109	+	-	
	13	+	+			61	+	+			110	+	-	4 (3 ME)		
5	14	+	+			62	+	+		47	111	+	+			
	15	+	+		30	63	+	+			112	+	-			
	16	+	-	1 (ME)		64	+	+			113	+	-			
6	17	+	-	1 (ME)		65	+	+		48	114	+	-			
	18	+	+		31	66	+	+			115	+	-	9 (4 ME)		
	19	+	+			67	+	+			116	+	+			
7	20	+	+			68	+	-		49	117	+	-	1 (ME)		
	21	+	+		32	69	+	-			118	+	+			
8	22	+	-	1 (ME)		70	+	-	4 (3 ME)		119	+	-	1 (ME)		
	23	+	+			71	+	+		50	120	+	+			
	24	+	+		33	72	+	+			121	+	+			
9	25	+	+			73	+	+		51	122	+	+			
	26	+	+		34	74	+	+			123	+	+			
	27	+	+			75	+	-			124	+	+			
10	28	+	+			76	+	-		52	125	+	+			
	29	+	+		35	77	+	-			126	+	+			
11	30	+	-	1 (ME)		78	+	-	9 (4 ME)	53	127	+	-	1 (ME)		
	31	+	+			79	+	+			128	+	+			
	32	+	+		36	80	+	+			129	+	+			
12	33	+	-	1 (ME)		81	+	-	1 (ME)	54	130	+	+			
	34	+	+			82	+	-	1 (ME)		131	+	+			
	35	+	+		37	83	+	+		55	132	+	+			
13	36	+	+			84	+	+			133	+	+			
	37	+	+			85	+	-			134	+	-	1 (ME)		
14	38	+	-	1 (ME)	38	86	+	-		56	135	+	+			
	39	+	+			87	+	-	4 (3 ME)		136	+	+			
	40	+	+			88	+	+			137	+	+			
15	41	+	+		39	89	+	+		57	138	+	+			
	42	+	+			90	+	-	1 (ME)		139	+	+			
16	43	+	+			91	+	-	1 (ME)	58	140	+	+			
	44	+	+		40	92	+	+			141	+	+			
	45	+	+			93	+	+			142	+	+			
17	46	+	-			94	+	+		59	143	+	+			
	47	+	-		41	95	+	+			144	+	+			
	48	+	-	4 (3 ME)		96	+	+		60	145	+	-	1 (ME)		
18	49	+	+		42	97	+	+								

Penalty Sums for 20-Min Blocks

0-20 min = 19      20-40 min = 34.36\*      40-60 min = 19  
 10-30 min = 15.83      30-50 min = 37

\*Experimenter break, penalty sums extrapolated from available minutes.

TABLE A-18

Monkey 864: Exposure dose = 1000 rad, rate = 50 rad/min, duration = 20 min, DMTS task, 2 match alternatives, 10-sec delay between sample and match

Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty
1	1	+	-	1 (ME)	18	50	+	-	1 (ME)	38	98	+	+	
	2	+	-	1 (ME)		51	+	+			99	+	+	
	3	+	+			52	+	+			100	+	+	
2	4	+	+		19	53	+	-		39	101	+	+	
	5	+	+			54	+	-			102	+	+	
	6	+	+			55	+	-	4 (3 ME)		103	+	-	1 (ME)
3	7	+	+		20	56	+	+		40	104	+	+	
	8	+	+			57	+	+			105	+	+	
	9	+	+			58	+	+			5 MIN. BREAK			
4	10	+	-	1 (ME)	21	59	+	+		46	106	+	+	
	11	+	+			3 MIN. BREAK			107		+	-	1 (ME)	
	12	+	+			60	+	+			108	+	+	
5	13	+	-	1 (ME)	25	61	+	-	1 (ME)	47	109	+	+	
	14	+	+			62	+	-	1 (ME)		110	+	+	
	15	+	+			63	+	+			111	+	+	
6	16	+	+		26	64	+	+		48	112	+	+	
	17	+	+			65	+	+			113	+	+	
	18	+	-	1 (ME)		66	+	-	1 (ME)		114	+	+	
7	19	+	+		27	67	+	-	1 (ME)	49	115	+	+	
	20	+	-	1 (ME)		68	+	+			116	+	-	1 (ME)
	21	+	+			69	+	+			117	+	+	
8	22	+	+		28	70	+	-	1 (ME)	50	118	+	+	
	23	+	+			71	+	+			119	+	+	
	24	+	+			72	+	+			120	+	+	
9	25	+	+		29	73	+	+		51	121	+	-	
	26	+	+			74	+	-	1 (ME)		122	+	+	
	27	+	+			75	+	+			123	+	-	1 (ME)
10	28	+	+		30	76	+	+		52	124	+	+	
	29	+	-	1 (ME)		77	+	+			125	+	-	1 (ME)
	30	+	+			78	+	+			126	+	+	
11	31	+	-	1 (ME)	31	79	+	-		53	127	+	+	
	32	+	+			80	+	-			128	+	+	
	33	+	+			81	+	-	4 (3 ME)		129	+	+	
12	34	+	+		32	82	+	+		54	130	+	+	
	35	+	-	1 (ME)		83	+	+			131	+	+	
	36	+	+			84	+	-	1 (ME)		132	+	+	
13	37	+	+		33	85	+	+		55	133	+	-	1 (ME)
	38	+	+			86	+	+			134	+	+	
	39	SO		4 (SO)		87	+	+			135	+	+	
14	40	+	+		34	88	+	+		56	136	+	-	1 (ME)
	41	+	+			89	+	+			137	+	+	
	42	+	MO	16 (MO)		90	+	+			138	+	+	
15	43	+	+		35	91	+	+		57	139	+	+	
	44	+	+			92	+	+			140	+	+	
	45	+	-	1 (ME)		93	+	+			141	+	+	
16	46	+	+		36	94	+	+		58	142	+	+	
	47	+	+			95	+	+			143	+	+	
	48	+	+			96	+	+			144	+	+	
17	49	+	+		37	97	+	+		59	145	+	+	

Penalty Sums for 20-Min Blocks - 0-20 min = 35      20-40 min = 14.25\*      40-60 min = 8.00\*  
 10-30 min = 41.17\*      30-50 min = 10.67\*

\*Experimenter break, penalty sums extrapolated from available minutes.

TABLE A-19

Monkey 894: Exposure dose = 1000 rad, rate = 50 rad/min, duration = 20 min, DMTS task, 2 match alternatives, 10-sec delay between sample and match

Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty
1	1	+	-	1 (ME)	19	51	+	+			101	+	+	
	2	+	+			52	+	+			102	+	+	
1	3	+	+			53	+	+		42	103	+	+	
	4	+	+		20	54	+	-	1 (ME)		104	+	+	
	5	+	+			3 MIN. BREAK					105	+	+	
2	6	+	+			55	+	+		43	106	+	+	
	7	+	+		24	56	+	+			107	+	+	
3	8	+	+			57	+	+		44	108	+	-	1 (ME)
	9	+	+		25	58	+	+			109	+	-	1 (ME)
	10	+	+			59	+	+		45	110	+	+	
4	11	+	+			60	+	+			111	+	-	1 (ME)
	12	+	+		26	61	+	+		46	112	-	-	TRIAL OMITTED EQUIPMENT FAILURE
5	13	+	+			62	+	+			113	+	+	
	14	+	+		27	63	+	+			114	+	+	
	15	+	+			64	+	+		47	115	+	+	
6	16	+	+		28	65	+	+			116	+	+	
	17	+	+			66	+	+		48	117	+	+	
7	18	+	+		29	67	+	-	1 (ME)		118	+	+	
	19	+	-	1 (ME)		68	+	+		49	119	+	+	
8	20	+	+			69	+	+			120	+	+	
	21	+	-	1 (ME)	30	70	+	-	1 (ME)		121	+	+	
	22	+	+			71	+	+		50	122	+	-	1 (ME)
9	23	+	+			72	+	+			123	+	+	
	24	+	+		31	73	+	+			124	+	-	1 (ME)
	25	+	-	1 (ME)		74	+	+		51	125	+	+	
10	26	+	+		32	75	+	+			126	+	+	
	27	+	-	1 (ME)		76	+	-	1 (ME)	52	127	+	+	
	28	+	+			77	+	+			128	+	+	
11	29	+	+		33	78	+	-	1 (ME)		129	+	-	1 (ME)
	30	+	+			79	+	+		53	130	+	+	
	31	SO		4 (SO) 25 (MX) 1 (ME)		80	+	+			131	+	+	
	32	+	-		34	81	+	+			132	+	+	
12	33	+	+			82	+	+		54	133	+	+	
	34	+	+		35	83	+	+			134	+	+	
13	35	+	+			84	+	+		55	135	+	-	1 (ME)
	36	+	+		36	85	+	+			136	+	+	
	37	+	+			86	+	+			137	+	-	
14	38	+	+		37	87	+	+		56	138	+	-	
	39	+	+			88	+	-	1 (ME)		139	+	-	4 (3 ME)
15	40	+	-	1 (ME)		89	+	-	1 (ME)		140	+	+	
	41	+	+		38	90	+	+			141	+	+	
	42	+	+			91	+	+		57	142	+	+	
16	43	+	-			92	+	+			143	+	+	
	44	+	-		39	93	+	-	1 (ME)		144	+	-	1 (ME)
	45	+	-	4 (3 ME)		94	+	+		58	145	+	-	1 (ME)
17	46	+	+			95	+	-	1 (ME)		146	+	+	
	47	+	+		40	96	+	-	1 (ME)		147	+	+	
	48	+	+			97	+	+		59	148	+	+	
18	49	+	+			98	+	-	1 (ME)		149	+	+	
	50	+	+		41	99	+	+		60	150	+	+	
						100	+	+						

Penalty Sums for 20-Min Blocks

0-20 min = 41      20-40 min = 10.58      40-60 min = 14\*\*  
 10-30 min = 44.71\*      30-50 min = 12

\* Experimenter break, penalty sums extrapolated from available minutes.

\*\* Equipment failure, penalty sums extrapolated from available minutes.

TABLE A-20

Monkey 901: Exposure dose = 1000 rad, rate = 50 rad/min, duration = 20 min, DMTS task, 2 match alternatives, 10-sec delay between sample and match

Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty	Min.	Trial	Sample	Match	Penalty
	1	+	+			53	+	+			103	+	-	1 (ME)
	2	+	+			54	SO				104	+	+	
1	3	+	-	1 (ME)	20	55	SO			41	105	+	-	1 (ME)
	4	+	+	1 (ME)		56	SO				106	+	+	
	5	+	+			57	SO		100 (4 SO)		107	+	+	
2	6	+	+			58	+	+		42	108	+	+	
	7	+	+		21	59	+	+			109	+	+	
3	8	+	+			60	+	+			110	+	-	1 (ME)
	9	+	-	1 (ME)		61	+	+			111	+	+	
	10	+	+		22	62	+	+			112	+	+	
4	11	+	+			63	+	+		44	113	+	-	1 (ME)
	12	+	+		23	64	+	+			114	+	+	
	13	+	+			65	+	+			115	+	+	
5	14	+	+			66	+	-	1 (ME)	45	116	+	+	
	15	+	+		24	67	+	+			117	+	+	
	16	+	+			68	+	+		46	118	+	+	
6	17	+	-	1 (ME)		69	+	+			119	+	+	
	18	+	+		25	70	+	+			120	+	+	
	19	+	+			3 MIN. BREAK				47	121	+	-	
7	20	+	+			71	+	+			122	+	-	
	21	+	-	1 (ME)	29	72	+	-	1 (ME)		123	+	-	4 (3 ME)
8	22	+	+			73	+	+		48	124	+	+	
	23	+	+			74	+	-	1 (ME)		125	+	+	
	24	+	+		30	75	+	+			126	+	+	
9	25	+	+			76	+	+		49	127	+	+	
	26	+	+			77	+	-	1 (ME)		128	+	+	
10	27	+	+		31	78	+	-	1 (ME)	50	129	+	+	
	28	+	+			79	+	+			130	+	+	
	29	+	+		32	80	+	+			131	+	-	
11	30	+	+			81	+	+		51	132	+	-	4 (3 ME)
	31	+	+			82	+	+			133	+	+	
	32	+	+		33	83	+	+			134	+	+	
12	33	+	+			84	+	+		52	135	+	+	
	34	+	+			85	+	+			136	+	+	
13	35	+	-	1 (ME)	34	86	+	+		53	137	+	+	
	36	+	+			87	+	-	1 (ME)		138	+	+	
	37	+	+			88	+	-	1 (ME)		139	+	-	1 (ME)
14	38	+	+		35	89	+	+		54	140	+	-	1 (ME)
	39	+	+			90	+	+			141	+	+	
	40	+	+			91	+	-	1 (ME)		142	+	+	
15	41	+	+		36	92	+	+		55	143	+	+	
	42	+	+			93	+	+			144	+	+	
16	43	+	+		37	94	+	+		56	145	+	+	
	44	+	+			95	+	-	1 (ME)		146	+	+	
	45	+	+			96	+	+			147	+	-	1 (ME)
17	46	+	+		38	97	+	+		57	148	+	-	1 (ME)
	47	+	-	1 (ME)		98	+	+			149	+	+	
	48	+	+			99	+	+			150	+	+	
18	49	+	+		39	100	+	+		58	151	+	+	
	50	+	+			101	+	-	1 (ME)		152	+	-	1 (ME)
	51	+	-	1 (ME)	40	102	+	+			153	+	+	
19	52	+	+							59	154	+	-	1 (ME)
											155	+	+	
											156	+	-	1 (ME)
										60	157	+	-	1 (ME)

Penalty Sums for 20-Min Blocks

0-20 min = 58

20-40 min = 70.58\*

40-60 min = 20

10-20 min = 127.2

30-50 min = 15

\*Experimenter break, penalty sums extrapolated from available minutes.

TABLE A-21

PRE- AND POSTRADIATION MEAN BP AND HR FOR EACH 33 RAD/MIN MONKEY

Monkey No.	804		834		820		849		881		860		868		877		898		854		915		923		
	BP	HR	BP	HR	BP	HR	BP	HR	BP	HR	BP	HR	BP	HR											
Preradiation	120.3	183	101	167	134.7	225	106.3	187	106	245	137.0	182	126	225	105.6	205	104	190	114	225	117	205	81	190	
Postradiation	120	183	99.7	175	134.7	225	106.7	187	106	244	138	185	125.3	225	105.6	205	104	190	114	225	117	205	81	190	
Minutes	120	183	102	174	134	225	109.3	189	103.8	246	131.3	185	126.3	225	105.6	205	104	190	114	225	117	205	81	185	
1	121	183	101.3	165	132	225	104.7	181	102	245	134.3	182	119.3	225	105.6	205	104	190	114	220	117	205	78	185	
2	124	182	102	165	132	230	103.3	189	99.3	247	131.3	185	120.7	225	105.6	205	105	190	112	245	117	205	73	-	
3	122.7	184	102	185	134.7	250	106	189	103	243	131.7	187	124	225	105.6	205	102	195	106	240	117	205	81	190	
4	124	185	101.7	166	134	255	106	186	103.7	243	134.3	183	123	225	100.7	205	98	195	106	240	117	205	79	185	
5	123.3	180	103	165	137.3	240	106.7	191	105.7	240	123	187	132.7	217	89	210	91.6	200	107	240	112	205	81	180	
6	123.3	186	102.7	167	135.3	245	110.7	200	104.3	245	103	192	119.3	225	80.7	220	87.5	225	115	240	107	215	77	205	
7	123.3	182	102.7	173	136	243	107.3	197	104	248	83.3	191	129.3	220	76	235	86.7	270	114	235	107	215	81	240	
8	118.7	181	102.7	171	134	245	103.2	195	105.3	245	62	189	112.7	230	67.3	240	73.3	280	118	235	107	215	80	275	
9	123.3	185	103	175	134.7	255	99.3	181	92	253	49.7	187	120.3	225	65.7	245	64.3	285	108	260	107	225	69	280	
10	124	180	104.7	177	134	250	97	182	78.7	250	48	186	112	232	59	250	58.6	287	104	260	104	235	65	280	
11	126.3	184	105.7	175	134	248	98	185	80.7	247	46.7	175	117.3	227	59	250	52.3	285	101	270	104	235	60	280	
12	128	185	105.3	180	132	243	93.3	201	68.3	243	-	175	116.7	232	57.3	250	54.7	285	96	275	111	235	45	280	
13	126.7	187	105.3	185	127.3	247	91.7	211	63.0	240	-	160	112	230	64	250	54.7	285	87	275	104	245	36	285	
14	126.3	192	109.7	195	127.3	252	74	225	47.3	235	-	157	107.7	235	66	245	59.7	285	91	275	107	247	36	283	
15	126	205	106.7	211	125.7	260	78	232	53.3	230	-	163	111	235	67.3	244	59.7	285	88	275	100	255	43	280	
16	120	210	103.3	225	122.7	255	68.7	238	49.0	233	-	167	102.7	243	89	240	61	295	66	275	105	255	55	280	
17	120	210	102.7	245	122	270	70.7	233	49.7	230	-	167	91.7	244	69.3	238	62	285	53	265	98	255	61	269	
18	122	216	96.3	242	120.3	260	76	233	50.7	225	-	168	102	238	62.3	245	61.3	285	63	265	98	262	60	269	
19	110.3	237	86.7	243	116.7	255	77	227	42.7	227	-	168	99	243	65.7	235	63	285	67	262	100	262	62	255	
20	118	225	64.7	245	109.3	257	80	230	41.7	224	-	170	93.3	241	65.7	235	63	285	64	255	101	263	72	270	
21	114	223	57.3	240	108.7	257	79	215	52.3	225	-	167	62	243	65.7	235	64	285	58	255	102	262	78	273	
22	117.3	209	48.0	237	108	257	62	227	58.0	224	-	171	70.7	243	62	235	76.7	285	67	255	103	262	73	277	
23	119.3	210	43.7	204	112	250	73.7	221	52.0	223	-	172	70.7	240	70.7	237	72	285	64	252	104	240	78	277	
24	113.3	210	52.7	204	111	245	74.7	215	50.3	225	-	175	52.3	240	66.3	235	65.3	285	77	245	106	240	83	275	
25	120	225	48	190	110	240	65.3	220	49.3	225	-	176	62.0	242	62.3	232	65.3	285	82	245	108	240	84	275	
26	122.7	200	73.7	190	94	250	68	220	48.7	227	-	177	68.7	239	63	235	72	285	66	250	110	240	86	268	
27	116.7	210	79.3	190	99.3	255	72	210	47.0	225	-	175	47.7	240	62	235	73	280	78	245	112	240	87	268	
28	119.7	212	62.3	190	108.3	250	68.7	200	65.3	227	-	175	44.7	240	70.7	235	70	280	89	235	115	215	85	277	
29	114.7	183	66.3	200	122	260	61.7	200	54.0	238	-	81.3	185	39.3	223	80.7	215	90.7	280	100	252	116	210	88	278
30	115	205	53.3	208	106.7	260	61.3	252	58.7	250	-	64.0	198	-	-	74.7	240	86.7	280	100	260	109	250	82	285

- Signifies lost data.

TABLE A-22

PRE- AND POSTRADIATION MEAN BP AND HR FOR FOUR 50 RAD/MIN MONKEYS

Monkey No. :		901		894		864		921	
		BP	HR	BP	HR	BP	HR	BP	HR
Preradiation		106	190	105	185	115	210	105	200
Postradiation	1	106	190	105	185	115	210	105	200
Minutes	2	106	190	105	185	115	210	105	200
	3	106	190	105	185	115	210	105	200
	4	106	190	105	185	115	210	103	200
	5	102	190	105	185	115	210	103	200
	6	99	200	107	190	115	210	103	200
	7	99	200	105	225	115	215	105	200
	8	97	220	94	250	115	215	105	200
	9	97	225	70	250	117	225	105	200
	10	92	240	55	245	117	235	105	200
	11	86	248	51	245	117	265	105	200
	12	80	250	47	245	97	265	105	200
	13	59	245	47	230	69	260	105	200
	14	58	237	59	220	42	225	105	200
	15	57	225	61	225	42	250	105	210
	16	53	220	71	230	42	210	105	215
	17	48	200	72	235	42	215	105	220
	18	34	195	81	235	51	210	105	240
	19	32	190	87	232	51	205	105	240
	20	39	200	87	235	49	215	105	240
	21	37	180	83	235	61	215	105	235
	22	45	185	94	235	61	215	105	235
	23	59	170	97	235	61	215	105	235
	24	61	180	97	235	61	215	105	235
	25	68	165	97	235	65	225	105	235
	30	79	205	95	235	93	220	105	200
	45	83	210	85	205	85	200	92	200
	60	77	220	79	205	83	235	88	250

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