RELATIVE SENSITIVITY OF DELAYED AND DIFFERENTIAL

CONDITIONED APPROACH TO IONIZING RADIATION

A Thesis

Presented to

The Faculty of Graduate Studies and Research

University of Manitoba

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

by

Ying Cheng

April 1968

TO   MY BELOVED PARENTS

for THEIR LOVE, PRAYER

and   ENCOURAGEMENT

ABSTRACT

Radiosensitivity of behaviour depends on task demand. Discrepancies between experiments may be attributed to differences in radiation parameters or to specificities of the diverse tests employed.

The present study compared the gamma-sensitivity of two related water-reinforced conditioned approach responses to auditory CS's in Skinner boxes. Delayed and differential conditioned approach (DCA and DiffCA) include similar stimuli, motor skills and measures, but DCA requires "timing", while DiffCA involves only a frequency discrimination.

Following single exposure of twenty rats to sham-, 300, 450 or 600 rads Co-60 gamma irradiation, DCA behaviour showed a dose-dependent increase of reaction latency. Corresponding indices for CS+ and CS- in DiffCA were little affected.

Assuming conditioned delay to be more complex behaviour, results suggest possible radiation impairment in the integrative functions of the CNS. Selectivity of radiation effects may reflect specificity to "timing" functions, or differential attentional requirements between the tasks, either deficit being a form of impaired integrative functioning in the CNS.

i

ACKNOWLEDGEMENTS

I wish to express my sincere thanks and gratitude to
Dr. M.F. Halasz for his help, guidance and encouragement
during the course of this research.

Also, I would like to thank Dr. E. Schludermann for
many valuable and helpful directions received from him.

Appreciation is extended to Dr. Holloway for his in-
terest and directions in the present work as well as his
staff of Manitoba Cancer and Research Foundation for their
ready assistance.

I am also thankful to Mrs. F. Lee who typed the manu-
script.

TABLE OF CONTENTS

iii

LIST OF TABLE

iv

LIST OF FIGURES

v

Chapter I. THE PROBLEM AND INTRODUCTION

1. STATEMENT OF THE PROBLEM

The effect of ionizing radiation on the adult mammalian
central nervous system (CNS) has been the focus of much con-
troversy. Influenced perhaps to a large extent by Pavlovian
"nervism" (Stahl, 1959, 1960, 1962), most Russian workers
assess the effects of penetrating radiations by observing
its effects on conditioned reflexes. With some exceptions,
the majority of their experimental results suggest the CNS
to be highly radiosensitive. American and Western European
studies, on the other hand, predominantly argue that the CNS
is very radioresistant.

However, with the development of laboratory facilities
and improved techniques, this problem was shown to be much
more complicated.

More recent studies (Novakova, 1967; Upton 1966; Brown,
1966; Vernadakis, 1964; Zeman, 1961; Burt and Ingersoll, 1965;
Ingersoll et. al.; 1966, 1967) suggest that the observed beha-
vioural consequences of CNS radiation are to a large extent a
function of the behaviour paradigms, i.e. the method whereby
behavioural changes are measured.

The present study tested the differential sensitivity of
two conditioning paradigms which may be mediated by conditioned
inhibition of various kinds, and which are also sensitive to
general motivational and performance changes.

The delayed conditioned approach paradigm (DCA), corresponding to the Pavlovian "inhibition of delay", was designed to test the temporal accuracy of behavioural response to conditioned stimulus for water reward. DCA was so designed that response to CS was tested only at times of quiesence at the test situation, eliminating contamination of timing function by artifacts of general hyperreactivity or increased response variability (Halasz, 1967; Cheng and Halasz, 1967). In this paradigm, any experimental variable affecting behavioural response by way of a directly or indirectly induced "inattention" to the finer cues of the conditioned stimulus would result in increased means and variations of the CR latency. (Cheng and Halasz; 1967). True impairment of timing function, on the other hand, would cause a systematic shift of the mean CR latency without significant changes in response variation (Halasz and Marrazzi, 1965).

The differential conditioned approach paradigm DiffCA requires the subjects to differentiate between a positive and a negative conditioned auditory stimulus. While response during the presentation of the positive stimulus lead to water reward, no reinforcement is available for responses during the presentation of the negative conditioned stimulus. Thus conditioned inhibitory processes are an important aspect of efficient performance on this paradigm.

Since performance of animals on both DCA and DiffCA is affected to various degrees by changes in motivation, attention and specific CNS impairment, comparison of post-irradia-

tion performance in these paradigms would reflect in the relative sensitivity. Any differential effects of gamma radiation on performance between paradigms would indicate that observed changes were not predominantly general or motivational in nature, but more specific changes, such as this or that "inhibitory process".

2. HISTORICAL BACKGROUND

Since the discovery of the X-ray in the late 19th century, numerous researches have been carried out to assess the effect of various forms of ionizing radiation on living organisms. However, one finds relatively few papers on the behavioural and functional aspects of penetrating radiation on the mammalian adult central nervous system.

On the basis of morphological and histological studies, the mature CNS has long been considered to be highly radio-resistant. This belief has influenced both the design and interpretations of many experimental studies. Even up to the present, many American and Western European psychological experiments on ionizing radiation and CNS functions fail to consider the possible difference between morphological and functional results. The threshold dosage for meaningful CNS effect depends on which of these points of view is adopted.

Reynolds' (1946) study used the polarized light method to measure the sensitivity of dog brain tissue to 12,000 R X-radiation. He found that the myelin was quite radiosensitive. Though the cells of the brain were very radioresistant, the ease with which the myelin lost its optical activity brought the measured brain radiosensitivity to a much lower level. Thus, in spite of numerically few histological changes, brain damage may already be present. He further stressed

the long latency between irradiation and the onset of myelin

degeneration. This early study called attention to a sig-

nificant yet often neglected variable, namely, the sensitivity

of employed methods in measuring behavioural and functional

alteration of brain structure. His results were substantiated

by subsequent laboratory and clinical cases which all verified

the phenomenon of delayed necrosis (Pennymaker and Russell,

1948; Russell, et.al. 1949; Innes and Carsten, Krabbenholt,

1955; Arnolds, et. al. 1954 (a), (b), (c), (d).) The latest

estimation of threshold dose for microscopic change was between

1000-2000 R in general and 4500-5000 rem/30 days in humans

(Stahl, 1962; Upton 1966).

On the functional side, "radiosensitivity is determined

by that response which is used as the dependent variable"

(Zeman, 1961). Radiosensitivity of mature nervous tissue

would be determined by various stimulus-response complexes.

This is due partially to the unique capacity of the nervous

tissue to produce a tremendous variety of responses.

Conditioned reflexes, introduced first by Pavlov, have

been used very extensively by Russian workers (Stahl, 1959,

1960, 1962; Livshits, 1960; Furchtgott, 1963) to assess the

CNS radiosensitivity. It was shown to be a useful tool in

detecting the effects of irradiation on the cortical inhibi-

tory processes (Livshits, 1960). Nemenov (1928, 1944) claimed

that 1000 R total head irradiation caused phasic change in

delayed CR activity. Grafov's (1958) study also showed the

post-irradiation phasic changes in the conditioned reflexes.

Total-body acute irradiation with doses 600 to 800 R was followed in 20 minutes by an increase in positive conditioned reflexes accompanied by a disinhibition of differentiations, which was considered a manifestation of the weakened inhibitory processes and was followed by second phase of progressive disappearance of conditioned response. The third phase of recovery was characterized by instability of the functional state of the cortex. Miklashevsky's (1958) study with total-body irradiation of rats at 650 R rendered similar results. Kurstin (1958) irradiated dogs with 250-350 R. Besides phasic changes, the animals also exhibited symptoms suggesting rapid exhaustion of the cortical cells, derangement of the equilibrium between excitation and inhibition as well as the phenomenon of inertia.

The effects of repeated doses of 300-4000 R of total X-radiation on dogs' conditioned food reflexes were studied by Livshits (1956, 1958). He claimed that deterioration of differentiation was mostly affected by the first exposure when no apparent symptom of radiation sickness was observed. Denisova (1957) claimed that some weakening of the inhibitory process was caused by doses as low as 110-115 R in dogs.

Kotlyarevskiy et.al. (1956) trained rats to remove a barrier to food during the presentation of a visual or auditory stimulus. The animals were then given successive doses of 50 R of X-ray. Post-irradiation responses of the rats to the conditioned stimulus showed that the first two doses of 50R resulted in increased cortical excitability,

followed by "active inhibition" and phasic phenomenon. Accumulation of doses to a total of 150-350 R resulted first in gradual decline and then a marked increase of conditioned reflexes.

Yanson's (1957) study on CR of rabbits suggested that failure of post-irradiation CR could be attributed primarily to the CNS effects. While failure of some conditioned protective reflexes were present in rabbits 15-20 minutes after 500 R of whole-body irradiation, the CR was nearly normal after irradiation of the trunk alone. Shielding of the body produced effects similar to that of the whole-body, except that the former showed a faster recovery.

While majority of the Pavlovian workers report definite effects of ionizing radiation on the CNS, Lomonos's (1953) study using doses of 750-4000 R with shielding of the head showed acute effects on digestive CR's only. Protective-motor CR's revealed equivocal changes. Rather than considering the effects as being on the cortex, he attributed them to "an increase in the excitability centre, which, as the result of negative induction, induced a decrease in digestive CR's". Bryukhanov and Lomonos (1954) study following intravenous injection of P^{32} showed variable results. His more recent reports on dog salivary reflexes reinforced by food or weak acid following 700 R whole-body irradiation, 1000 R body only and 300R body only irradiation showed decline in the CR's following a short period of increase,

(Lomonos, 1956). Lomonos' 1957 report concluded that "both local and whole-body irradiation does not directly influence the strength of the cortical excitatory and inhibitory processes". Korol'kova (1958), Biryukov (1957), Peacock et.al. (1964) and others also failed to notice any significant alternations in certain CR's after 1300 - 5000 R chronic exposure or 20 R/week gamma-ray.

Attempts to resolve the apparent discrepancy have been unsuccessful. As Stahl stated: "In studies of radiation effects on CR's, Soviet physiologists have found differing reaction, and no final opinion concerning the radiosensitivity of the CR mechanism ought to be reached at this time" (Stahl, 1962). Even though this be the case, Livshits proposed that there was some ground to assume that "the inhibitory process is the most vulnerable one and the first one to be affected by radiation" (Livshits, 1960; Stahl, 1962).

On the other hand, Harlow et.al. working primarily with the effects of radiation on learning, and performance of primates, have reached a very different theoretical position. In the 1962 report, Harlow stated that the cerebral cortex is very radioresistant, regardless of the criterion of measurement. "Since learning, particularly complex learning, is largely dependent on the integrity of the cerebral cortex in mammals, and since the cortex is radioresistant, one should not be surprised to find that learned behaviours are not adversely affected by whole body radiation". (Harlow, 1962). However, Furchtgott, in his two review articles,

pointed to a similar conclusion (Furchtgott, 1956, 1963).
According to him, no behavioural changes would be found in
activities mediated directly by the nervous system. Any
decrements in learning was explained as a consequence of
changes in nonassociative factors such as motivation or
perception of stimuli. Indeed, by using methods other than
that of classical conditioning, some experimenters failed
to find any obvious learning or performance deficits. In
some cases, there was even an apparent post-irradiation
facilitation effect. Among the work reported in this re-
gard, some of the more recent is presented in the following.

Harlow and Moon (1956) studied the progressive and phy-
siological changes following repeated mild doses of X-irradia-
tion. 23 rhesus monkeys were trained on Wiscons in General
Test Apparatus (WGTA) on object discrimination, oddity, de-
layed response and successive discrimination. The first three
tests were valid in differentiating between normal and brain
damaged animals (Harlow et.al. 1951; Meyer et.al. 1952). The
trained animals were given 100 R every 35 days until death.
The results showed no deterioration of ability of irradiated
monkeys to solve even the most complicated problems. The au-
thors attributed the results to decreased activity and conse-
quently decreased distractibility in the irradiated animals.

Riopelle et.al. (1956) studied effects of 350 R on learn-
ing set behaviour in young and adulescent rhesus monkeys. Six

discrimination learning tasks on avoidance learning and spatial delayed response were used. Delayed response testing was done 4 months after the last irradiation. The performance of the irradiated animals not only showed no impairment but was superior to that of the normals. Tests on animals which received rated irradiation of 100 R/2 weeks, totaling to 1000-2000 R showed essentially the same results.

McDowell's (1958, 1959, 1960a, 1960b) series of studies on the effects of radiation on primates can be briefly summarized as follows: chronically-irradiated monkeys were less distractible than the normals. Radiation exposure reduced the probability of response to the weaker stimuli in the environment. Consequently the relative effectiveness of the strongest stimuli was increased. The observed behavioural changes were recorded from systematic observations in free home cage (1958), and performance on object-discrimination testing in WGTA (1959, 1960, 1961a, 1961b). Brown and McDowell (1962) studied effects of radiation on the psychological processes in the rhesus monkeys. Chronic whole-body radiation from various mixed doses were delivered to 2 groups of male and female animals. Total doses ranged from 77-616 R. The results showed differential effects of radiation on the chosen tests. There were obtained both performance facilitation and performance decrement, depending on nature of the tests. They concluded that radiation facilitated learning performance on tasks requiring attention or concentration to site of food reward, but

reduced efficiency on those requiring attention to peripherally placed stimuli.

Harlow's (1962) series of experiments with monkeys' post-irradiation performance, on the other hand, did not provide any conclusive results. Blair and Arnold's (1956) 2500 R head irradiation on rats produced better retention of a learned maze behaviour. The effects were present at 25-80 days post-irradiation. Blair (1958) delivered 5000 R of restricted area cranial X-ray to rats at 105 days of age. Rats were tested at one day, 30 days or 90 days after irradiation. The results were consistent with those of Blair and Arnold (1956) and Harlow and Moon (1956). Large doses were thus reported to result in quicker learning, faster running speed and less variability in maze acquisition. Gentry et.al. (1956) also reported improvement in post-irradiation performance.

These experimental results have been used to support Furchtgott (1963) and Harlow's (1962) contention that the CNS is very radioresistant. Little behaviour change in learning and performance could be present after irradiation of a sub-lethal dose. The report that irradiation resulted in changed level of motivation (Upton, 1966; Jarrard, 1963; Brown et.al. 1960, 1962; Wicker et.al. 1965) seemed to lend further support to this view.

However, since then some experimental results have cast serious doubts on this position. Naitoh et.al. (1965) examined the effects of whole brain cobalt-60 gamma irradiation on the cortical arousal in the burrow. Single doses of 200, 400 or

600 R were given to 32 adult burrows. Post-irradiation
study on the defensive motor conditioned response revealed
a facilitation of extinction with 400 and 600 R. Collateral
data rejected the motivational-emotional hypothesis, because
they showed the unchanged efficacy of the UCS in eliciting
the UCR; neither was there any change in the level of per-
formance with the presence of UCS. The EEG record, on the
other hand, did not favor the increased concentration of at-
tention hypothesis. Animals' improved extinction was actually
accompanied by an inferior discrimination of the positive and
negative CS's on the EEG. He attributed the apparent facili-
tatory effect to the radiogenic difficulties in emotional
activation in response to the learned stimulus cues. Ordy et.
al. (1963) study to assess the pathologic and behavioural
changes in mice after deuteron irradiation of the CNS. Localized
irradiation of unilateral and bilateral parietal region with
8000 R and of the cerebellum produced histopathologic changes
in the nerve cells. Delayed necrosis and degeneration of af-
fected cells were present. The behavioural tests results
showed no significant differences. However, delayed lo-
comotor performance started to set in at 4 month post-irradia-
tion, while no further gross neuronal or vascular changes
were presented beyond 30 days post-irradiation. Peacock et.al.
(1964) failed to observe any behaviour change in rats given
20 R/week whole-body gamma irradiation. But the authors sug-
gested that different results could be obtained had a more
complicated experimental design been used. They also called
attention to the danger of drawing conclusions on pooled results

alone.

Brown et. al. (1966) studied the effects of large single doses of 1000, 2000, 4000 and 8000 R of whole-head irradiation on rat avoidance and appetitional behaviour. The results reflected the presence of post-irradiation depression in performance 1 hour after the irradiation was delivered. The depression was dose-dependent. The authors attributed the discrepancy between the present and past results to relative sensitivity of the experimental parameters. Rieopelle et.al. (1962) studied performance of chimpanzees received 375-400 R radiation and of monkeys received 2000 R. Both sets of results showed the permanent impairment in performance.

Davis and McDowell (1962) monkeys receiving two large doses of 3000 R in the head also showed definite CNS distrubance. The nature of CNS impairment was similar to brain injury of the comparable area. The authors attributed the phenomenon to effects of delayed neurosis.

In view of their research on the histoligic and histochemical changes in the rat brain following X-irradiation (1964), Roth and Ingersoll (1965) and Ingersoll et.al. (1966, 1967) challenge the validity of Furchtgott (1963) hypotheses. In the 1965 study, rats 65 days old were given 5000 R to the frontal area of the brain. To avoid contamination of experimental results due to changes in motivational variables, all behavioural studies were done 2 weeks after irradiation. The irradiated rats showed a significant retardation in acquisition of an alternating pattern of immediate and delayed re-

ward in a run way situation. Examination of the irradiated brains revealed extensive histological and histochemical changes in the rostral half of the forebrain. The 1967 study with 90 days old rats receiving either 2500 or 5000 rads to the forebrain confirmed the previous results. There was a significant learning deficit in irradiated rats on the 60 sec. delayed reward runway situation. As no learning deficits were present on the immediately reward trials the effect was ascribed to ionizing radiation and not due to abscropal effects. Urmer and Brown (1960), Novakova (1967), Vernadakis et.al. (1964), Upton (1966), Nair (1964 & 1966) etc. all pointed to this problem of methodology.

In fact, this problem of methodology was discussed by Nemenov as early as 1944. Nemenov and Yakovleva (1942) first observed the phenomenon of improved cortical inhibitory process after irradiation. But he considered it to be a superficial phenomenon secondary to the weakened cortical functioning. Derangement of this apparent facilitory effect would disappear if the animals were presented with more complicated tasks. Zeleny (1956), Lomonovs (1957) and Livshits (1960) also reported the post-irradiation improvement of inhibitory processes. Rather than considering the phenomenon an indication of the harmlessness of irradiation, it was attributed to the effect of radiation injury to both nervous tissue and to hemopoetic system. It should be mentioned at this point that Arnolds (1962) study had shown that

radiation injury could be masked by a post-irradiation increase in hunger motivation. This might have resulted in distorted radiation effects as measured by operant conditioned technique.

The review of available literature thus suggests that there is no real controversy with regard to the functional effects of ionizing radiation on the mature mammalian central nervous system. The relative sensitivity of various learning and performance tests is one of the most immediate problems that besets us. Only when this question is meaningfully answered, can one assesses with more accuracy the radiosensitivity of the central nervous system to penetrating radiations.

Chapter II. THE INVESTIGATION

Subject:

Twenty male albino rats of the Quebec strain, approximately 60 days old at the beginning of training, were used in the experiment involving single dose of gamma-irradiation. The subjects were between 150 to 200 days of age while being irradiated. One to three weeks of testing were carried out following irradiation.

Procedure:

(a)   General design:

Prior to irradiation all 20 animals were trained up to a stable baseline level. 10 animals were trained to the delayed conditioned approach paradigm (DCA) and the other 10 were trained to respond to the differential conditioned approach paradigm (DiffCA). 15 of these animals were subjected to one exposure to gamma radiation. The other animals were used as a control group. Of these 5 control animals, 3 animals were subjected to 10R irradiation while the other 2 were subject to sham irradiation. Of the irradiation group, 7 animals and of the control group, 3 animals were trained to the DCA paradigm. On the other hand, 8 animals of the irradiation group and 2 animals of the control group were trained to the DiffCA paradigm.

After irradiation (or sham irradiation) all animals were tested daily for 5 to 21 days on the same paradigm (DCS or DiffCA respectively) on which they were trained

prior to irradiation. In the post-irradiation testing session the DCA and DiffCA schedule paradigms were identical to the programs at the end of the pre-irradiation training period.

(b) Deprivation schedule:

Prior to the pre-irradiation training and post-irradiation testing sessions, all animals were put on a 23-hour water deprivation schedule. While the animals were water-deprived, laboratory chow food pallets were available ad. lib. except for the approximately 40-minute experimental periods. All animals were housed in individual wire mesh single cages. After the training or testing sessions were completed the animals were allowed to drink ad. lib. for 10 minutes.

(c) Apparatus:

The animals were trained and tested in a Skinner Box. The Skinner Box was of the sound attenuated LVE type with the left lever connected via the pannel to the reinforcement mechanism. Two EICO model 377 Audio Generators were used to produce the desired CSs. LVE counters were used to register presentations of CSs, lever presses and of response latencies. Randomization of inter-trial intervals, and of positive and negative CSs was achieved by a BRS Precision Probability Unit of Model No. PP-1 type. A Lehigh Valley Electronics Model 1302, 28 Volts power supply was connected to the Skinner Box, the pannel and the counters.

For this box, both the delayed conditioned approach (DCA) and the differential conditioned approach (DiffCA) paradigms were constructed with BRS model 4C004 - 12 volts D.C.

A cobalt-60 gamma ray source for therapeutic purpose at Manitoba Cancer Foundation was used for irradiation. Radiation was delivered at the rate of 7.5 rad/minute, when an animal was at the bar or drinking well. As some Ss stayed at the other end of the box for approximately 25% of total irradiating time, the maximum error in assessing the same dose-rate would be approximately minus 5%. The target-to-subject distance was approximately 53 cm.

(d) Training Procedure:

(i) DCA:

The animals were trained to respond to the delayed conditioned approach paradigm (DCA), first used by Halasz and Marrazzi (1964,1965) as a screen for centrally activating pharmacological agents.

This model behaviour was established by the following training procedure. The water-deprived animal was first trained to press the lever for water reward. Then the animal was reinforced only when it responded to a specific auditory CS. A 16 sec. 1kHz 80 db square wave was used as the CS. Originally the period of reward availability coincided with that of the CS. On all trials reinforcement was available during a CS interval of 16 sec. Later, a delay was introduced between the onset of the CS and onset of reward availability. The length of the delay period was increased stepwise from 0

sec. to 9 sec. by 0.5 sec. increment. When the delay period had increased to 6 sec., a 1 sec. penalty period was introduced. When the delay was increased to 9 sec. the penalty period was increased to 3 seconds. The penalty period was always at the beginning of the delay period. During the penalty period any lever pressing of the animal precluded the availability of reinforcement during that trial. When the DCA training was successfully completed the animal responded only after a waiting period of several seconds, and during the subsequent 16-second period of reward availability. To prevent the contamination of DCA responses (due primarily to non-specific effects of hyper-reactivity) the onset of the CS tone was preceded by a trial-abort period (Cheng and Halasz, 1967). If the animal pressed the bar during the 16 sec., trial abort period prior to the CS, the occurrence of the CS was delayed for at least 30 seconds.

Daily sessions consisted of 40 daily trials and the CR latency of each trial was obtained by counters. After three months of training, behaviour was relatively stable and baseline of performance was obtained. Depending on the experimental conditions, variations in the stabilized performance may reflect fluctuations in cortical functioning in general, and of cortical inhibitory processes in particular.

   (ii) DiffCA:

The Differential conditioned approach was used as an assay for the initial disinhibitory effects of CNS stimulant (Halasz and Marrazzi, 1966). Animals trained according to this paradigm were required to discriminate between two

auditory CSs of equal duration. Only responses during the correct CS led to water-reward.

This model behaviour was established by the following steps. The water-deprived animal was first trained to bar press for water reward. Later, a 16 sec. 1KHz 80 dbs. auditory CS+ was introduced and the animal was reinforced only for responses specific to this positive stimulus. The period of reinforcement availability corresponded to the 16 sec. positive CS duration. When this conditioned approach behaviour became stable, a negative CS of .7KHz 80 db . was introduced and responses to this CS- led to non-reward. The presentation of the positive-and negative-stimulus were randomized to ensure frequency discrimination. When the DiffCA was successfully completed, the animals' responsed only during positive CS duratinn. The trial-abort feature was also used to prevent contamination of results by non-specific hyperreactivity.

(e) Radiation session:

After the animals' baseline-performances were obtained, they were randomly assigned to one of the four pre-determined dose-level for a single dose of whole-body Cobalt 60 gamma ir-radiation. The four doses were sham-irradiation or 10 Rad, 300 Rads, 450 Rad and 600 Rad respectively.

Of the 10 rats trained according to the DCA paradigm, 3 received sham-irratiation or 10 Rad, 2 received 300 Rad, 3 received 450 Rad and 2 received 600 Rad of irradiation. Of the 10 rats on the DiffCA paradigm, 2 were in control group, 3 in 300 Rad-group, 3 in 450-Rad group and 2 were in

600 Rad-group. All radiation was given in the whole-body
radiation room with the back of the Skinner box facing the
single source of irradiation. Except for the delivering of
gamma-rays, the animal was on an otherwise 'normal' daily
testing session. Depending on the dosage delivered, the
length of each radiation session was slightly adjusted accord-
ingly.

(f)   Behavioural Measures:

The effects of gamma-irradiation were measured mainly
in terms of variations in the means and standard deviations
of the CR latencies over 40 daily trials. The weights of
12 rats were obtained daily throughout the experiment to con-
trol the possible effects of weight loss on the performance.

Chapter III. THE RESULTS AND DISCUSSION OF RESULTS

RESULTS

Gastrointestinal Syndrome:

During the first post-irradiation week, irradiated animals appeared lethargic, with reduced volitional activity and less resistance to handling. Between the second and the fifth post-irradiation days, Ss exhibited rapid onset of fatigue, sitting or lying down much of the time in the course of experimental sessions. This syndrome seemed equally present in both the DCA, and the DiffCA.

Weight loss was greatest during the first post-irradiation week, but showed little dose-dependency. Subsequent weight recovery was slight and Ss maintained on constant deprivation schedule never regained pre-irradiation control level (Appendix B).

There were no obvervable differences with regard to the ten minute drinking periods, nor was there any vomiting or diarrhea.

Most of the G.I. symptoms disappeared by the second post-irradiation week.

Behaviour measures:

The effects of single doses of 300, 450 and 600 rads gamma irradiation on the delayed and differential conditioned approach (DCA and DiffCA) are shown in Table I. Figure 1 and Figure 2. Data were analyzed according to the analysis of variance programme of Chebib and Becker, 1967. To meet the criterion for homogeneity

TABLE I

SUMMARY OF SHORT ANALYSIS OF VARIANCE:

on effects of irradiation and conditioning paradigms on Δ mean
response latencies during the first and the third post-irradia-
tion weeks.

Source	DF	MS	F
Control vs. irradiated groups (A)	1	0.3479	1.11
1st. vs. 3rd post-irradiation weeks performance (B)	1	0.8461	2.69
Interaction (A X B)	1	0.4234	1.35
DCA vs. CS+ vs. CS- (C)	2	1.9414	6.17*
Interaction (A X C)	2	0.5447	1.73
Interaction (B X C)	2	1.1493	3.65*
Interaction (A X B X C)	2	0.6020	1.91
Error	44	0.3146	
Total	55		

* $p < .05$

SS adjusted for unequal subclass numbers by the use of the
harmonic means of N.

All raw data transformed to x + 5.1 to meet the assumption
for homogeneity of variance.
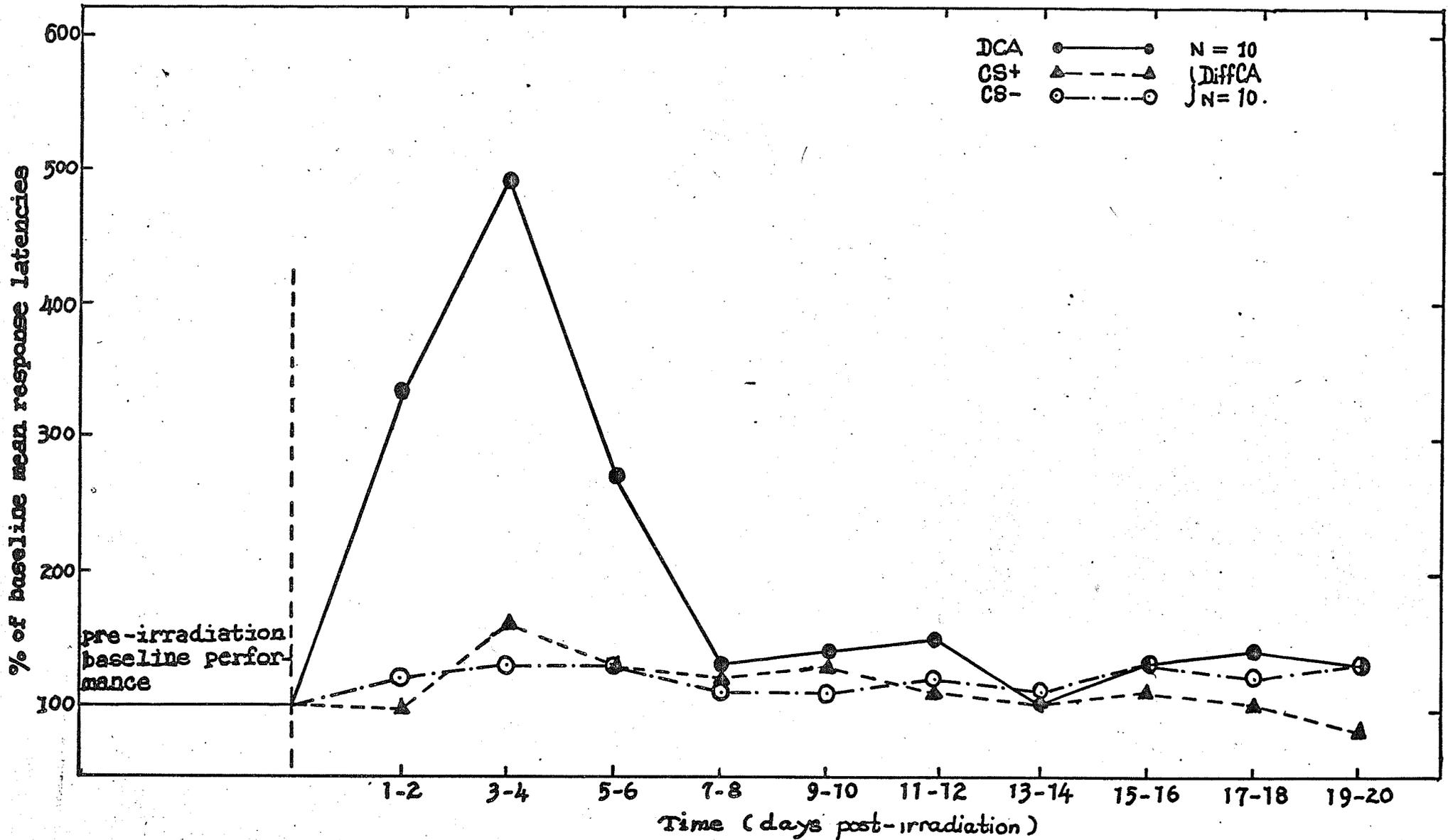
Fig. 1. Mean response latencies in delayed and differential conditioned approach, following gamma irradiation (300, 450 and 600R). (Each point represents mean of 2 consecutive daily sessions, each including 40 CS presentations).
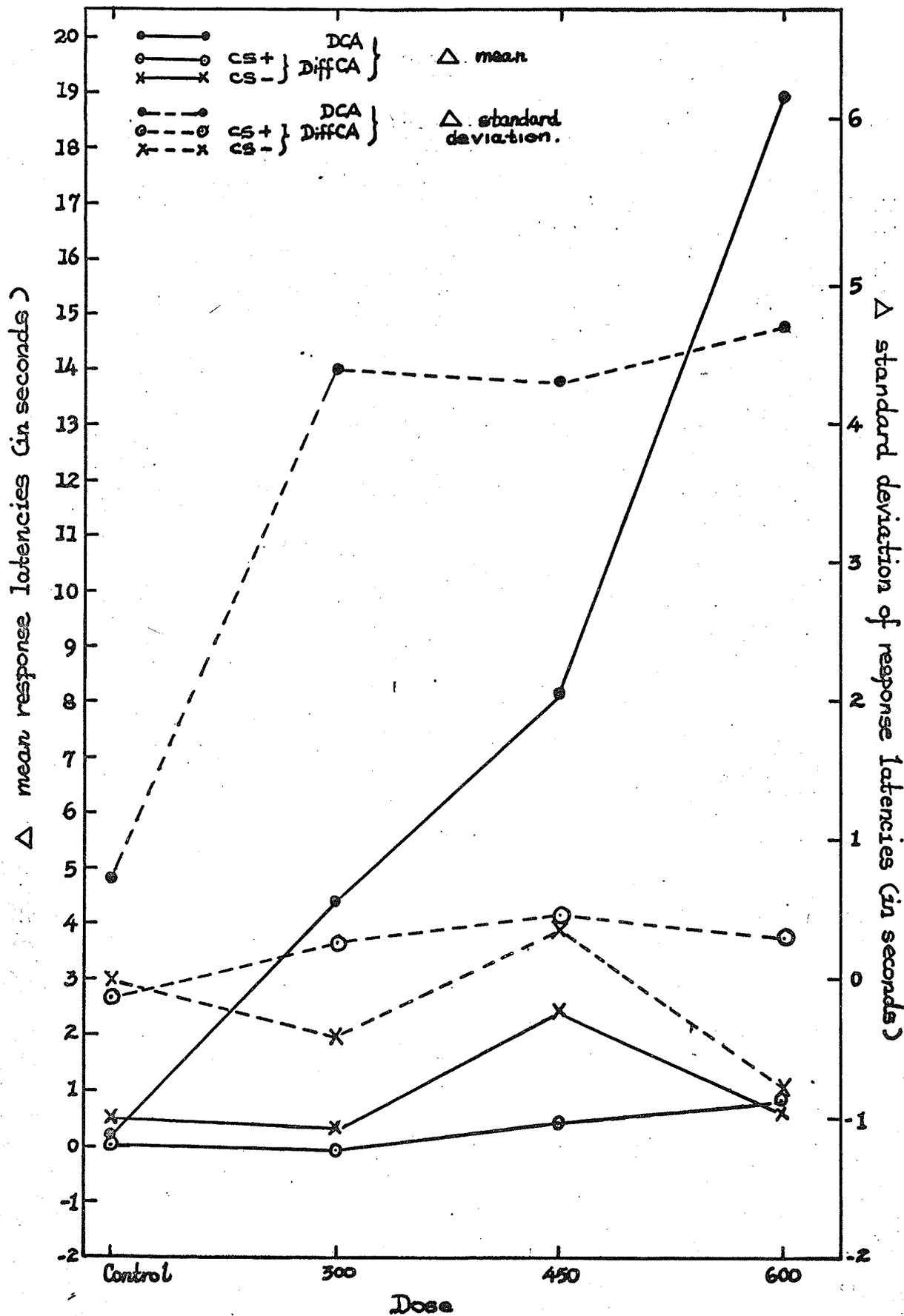
Fig. 2. Change (△) in mean response latencies and
in standard deviation of response latencies in delayed
and differential conditioned approach, following sham,
300, 450 and 600R gamma radiation.

of variance, individual scores were transformed to $\sqrt{x + 5.1}$,
and to reduce the effect of individual differences and initial differences between DCA and DiffCA performance, the effects of radiation on performance were considered in terms of difference between post-irradiation mean response latencies and corresponding pre-irradiation baseline performance. To control for onset of recovery, comparison was made between the first and the third post-irradiation weeks. Table I shows that there is a significant difference with regard to the effects of radiation on DCA performance as against response to CS+ and CS- of DiffCA ($p < .05$). A significant interaction between behavioural paradigms and week after irradiation ($p < .05$) indicates that the effects of radiation on the two conditioning paradigms are not parallel.

Figure 1 shows the time course of effects of radiation on mean response latencies in DCA and DiffCA. Post-irradiation performances are presented as percentage of pre-irradiation baseline mean response latencies. From Figure 1, it is clear that the effects were greatest during the first post-irradiation week, and most observable effects have subsided by the 6th. to 7th. post-irradiation day. The effects were most intense between second to 4th. post-irradiation days, during which there was approximately 500 per cent increase in the mean response latencies on DCA, while the effects on DiffCA, in comparison, were quite slight.

As effects were maximal during the first post-irradiation week, comparison was made at that time between paradigms, as

regards change (Δ) in mean response latencies (and standard deviations of response latencies) as a function of radiation dose (Figure 2). Inspection of Figure 2 reveals a dose-dependent increase in DCA mean response latencies. Increase of latencies to CS+ and CS- in DiffCA, on the other hand, was minimal, and not clearly dose-dependent. Standard deviation of DCA latencies also increased after irradiation, but the dose response relation was not monotonic. Standard deviations of latencies to CS+ and CS- in DiffCA show no monotonic relation to radiation dose in the range covered.

Combining the results on Figure 1 and 2 and Table I, it can be concluded that the two conditioning paradigms show significant differential sensitivity to acute sub-lethal single doses of gamma-irradiation. DiffCA is shown to be much more resistant to radiation than the DCA paradigm.

Figures 3 and 4 present the effects of sham-, 300, 450 and 600 rads of gamma-irradiation on mean response latencies to the DCA and DiffCA respectively, but here effects are expressed in terms of per cent of increase or decrease in latencies relative to Ss' pre-irradiation baseline performance, i.e. animals their own control. Again, there is a dose-dependency in both the magnitude of increase in latencies and in the duration of the effects in the DCA problem. The higher the dose, the greater and longer the effects on the delay behaviour. Figure 4, on the other hand, shows little suggestion of radiation dose dependency in any changes of mean response latencies
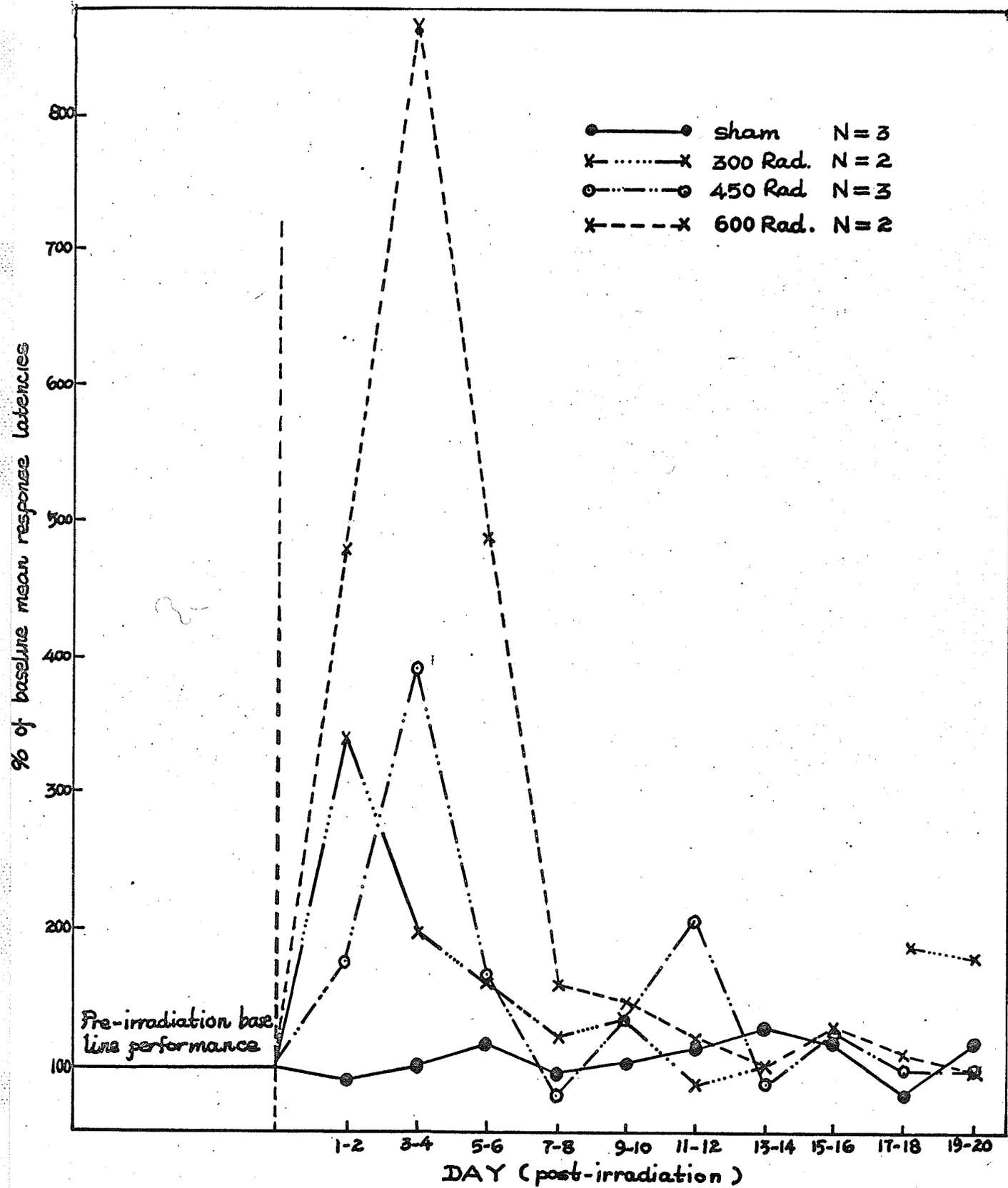
Fig. 3. Mean response latencies to DCA, following exposure to sham, 300, 450 and 600R gamma radiation, expressed as % of baseline performance. Each point represents mean over 2 consecutive daily sessions, each session including 40 CS presentations.
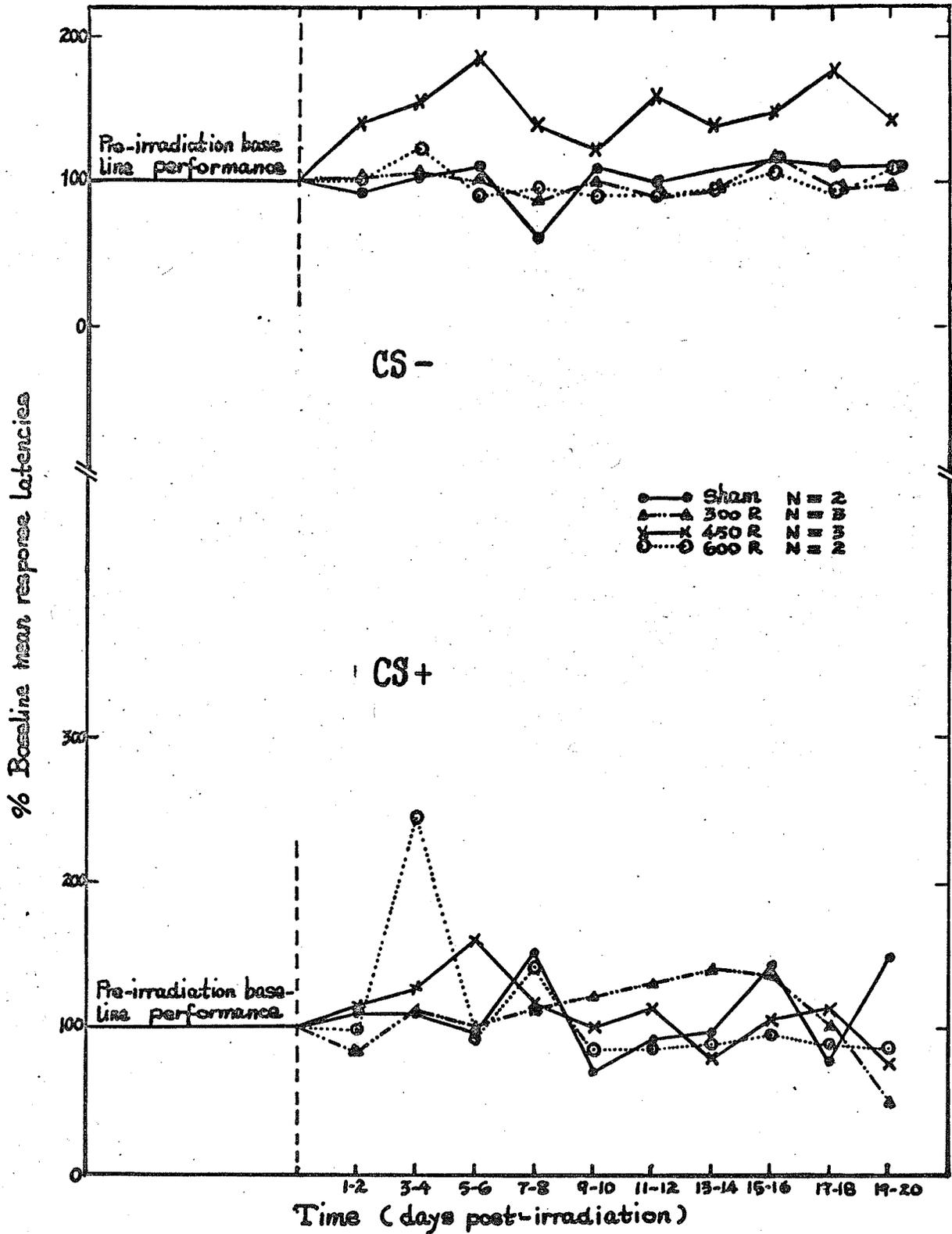
Fig. 4. Mean response latencies to CS+ and CS- of DiffCA, following sham, 300, 450 and 600r gamma irradiation expressed as % of baseline performance. (Each point represents mean of 2 consecutive daily sessions, each session including 40 CS presentations).

in DiffCA. Except for the increased response latencies to the CS+ during the third and the fourth post-irradiation days for rats receiving 600 rads, there was no systematic change in either general performance or stimulus discrimination, differential reactions to CS+ and CS- being maintained throughout the experiment.

Of special interest are the results summarized in Figure 5. This figure consists of six separate figures, each of which shows day to day change in over-all responsiveness of Ss in the treatment conditions. Daily mean response latencies are expressed as percentage of baseline performance, and the percentage score for each day subtracted from that of the day following. Thus, the figures are presentations of between-day variations in the animals' performance before-and after-irradiation (or sham-irradiation). This figure shows that radiation produced the greatest day to day change in performance in groups trained to DCA, and the least on response latencies to CS- of DiffCA, with the effect on response latencies to the CS+ of DiffCA falling in between. At the peak of greatest radiation effects on DCA, there is a 500 percent change of response latencies from one day to the next, while there is only 150 percentage change in DiffCA.

Figure 6 shows the day to day changes in the standard deviation of response latencies (S.D.), also expressed as percentage of pre-irradiation baseline S.D. The effects of irradiation on S.D. are shown to be essentially similar to that on
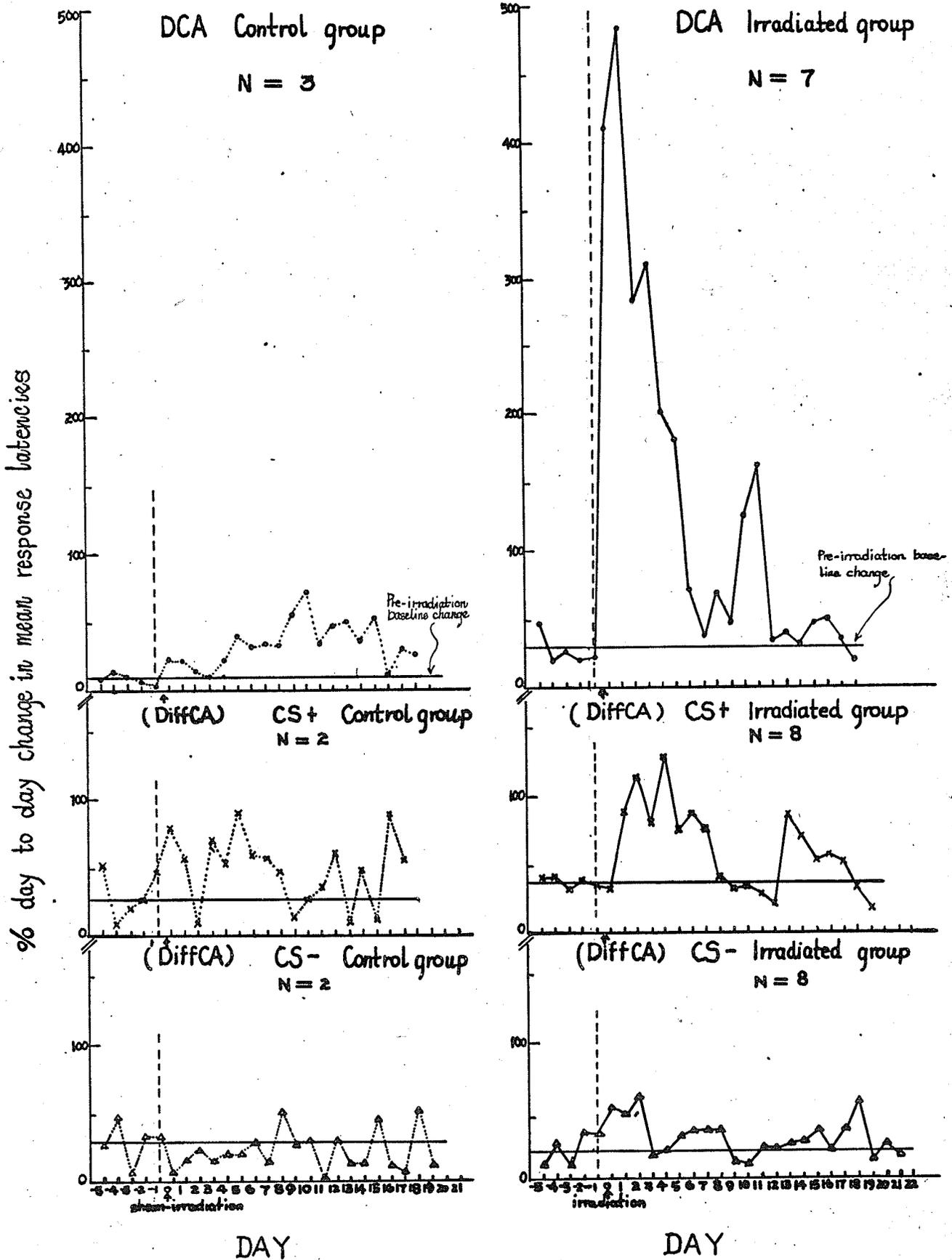
Fig. 5. Day to day changes in over-all responsiveness, as expressed in terms of percentage relative to baseline performance.
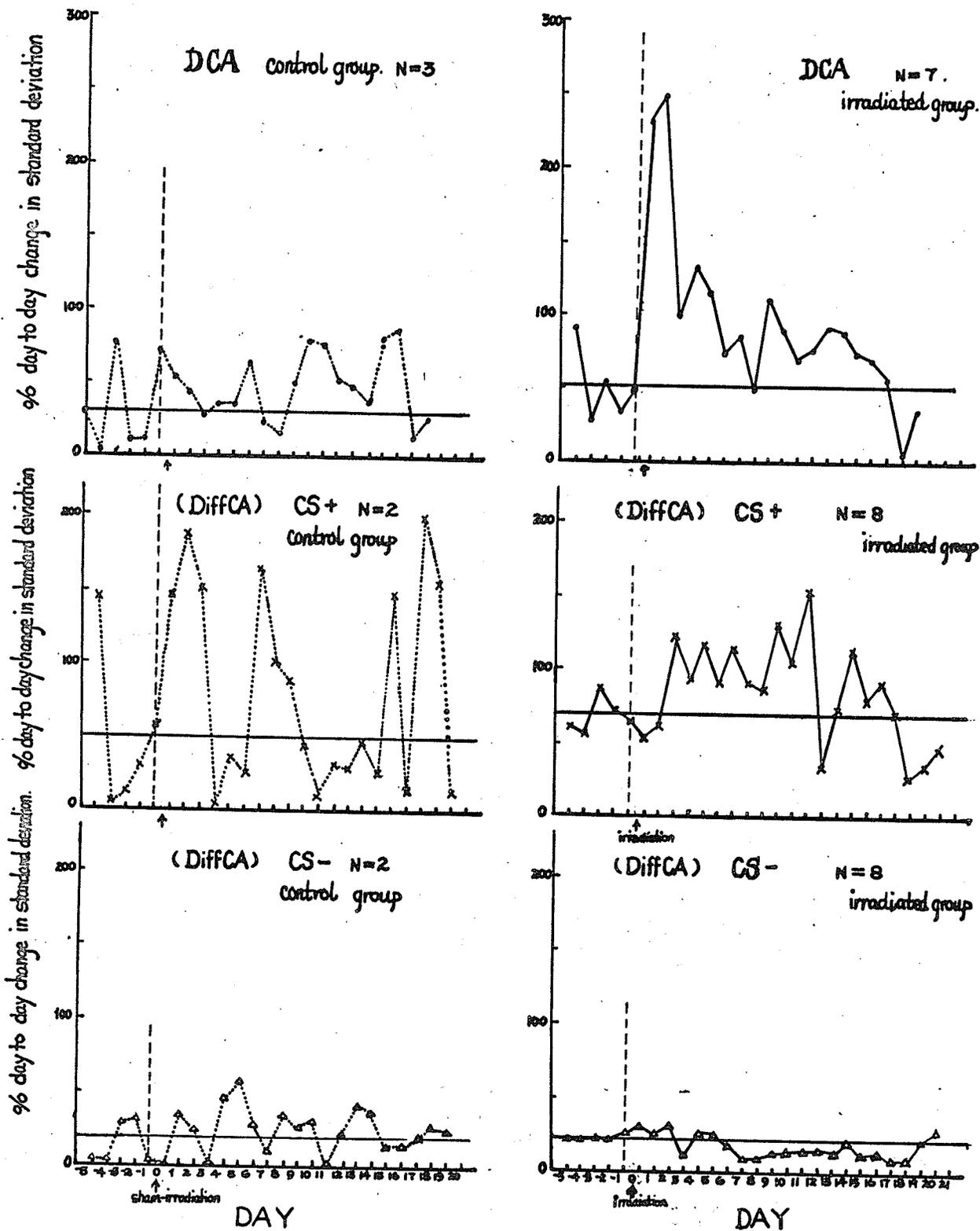
Fig. 6. Day to day changes in the Standard Deviation of response latencies (40 daily CS trials), expressed as % of pre-irradiation base line SD. Graphs on the right hand side represent changes in the irradiated groups, and the left hand side are the corresponding control groups. The mean baseline changes are shown by the horizontal lines.

mean response latencies. Thus, along with radiation-induced

changes in mean response latencies, there are also changes

in between-session, as well as within-session, variabilities.

The magnitude and duration of these changes are a function

of the sensitivities of the DCA or DiffCA paradigm to radia-

tion.

DISCUSSION

Gastrointestinal Syndrome:

The observed gastrointestinal symptoms corresponded well to Bond et. al.'s descriptions following sub-lethal doses of irradiation.

Post-irradiation weight measures also validated Nim et. al. (1952), Jackson (1958) and Bond et. al.'s (1965) findings. The absence of dose-dependency in radiation-induced weight loss and of subsequent weight recovery is in line with Nim's study. With single exposure to 300, 400, 500 and 700 R whole-body radiation in rats, Nim's results showed that, unlike fed rats, deprived animals did not recover to control level. Thus, except for the initial post-irradiation weight loss, daily weights of experimental rats followed similar trends as those of control animals. Any possible recovery would presumably be masked by the severe effects of long term water deprivation.

Behavioural Measures:

The period of maximal behavioural disturbance, if any, corresponded with the period of acute radiation sickness. This phenomenon suggests the effects of radiation to be on non-associative factors. But, contrary to conventional belief, ir-radiated animals are not less "motivated". There is a marked polydipsia in rats within the first two days after exposure to the doses employed (Bonds et. al., 1965; Jackson, 1958; Nims, 1952), which results in sharp increase in water intake (Smith et. al., 1965; Williams et. al. 1958), though water consumption

in an operant water-reinforcement situation decreases after
radiation (Brown et. al. 1960, 1962; Wicker et. al. 1956).
Therefore, part of the performance deficit can be attributed
to a diminution in strength and ability to perform (Brown et.
al. 1962; Wicker, 1965).

The employed doses were above the threshold for animals
to detect onset of radiation (less than 20 mR). But there
was no obversable interruption of performance during the irra-
diation sessions in either paradigm. Presumably, motivation
to perform the conditioned tasks was stronger than the aversive
effects of radiation, despite the fact that the employed doses
were sufficient for learning of conditioned aversion to radia-
tion (Feder et. al. 1966; Garcia, 1955, 1956, 1957, 1958, 1960
(a,b,c,), 1961, 1962, 1963, 1964; Garcia and Kimoeldorf, 1960;
Hunt, 1962; Cooper and Kimoeldorf, 1964). Garcia and Koelling
(1967) showed that Garcia-Kimoeldorf phenomenon can be established
for almost any kind of fluid, so long as there is a distinctive
fluid uniquely paired with X-rays, and an alternative fluid not
paired with radiation. Since unflavoured water was used thr-
oughout the experiment, the present experiment is not likely to
be contaminated by the Kimoeldorf phenomenon. Furthermore, the
use of unflavoured water avoided the possibility of temporary
loss of taste (Shaber et. al. 1967) with accompanying effects
on performance. In any case, both DCA and DiffCA behaviour
would presumably show such general motivational or incentive
changes.

The "paradigm specificity" of radiation effects makes
questionable the radiobiological explanations based on non-
associative factors alone (contrary to Furchtgott, 1956,
1963).

As stated in the introduction, "attention" has been used
to explain differential effects of radiation on various beha-
vioural tests. The requirement of self-inhibition in DCA, and
the painfully long training period required both to establish
and to maintain conditioned delay, argue that the DCA paradigm
requires more concentrated attention than differential con-
ditioned approach. It was our finding that radiation caused
greater impairment of DCA than DiffCA behaviour. Thus, radia-
tion apparently caused greater deficit in a task demanding
higher attentional level than in a related problem in which
concentration is presumably less importment. This finding is
in contradiction to McDowell (1958, 1959, 1960a, 1960b) and
Brown and McDowell's (1962) suggestion that radiation facili-
tates problems requiring more attention.

According to Pavlovian theory, conditioned delay requires
more "cortical inhibition" than simple stimulus discrimination,
presumably because fewer exteroceptive cues are provided.
Soviet literature argues that tasks requiring cortical inhibi-
tion are more radiosensitive. Results in the present experi-
ment are consistent with such a point of view.

The supposition of "cortical radiosensitivity" may further
be supported by any specific radiation effect on the "estimation
of time", presumably cortically mediated. Our results show a

systematic dose-dependent measure increase in DCA latency,
the increment in standard deviation not being dose-dependent.
Thus, the DCA response become slower, not just more variable,
after radiation. Since such slowing was not produced in the
"control" DiffCA paradigm, it cannot be explained as a non-
specific slowing of all reactions. Therefore, it may well
reflect a specific change in time estimation.

The results of the present experiment argue that either
level of attention or time estimation may be affected by sub-
lethal doses of gamma radiation. Either of these variables
would constitute an effect of radiation on the integrative
functions of the central nervous system.

SUMMARY AND CONCLUSIONS

This study has been concerned with the relative radio-sensitivity of delayed and differential conditioned approach behaviour (DCA and DiffCA) in the Skinner boxes. These two behaviour are similar with regard to motivation, stimuli, motor skill and measures. They differ in that DCA requires accurate "timing" function, while DiffCA involves only frequency discrimination.

Twenty male albino rats were used for the experiment, and they were given a single exposure to sham-, 300, 450 or 600 rads of Co-60 gamma irradiation.

Post-irradiation performances on the DCA showed a dose-dependent increase in reaction latencies, but the corresponding measures on the DiffCA showed little impairment.

The obtained differential sensitivity of the DCA as against the DiffCA paradigm was discussed in terms of attentional demands, "timing" functions, and possible impairment in CNS integrative functions.

BIBLIOGRAPHY

1. Arnold, A. Effects of X-irradiation on the hypothalamus:
    A possible explanation for the therapeutic benefits fol-
    lowing X-irradiation of the hypothalamic region for pitui-
    tary dysfunction. J. Clin. Endocrinol. Metabol., 1954, 14,
    859-868 (a).

2. Arnold, A., Bailey, P., Harvey, R.A., Haas, L.L., and
    Laughlin, J.S. Changes in the CNS following irradiation
    with 23-mev X-rays from the betatron. Radiology, 1954,
    62, 37-44 (b).

3. Arnold, A., Bailey, P., and Laughlin, J.S. Effects of be-
    tatron radiations on the brain of primates. Neruology,
    41954, 4, 165-178 (c).

4. Arnold, A., Bailey, P., and Harvey, R.A. Introduction
    Intolerance of the primate brainstem and hypothalamus
    to conventional and high energy radiation. Neurology,
    1954, 4, 575-585 (d).

5. Arnold, W.J. and Cho, J.B. The effects of brain irradia-
    tion femur irradiation and starvation on maze learning in
    rats. Abstracts of the Second International Congress of
    Radiation Research, 1962, p. 179.

6. Biryukov, D.A. Problems concerning the interrelationships
    of the cerebral cortex and the internal organs. Fisiol.
    Zhurn. im. I.M. Sechenov. 1956, 42, 142-148. Quoted from
    Stahl (1960).

7. Blair, W.C. and Arnold, W. The effects of cranial X-radia-
    tion on maze learning in rats. J. Comp. Physiol. Psychol.
    1956, 49, 525-528.

8. Blair, W.C. The effects of cranial X-radiation on maze
    acquisition in rats. J. Comp. Physiol. Psychol. 1958,
    51, 175-177.

9. Brown, W.L., Blodgett, H.C., Henderson, D., Ritter, R.M.,
    and Pizzuto, J.S. Some effects on operant conditioning
    of ionizing radiation to the whole head. J. Genet. Psychol.
    1966, 108, 253-261.

10. Bond, V.P., Fliedner, T.M. and Archambeau, J.O. Mammalian
    Radiation Lethality. New York and London: Academic Press,
    1965.

11. Brown, W.L. and McDowell, A.A. Some effects of radiation
    on psychological processes in rhesus monkeys in T. J. Haley
    and R.S. Snider (Eds.). Response of the N S to ionizing
    radiation, New York: Academic Press, 1965, p. 729.

12. Brown, W.L., Overall, J.E., Logie, L.C. and Wicker, J.E. Lever-pressing behaviour of albino rats during prolonged exposure to X-radiation. Radiation Res. 1960, 13, 617-631.

13. Burt, D.H., and Ingersoll, E.H. Behavioural and neuro-pathological changes in the rat following X-irradiation of the frontal brain. J. Comp. Physiol. Psychol. 1965, 59, 90-93

14. Caster, W.O., Redgate, E.S., and Armstrong, W.D. Changes in the CNS after 700 R total-body X-irradiation. Radiation Res. 1958, 8, 92-97.

15. Chebib, F., and Becker, G. IBM/360 Analysis-of-variance Program for Proportionate and Disproportionate Subclass Frequencies. University of Manitoba. 1967.

16. Cheng, Y., and Halasz, M.F. Amphetamine and conditioned delay behaviour: nonspecificity of effect on "timing". Report at the Annual Meeting of Canadian Psychol. Association, 1967.

17. Cooper, G.P. and Kimeldorf, D.J. EEF desychronization in irradiated rats with transected spinal cords. Science, 1964, 143, 1040-1041.

18. Davis, R.T. and McDowell, A.A. Performance of monkeys before and after irradiation to the head with X-rays in T.J. Haley and R.S. Snider (Eds.), Response of the nervous system to ionizing radiation. New York: Academic Press, 1962, 705-718.

19. Denisova, Z.N. Med. Radiol. 1957, 2, 10. Quoted from Livshits, 1960.

20. Feder, B.H., Garcia, J., Koelling, R.A. and Buchwald, N.A. Detection of minute doses of ionizing radiation. Acta Radiologia 1966, 5.

21. Furchtgott, E. Behavioural effects of ionizing irradiation. Psychol. Bull. 1956, 53, 321-334.

22. Furchtgott, E. Behavioural effects of ionizing radiations: 1955-1961. Psychol. Bull, 1963, 60, 167-199.

23. Gangloff H. and Hug, O. The effects of ionizing radiation on the nervous system, in J.H. Lawrance and J.W. Gofman (Eds.). Advances Biol. Med. Phys., New York: Academic Press, 1965, 10, 1-90.

24. Garcia, J., Buchwald, N.A., Bach-y-Rita., Feder, B.H. and Koelling, R.A. Electroencephalographic responses to ionizing radiation. Science, 1963, 140, 289.

25. Garcia, J., Buchwald, N.A., Feder, B.H., and Koelling, R.A. Immediate detection of X-rays by the rat. Nature, 1962, 196, 1014-1015.

26. Garcia, J., Buchwald, N.A., Feder, B.H., Koelling, R.A. and Feduow, L.F. Ionizing radiation as a perceptual and aversive stimulus. I. instrumental conditioning studies; in T.J. Haley and R.S. Snider (Eds.) Response of the CNS to ionizing radiation, Boston: Little Brown and Co. 1964.

27. Garcia, J. and Kimeldorf, D.J. Temporal relationship within the conditioning of saccharin aversion through radiation exposure. J. Comp. Physiol. Psychol. 1957, 50, 180-183.

28. Garcia, J. and Kimeldorf, D.J. The effects of ophthalmectomy upon responses of the rat to radiation and taste stimuli. J. Comp. Physiol. Psychol., 1958, 51, 288-291.

29. Garcia, J. and Kimeldorf, D.J. Conditioned avoidance behaviour induced by low dose fast neutron exposure. Nature, 1960, 185, 261 (a).

30. Garcia, J. and Kimeldorf, D.J. Some factors which influence radiation conditioned behaviour of rats. Radiation Res. 1960, 12, 719-727 (b).

31. Garcia, J., Kimeldorf, D.J., and Hunt, E.L. Conditioned responses to manipulative procedures resulting from exposure to gamma radiation. Radiation Res., 1956, 5, 79

32. Garcia, J., Kimeldorf, D.J., and Hunt, E.L. The use of ionizing radiation as a motivating stimulus. Psychol. Rev. 1961, 68, 383-395.

33. Garcia, J., Kimeldorf, D.J., and Koelling, R.A. Conditioned aversion to saccharin resulting from exposure to gamma radiation. Science, 1955, 122, 157-158.

34. Garcia, J., and Koelling, R.A. A comparison of aversions induced by X-rays, toxins, and drugs in the rat. Radiation Res. (suppl.) 1967, 7, 439-450.

35. Grafov, A.A. in Patol. Fiziol. Ostroi, Luchevoi. Bolezni. Medgiz, Moscow, 1958, p. 49. Quoted from Livshits, 1960.

36. Halasz, M.F., Stability of an inhibition of delay determined by transient response to pertubation. Activitas Nervosa Superior, 1967, 9, 1-4.

37. Halasz, M.F. and Marrazzi, A.S. Releasing factors effects of LSD 25 on differential conditioning in cats. Fed. Proc. 1966, 25, 261.

38. Halasz, M.F. and Marrazzi, A.S. Psychotogen vs. tranquilizer on monkey conditioned approach. Fed. Proc., 1964, 24, 103.

39. Harlow, H.F. Effects of radiation on the CNS and on behaviour-general survey; in T.J. Haley and R.S. Snider (Eds.), Response of the Nervous System to Ionizing Radiation. New York: Academic Press, 1962, 627-644.

40. Harlow, H.F., Meyer, D., and Settlage, P.H. The effects of large cortical lesions on the solution of oddoty problems by monkeys. J. Comp. Physiol. Psychol., 1951, 44, 320-326.

41. Harlow, H.F., and Moon, L.E. The effects of repeated doses of total-body X-radiation on motivation and learning in the ruhesus monkeys. J. Comp. Physiol. Psychol., 1956, 49, 60-65.

42. Hunt, E.L., and Kimeldorf, D.J. Evidence for direct stimulation of the mammalian NS with ionizing radiation. Science. 1962, 137, 857, 1962.

43. Ingersoll, E.H., Casten, A.W., and Brownson, R.H. Performance of the Sroague-Dawley rat in an delay runway following X-irradiation of the forebrain. Amer. Zoologists, 1966, 6, 296-297.

44. Ingersoll, E.H., Carsten, A.W. and Brownson, R.H. Behavioural and structural changes following X-irradiation of the forebrain in the rat. Proc. Soc. Exp. Biol. and Med., 1967, 125, 382-385.

45. Innes, J.R.M., and Carsten, A. Delayed effects of localized X-irradiation of the nervous system of experimental rats and monkeys. Brookhaven Symposia in Biology, 1961, 14, 200-203.

46. Jackson, K.L., Rhodes, R., and Entenman, C. Electrolyte excretion in the rat after severe intestinal damage by X-irradiation. Radiation Res., 1958, 8, 361-373.

47. Jarrard, L.E. Effects of X-irradiation on operant behaviour in the rat. J. Comp. Physiol. Psychol., 1963, 56, 608-611.

48. Kimeldorf, D.J., Garcia, J., and Rubadean, D.O. Radiation-induced conditioned avoidance behaviour in rats, mice and cats. Radiation Res., 1960, 12, 710.

49. Kim eldorf, D.J. and Hunt, E.L. Conditioned behaviour and the radiation stimulus; in T.J. Haley and R.S. Snider (Eds.) Response of the CNS to Ionizing Radiation. Little Brown and Co. 1964, 625-661.

50. Korot'kova, T.A. Electrophysiological studies of the effects of ionizing radiation on the normal and pathological conditions. Tr. Inst. Vysh. Nerv. Deyatel., 1958, 3, 121-135. Quoted from Stahl, 1960.

51. Kotlyarevsky, L.I., Gorsheleva, L.S., and Khozak, L.E. Med. Radiol., 1956, 1, 11. Quoted from Livshits, 1960.

52. Krabbenhoft, K.L. Radiation injury of the CNS. Am. J. Roentgenol. Radium Therapy Nuclear Med., 1955, 73, 850-852.

53. Kuhn, U.S., and Brown, D.G. Head Irradiation of the Burro. JAMA 1962, 180, 671-675.

54. Kurtsin, I.T. ±[Trudy Vsesoyuz. Nauch, Tekh. Konf. po Rumenen. Radioactiv i Slabil. Iztopov i Izluuchenii v Narod. Khoz. i Nauke Radiobiol. Moscow, 1958, 211] Quoted from Livshits, 1960.

55. Livshits, N.N. The nervous system and ionizing radiation. A E C Rev. Radiobiol., Trans. Ser. 1956, No. 3353. Quoted from Stahl, 1959.

56. Livshits, N.N. in [Radiobiol. Itogi Nauki., Acad. Sci., USSR, Moscow, 1958, 262]. Quoted from Livshits, 1960.

57. Livshits, N.N. Physiological effects of nuclear radiations on the central nervous system.; in C.A. Tobias, and J.H. Lawrence (Eds.), Advance in biological and medical physics. 7, New York: Academic Press, 1960, 7, 173-248.

58. Lomonos, P.I. [Vestn. Rentgenol. i. Radiol., 1953, 4, 30.] Quoted from Gangloff and Hug, 1965.

59. Lomonos, P.I. in [Pohedinskiy, M.N. and P.N. Kiselev (Eds.) Problems of Radiobiology, 1956, 5-20]. Quoted from Furchtgott, 1963.

60. Lomonos, P.I. [Conditioned-reflex activity of dogs on intravenous administration of radioactive cobalt] in [Works of the All-Union Conference on Medical Radiology], Moscow, Trudy, 1957. Quoted from Furchtgott, 1963.

61. Meyer, D.R., and Harlow, H.F. Effects of multiple variables on delayed response performance by monkeys. Gen.J. Genet. Psychol., 1952, 81, 53-61.

62. Miklashevsky, V.E. [Trudy Inst. Vysshei Neronoi Deyatel nosti, 1958, 4, 5.]. Quoted from Livshits, 1960.

63. McDowell, A.A. and Brown, W.L. Facilitative effects of irradiation on performance of monkeys on discrimination problems with reduced stumulus cues. J. Genet. Psychol. 1958, 93, 73-78.

64. McDowell, A.A. and Brown, W.L. Latent effects of chronic whole-body irradiation on the spatial delayed response problem. J. Genet. Psychol., 1959, 61, 61-64.

65. McDowell, A.A. and Brown, W.L. Comparison of running wheel activity of normal and chronic radiated rats under varying conditions of food deprivation. J. Genet. Psychol., 1960, 96, 79-83 (a).

66. McDowell, A.A. and Brown, W.L. Visual activity performance of normal and chronic focal-head irradiated monkey. J. Genet. Psychol., 1960, 93, 139-144. (b).

67. McDowell, A.A., Brown, W.L., and Wicker, J.E. Effects of radiation exposure on response latencies of rhesus monkeys. USAF Sch. Aerospace Med. 1961, 61-94, 1-3 (a).

68. McDowell, A.A., Brown, W.L. and White, R.K. Oddity - reversal and delayed-response performance of monkeys previously exposed to focal-head irradiation. J. Genet. Psychol., 1961, 99, 75-81 (b).

69. Nair, V., and Roth, L.J. A Pharmachological assessment of the changes in the CNS following X-irradiation; in T.J. Haley and R.S. Snider (Eds.), Response of the central nervous system to ionizing radiation, Boston: Little Brown and Co., 1964, 421-447.

70. Naitoh, P., Spurrell, F.A., and Herstad, G.T. Effects of whole brain cobalt-60 gamma irradiation on cortical arousal in the burro. Electroenceph. and Clin. Neurophysiol., 1965, 19, 172-181. 1944.

71. Nemenov, M.I. in [Vestnik Rentgenol. i. Radiol., 26, 43.] Quoted from Livshits, 1960.

72. Nemenov, M.I. in Acta Radiol., 1928, 2 suppl. 3, 169, Quoted from Livshits, 1960.

73. Nims, L.F., and Sutton, E. Weight changes and eater consumption of rats exposed to whole-body X-irradiation. Am. J. Physiol., 1952, 171, 17-21.

74. Novakova, V., and Stero, J. Higher nervous activity in rats irradiated with X-rays at different periods of postnatal development. Physiol. Behav., 1967, 2, 421-423.

75. Ordy, J.M. Samorajski, T., Zeman, W., Collins, R.L. and Curtis, H.J. Pathological and behavioural changes in mice after deuteron irradiation of the CNS, Radiation Res. 1963, 18, 31-45

76. Peacock, L.J., and James, W.T. Effects of repeated small doses of gamma radiation on conditioned reflexes; in T.J. Haley and R.S. Snider (Eds.), Response of the central nervous system to ionizing radiation, Boston: Little Brown and Co., 1964, 625-631.

77. Pennymaker, J., and Russell, D.S. Necorsis of the brain due to radiation therapy. J. Neurol. Neurosurg. Psychiat., 1948, 11(3), 183-198.

78. Reynolds, L. Newer investigations of radiation effects and their clinical applications. Am. J. Roentgenol. Radium Therapy, 1946, 55(2), 135-152.

79. Riopelle, A.J., Gronsky, M.A., and Ades, H.W. Learned performance of monkeys after single and repeated X-irradiation. J. Comp. Physiol. Psychol., 1956, 49, 521-524.

80. Russell, D.S., Wilson, C.W., and Tansley, K. Experimental radio-necrosis of the brain in rabbits. J. Neurol. Neurosurg. Psychiat., 1949, 12, 187-195.

81. Smith, D.E. and Tyree, E.B. Influence of X0irradiation upon water consumption by the rat. Am. J. Psychol., 1955, 184, 127-133.

82. Stahl, W.R. A review of Soviet research on the CNS effects of ionizing radiations. J. Nervous Mental Disease., 1959, 129, 511-529.

83. Stahl, W.R. Recent Soviet work on reaction of the central nervous system to ionizing radiation. J. Nervous Mental Disease, 1960, 131 (3), 212-232.

84. Stahl, W.R. Review of neurophysiologic and psychologic research on irradiation injury in the USSR; in T.J. Haley and R.S. Snider (Eds.), Response of the Nervous System to Ionizing Radiation, New York: Academic Press 1962, 469.

85. Upton, A.C. Pathological Effects. in E.E. Schwartz (Ed.), The Biological Basis of Radiation Therapy, Toronto and Philadelphia: J.B. Lippincott Co., 1966, 126-162.

86. Urmer, A.H., and Brown, W.L. The effects of gamma radiation on the reorganization of a complex maze habit. J. Genet. Psychol. 1960, 97, 67-76.

87. Vernadakis, A., and Timiras, P.S. Effects of whole-body X-irradiation on electroshock seizure responses in developing rats. Am. J. Physiol., 1964, 205, 177-180.

88. Wicker, J.E., and Brown, W.L. The effects of gamma radiation upon operant water-reinforcement behaviour. J. Genet. Psychol., 1965, 106, 295-299.

89. Yanson, Z.A. [Electrophysiol study of the changes occurring in conditioned reflex activity of rabbits after total and partial exposure to X-rays]. in [Works of All-Union Conference on Medical Radiology.] Moscow: Trudy, 1957, Quoted from Furchtgott, 1963.

90. Zeman, W. Radiosensitivities of nervous tissues: in Brookhaven National Laboratory (Ed.), Fundamental Aspects of Radiosensitivity, New York: Upton, 1961, 176.

APPENDIX A

Data for individual $\underline{S}$ daily means and standard deviation
of response latencies over 40 daily trials. Data in se-
conds.

1. Subject: No. 13

    Conditioning paradigm: DCA

    Treatment: single exposure to 450 rads gamma radiation

Days		$\overline{X}$	SD
1.	Pre-I.T.S.*	3.7571	3.3686
2.	Pre-I.T.S.	4.8286	6.1086
3.	Pre-I.T.S.	4.9114	9.5571
4.	Pre-I.T.S.	4.5397	5.6856
5.	Pre-I.T.S.	6.8329	10.7643
6.	radiation	3.5085	2.4557
7.	Post-I.T.S.**	16.5725	18.0697
8.	Post-I.T.S.	3.6891	2.3657
9.	Post-I.T.S.	5.8908	7.1541
10.	Post-I.T.S.	13.2298	15.0772
11.	Post-I.T.S.	3.7314	2.0405
12.	Post-I.T.S.	2.6234	2.6328
13.	Post-I.T.S.	6.0132	7.6855
14.	Post-I.T.S.	4.7553	4.5896
15.	Post-I.T.S.	12.2629	15.4190
16.	Post-I.T.S.	7.9486	11.7771
17.	Post-I.T.S.	38.5028	16.0320
18.	Post-I.T.S.	4.6761	2.4878
19.	Post-I.T.S.	7.0772	11.6968
20.	Post-I.T.S.	9.4914	9.3905
21.	Post-I.T.S.	8.5311	10.1224
22.	Post-I.T.S.	6.2109	6.2863
23.	Post-I.T.S.	4.1902	2.2919
24.	Post-I.T.S.	3.2212	2.3290
25.	Post-I.T.S.	5.4783	7.0659

$\overline{X}$ mean response latencies (in sec.)

SD standard deviation (in sec.)

*   Pre-irradiation training sessions

**   Post-irradiation testing sessions

2. Subject: No. 14

Conditioning paradigm: DCA

Treatment: single exposure to 300 R gamma radiation

Days		$\overline{X}$	SD
1.	Pre-I.T.S.*	3.0741	1.7156
2.	Pre-I.T.S.	3.4051	2.0488
3.	Pre-I.T.S.	4.4984	3.4804
4.	Pre-I.T.S.	4.9192	4.4112
5.	radiation	5.6494	3.8499
6.	Post-I.T.S.**	9.1814	9.0471
7.	Post-I.T.S.	6.4329	5.9000
8.	Post-I.T.S.	6.3429	3.3100
9.	Post-I.T.S.	3.9043	1.5629
10.	Post-I.T.S.I	9.7786	5.1043
11.	Post-I.T.S.	------	------
12.	Post-I.T.S.	------	------
13.	Post-I.T.S.	------	------
14.	Post-I.T.S.	------	------
15.	Post-I.T.S.	------	------
16.	Post-I.T.S.	------	------
17.	Post-I.T.S.	------	------
18.	Post-I.T.S.	------	------
19.	Post-I.T.S.	5.6238	2.3464
20.	Post-I.T.S.	10.0539	10.5761
21.	Post-I.T.S.	7.2857	3.7295
22.	Post-I.T.S.	7.8152	4.4476
23.	Post-I.T.S.		

* Pre-irradiation training sessions
** Post-irradiation testing sessions

3. Subject: No. 17

   Conditioning paradigm: DCA

   Treatment: single exposure to 300 R gamma radiation

Days		$\overline{X}$	SD
1.	Pre-I.T.S.*	2.2060	1.8266
2.	Pre-I.T.S.	2.0768	1.0172
3.	Pre-I.T.S.	3.6050	6.5477
4.	Pre-I.T.S.	5.0000	7.5778
5.	radiation	5.0071	4.8100
6.	Post-I.T.S.**	24.4414	28.2143
7.	Post-I.T.S.	7.3457	10.1014
8.	Post-I.T.S.	8.3786	10.7928
9.	Post-I.T.S.	6.0186	6.6371
10.	Post-I.T.S.	3.3013	1.7194
11.	Post-I.T.S.	2.1883	1.6798
12.	Post-I.T.S.	5.7156	8.2279
13.	Post-I.T.S.	5.1375	7.6196
14.	Post-I.T.S.	3.8606	4.3126
15.	Post-I.T.S.	3.0923	1.9887
16.	Post-I.T.S.	3.0282	1.6940

* Pre-irradiation training sessions

** Post-irradiation testing sessions

4. Subject: No. 15

   Conditioning paradigm: DCA

   Treatment: single exposure to 600 R gamma radiation

Days		$\overline{X}$	SD
1.	Pre-I.T.S.*	2.4965	1.8654
2.	Pre-I.T.S.	3.9329	6.8614
3.	Pre-I.T.S.	4.6291	7.1645
4.	Pre-I.T.S.	3.5628	7.0129
5.	Pre-I.T.S.	4.2760	4.5149
6.	radiation	3.3240	1.9255
7.	Post-I.T.S.**	46.5549	0.0000
8.	Post-I.T.S.	9.1329	11.2312
9.	Post-I.T.S.	46.5549	0.0000
10.	Post-I.T.S.	5.1846	6.8832
11.	Post-I.T.S.	37.7928	16.4501
12.	Post-I.T.S.	3.0847	0.7740
13.	Post-I.T.S.	3.0377	1.2166
14.	Post-I.T.S.	3.9134	2.3427
15.	Post-I.T.S.	4.7797	6.4087
16.	Post-I.T.S.	3.2731	1.4256
17.	Post-I.T.S.	2.8588	1.2260
18.	Post-I.T.S.	3.0659	1.3653
19.	Post-I.T.S.	2.7928	2.3729

* Pre-irradiation training sessions

** Post-irradiation testing sessions

5. Subject: No. 18

Conditioning paradigm: DCA

Treatment: single exposure to 450 R gamma irradiation

Days		$\overline{X}$	SD
1.	{pre-irradiation	5.1827	4.4124
2.	{training sessions	10.2354	12.0094
3.	" "	6.6855	10.2354
4.	" "	3.2909	2.7183
5.	radiation	3.5000	2.6778
6.	{post-irradiation	3.4126	4.1549
7.	{testing sessions	18.2930	17.7539
8.	" "	42.3488	11.7438
9.	" "	27.7487	18.5665
10.	" "	14.9116	16.5004
11.	" " " "	6.8512	7.4474
12.	" "	6.1711	7.2762
13.	" "	2.7476	1.6322
14.	" "	9.7457	12.7119
15.	" "	3.7153	2.9148
16.	" "	3.9442	3.1720
17.	" "	5.6977	7.7749
18.	" "	2.2884	1.6925
19.	" "	4.5244	7.0761
20.	" "	3.1510	2.1295
21.	" "	3.5849	2.0126
22.	" "	3.4634	2.1319
23.	" "	3.4457	2.3943
24.	" "	3.3665	2.0416
25.	" "	4.7591	3.5324

6. Subject: No. 23

Conditioning paradigm: DCA

Treatment: single exposure to 10 R gamma radiation
            (control S)

Days		$\overline{X}$	SD
1. ⌠pre-irradiation		3.2259	1.7484
2. ⌡training sessions		3.0648	2.1130
3. " "		2.9237	1.8821
4. " "		3.3616	2.1507
5. " "		3.6723	1.8832
6. " "		3.4689	2.1770
7. radiation		3.3427	1.7262
8. ⌠post-irradiation		3.6098	2.5000
9. ⌡testing sessions		3.1371	1.3914
10. " "		3.3037	1.3284
11. " "		3.3093	1.6431
12. " "		3.5523	1.6327
13. " "		3.2504	1.5098
14. " "		3.8487	1.3217
15. " "		3.2953	1.4432
16. " "		2.9789	1.3382
17. " "		3.2133	1.9939
18. " "		2.7530	1.6414
19. " "		3.3916	1.4423
20. " "		3.1565	1.8071
21. " "		3.2640	1.2955
22. " "		3.3480	2.9033
23. " "		3.2833	1.6030
24. " "		3.3400	1.4500
25. " "		2.7550	1.6867

7. Subject: No. 24

    Conditioning paradigm: DCA

    Treatment: Sham-control

Days		$\overline{X}$	SD
1.	Pre - I.T.S.*	8.2857	1.1610
2.	Pre - I.T.S.	7.0533	1.0307
3.	Pre - I.T.S.	7.1902	10.2655
4.	Pre - I.T.S.	6.2806	9.9416
5.	Pre - I.T.S.	5.7439	9.8889
6.	radiation	3.9040	3.9661
7.	Post - I.T.S.**	3.6874	2.4256
8.	Post - I.T.S.	4.1111	3.0942
9.	Post - I.T.S.	6.0263	7.2104
10.	Post - I.T.S.	4.7869	4.0480
11.	Post - I.T.S.	7.9385	10.5326
12.	Post - I.T.S.	3.5933	2.1829
13.	Post - I.T.S.	4.8632	3.9147
14.	Post - I.T.S.	4.7069	3.0551
15.	Post - I.T.S.	6.6483	8.6625
16.	Post - I.T.S.	4.8899	3.5169
17.	Post - I.T.S.	8.2392	9.8343
18.	Post - I.T.S.	4.7043	2.2053

* Pre - Irradiation training sessions
** Post - Irradiation testing sessions

8. Subject: No. 31

   Conditioning paradigm: DCA

   Treatment: single exposure to 10 rads gamma radiation
               (control subject)

Days		X	SD
1.	Pre - I.T.S.*	4.1488	6.2072
2.	Pre - I.T.S.	3.8418	3.3473
3.	Pre - I.T.S.	3.8606	2.7175
4.	Pre - I.T.S.	5.2808	7.6895
5.	Pre - I.T.S.	5.5687	6.6696
6.	Pre - I.T.S.	5.6181	7.9307
7.	Radiation	5.8957	4.2278
8.	Post - I.T.S.**	8.6313	10.3583
9.	Post - I.T.S.	6.4487	6.4209
10.	Post-- I.T.S.	8.7852	7.8169
11.	Post - I.T.S.	6.5493	4.8398
12.	Post - I.T.S.	5.9301	5.7430
13.	Post - I.T.S.	3.5217	2.0452
14.	Post - I.T.S.	6.4248	4.2185
15.	Post - I.T.S.	7.5559	6.1962
16.	Post - I.T.S.	4.4574	2.5183
17.	Post - I.T.S.	11.1003	9.9863
18.	Post - I.T.S.	3.7333	3.0550
19.	Post - I.T.S.	5.3050	4.9800
20.	Post - I.T.S.	9.5330	9.4043
21.	Post - I.T.S.	4.8019	3.5132
22.	Post - I.T.S.	8.2186	8.2835
23.	Post - I.T.S.	3.2046	2.0726
24.	Post - I.T.S.	4.1109	2.8541
25.	Post - I.T.S.	6.2319	4.6608
26.	Post - I.T.S.	5.0691	3.8698
27.	Post - I.T.S.	4.7970	2.6947
28.	Post - I.T.S.	4.8345	2.7438
29.	Post - I.T.S.	5.1757	2.4778

* Pre-irradiation training sessions

** Post-irradiation testing sessions

9. Subject: No. 25

Conditioning paradigm: DCA

Treatment: single exposure to 600 R gamma radiation

Days		$\overline{X}$	SD
1.	Pre-I.T.S.*	5.3917	9.8814
2.	Pre-I.T.S.	2.9190	1.4384
3.	Pre-I.T.S.	3.6346	3.2731
4.	Pre-I.T.S.	3.8826	2.3339
5.	Pre-I.T.S.	3.7000	2.4711
6.	radiation	2.9796	1.7041
7.	Post-I.T.S.**	18.1750	16.9181
8.	Post-I.T.S.	43.9981	9.0801
9.	Post-I.T.S.	29.1247	19.0168
10.	Post-I.T.S.	14.4823	15.0503
11.	Post-I.T.S.	14.5251	14.4209
12.	Post-I.T.S.	12.4804	13.5736
13.	Post-I.T.S.	5.5602	7.1436
14.	Post-I.T.S.	6.5111	7.9881
15.	Post-I.T.S.	3.7583	2.5433
16.	Post-I.T.S.	7.7372	9.6640
17.	Post-I.T.S.	4.9529	4.0998
18.	Post-I.T.S.	3.5591	2.2082
19.	Post-I.T.S.	6.1297	9.3610
20.	Post-I.T.S.	3.6534	1.9647
21.	Post-I.T.S.	6.1213	4.2777
22.	Post-I.T.S.	4.1248	2.9121
23.	Post-I.T.S.	4.1740	2.3585
24.	Post-I.T.S.	3.7567	2.6075
		3.7975	1.9964

* Pre-irradiation training sessions
** Post-irradiation testing sessions

10. Subject: No. 33

Conditioning paradigm: DCA

Treatment: single exposure to 450 R gamma radiation

Days		X	SD
1. (pre-irradiation		3.9814	2.7896
2. (training sessions		5.2514	2.8454
3. " "		4.8418	2.0158
4. " "		4.7153	1.8541
5. " "		5.5671	3.4423
6. radiation		4.6174	2.2991
7. (post-irradiation		10.4922	4.5304
8. (testing sessions		30.8609	16.6783
9. " "		17.8609	17.0104
10. " "		7.7791	6.7826
11. " "		7.4738	3.8724
12. " "		5.2759	2.5062
13. " "		5.9091	2.6381
14. " "		5.6116	3.1019
15. " "		4.3270	1.8174
16. " "		4.9791	5.2939
17. " "		4.0583	2.2000
18. " "		5.3217	3.2433
19. " "		4.8250	2.7200
20. " "		3.7750	1.8519
21. " "		5.2937	1.9917
22. " "		4.3119	2.1865
23. " "		9.0956	6.8333
24. " "		5.0125	1.1663
25. " "		3.5250	1.7583
26. " "		3.8042	1.4150
27. " "		3.5417	1.6033
"			

11. Subject: No. 22

Conditioning paradigm: DiffCA

Treatment: Sham-Control

Days		CS+		CS-	
		X̄	SD	X	SD
1.	Pre-I.T.S.*	5.2276	4.8313	13.0421	5.4097
2.	Pre-I.T.S.	3.6992	4.2971	5.2272	4.8967
3.	Pre-I.T.S.	9.5295	5.6905	13.4722	4.7370
4.	Pre-I.T.S.	4.2778	5.4814	13.3718	5.2849
5.	Pre-I.T.S.	4.3716	4.8088	15.3362	2.7787
6.	Pre-I.T.S.	4.8591	3.7965	13.1275	5.6247
7.	radiation	3.4318	3.4353	12.1206	6.0681
8.	Post-I.T.S.**	6.6643	6.9475	11.9108	6.2097
9.	Post-I.T.S.	1.5314	0.4300	14.9510	3.3426
10.	Post-I.T.S.	2.9565	3.4747	13.9200	4.8052
11.	Post-I.T.S.	3.5211	3.7517	12.9207	5.9066
12.	Post-I.T.S.	9.3820	7.1654	15.8750	0.6901
13.	Post-I.T.S.	3.6423	5.2491	13.8967	4.7651
14.	Post-I.T.S.	8.7426	6.4208	13.7060	5.2529
15.	Post-I.T.S.	4.0357	4.9608	14.5468	4.4003
16.	Post-I.T.S.	5.5262	6.1015	11.2284	6.4517
17.	Post-I.T.S.	2.0800	2.5979	9.8228	7.2146
18.	Post-I.T.S.	2.6971	3.5143	10.9086	6.9340
19.	Post-I.T.S.	3.7394	5.1996	11.0693	6.9644
20.	Post-I.T.S.	5.9625	5.7223	14.0408	7.0459
21.	Post-I.T.S.	2.5465	3.1759	15.3164	3.0473
22.	Post-I.T.S.	3.1150	3.9137	12.8375	5.9847
23.	Post-I.T.S.	1.3288	0.7065	10.9156	6.9915
24.	Post-I.T.S.	1.4610	0.9983	12.3200	6.8756
25.	Post-I.T.S.	3.8623	4.7147	13.3532	5.6517
26.	Post-I.T.S.	3.7651	4.8791	11.4010	6.7516

---

* Pre-irradiation training sessions
** Post-irradiation testing sessions

12. Subject: No. 20

Conditioning paradigm: DiffCA

Treatment: single exposure to 10 rads gamma radiation
(control subject)

Days		CS+		CS-	
		X	SD	X	SD
1.	Pre-I.T.S.*	1.8530	3.3905	12.1245	6.3831
2.	Pre-I.T.S.	1.2069	0.4443	8.0286	7.1585
3.	Pre-I.T.S.	1.1371	0.5517	10.2787	7.2295
4.	Pre-I.T.S.	0.9303	0.3685	11.5047	6.6346
5.	Pre-I.T.S.	1.3370	0.9058	10.9397	7.1657
6.	radiation	1.6198	3.0772	9.0526	7.2530
7.	Post-I.T.S.**	1.2549	0.6482	10.2154	7.2470
8.	Post-I.T.S.	2.0166	3.3683	12.3250	6.3233
9.	Post-I.T.S.	0.9291	0.6256	7.7082	7.4130
10.	Post-I.T.S.	1.0421	0.5834	10.3532	7.2847
11.	Post-I.T.S.	1.4463	0.6572	12.0263	6.6748
12.	Post-I.T.S.	1.4323	0.8418	14.4885	4.4253
13.	Post-I.T.S.	2.5257	4.2806	8.6039	7.5612
14.	Post-I.T.S.	2.1406	2.2956	11.0226	6.6678
15.	Post-I.T.S.	0.9791	0.5356	14.1443	4.5860
16.	Post-I.T.S.	1.3200	0.7100	9.6889	7.2636
17.	Post-I.T.S.	1.1371	0.6906	15.1775	3.4551
18.	Post-I.T.S.	1.4655	1.0536	15.1868	3.2941
19.	Post-I.T.S.	1.0813	0.4723	10.8027	6.2941
20.	Post-I.T.S.	1.5252	0.9008	12.5686	6.2956
21.	Post-I.T.S.	1.9204	3.4653	13.4446	5.3373
22.	Post-I.T.S.	1.1339	0.8469	13.8782	4.9495
23.	Post-I.T.S.	0.9026	0.5759	15.3597	3.1699
24.	Post-I.T.S.	2.6062	4.4330	14.6111	3.8905
25.	Post-I.T.S.	1.2068	0.8768	12.4440	6.1592
26.	Post-I.T.S.	1.1083	0.5858	13.8341	4.5763

* Pre-irradiation training sessions
** Post-irradiation testing sessions

13. Subject: No. 26

Conditioning paradigm: DiffCA

Treatment: single exposure to 300 rads gamma radiation

Days		CS+		CS-	
		X	SD	X	SD
1.	Pre-I.T.S.*	5.1270	5.1789	10.1530	6.4005
2.	Pre-I.T.S.	2.3929	3.1657	10.6815	6.9962
3.	Pre-I.T.S.	5.0939	5.3947	8.8347	5.5443
4.	Pre-I.T.S.	2.0556	0.9408	9.8886	6.8939
5.	Pre-I.T.S.	3.6584	3.1173	13.4255	5.3169
6.	radiation	3.5218	3.6900	11.9772	6.2539
7.	Post-I.T.S.**	3.8834	4.8208	8.6382	7.1130
8.	Post-I.T.S.	2.7474	3.3823	11.0570	6.4740
9.	Post-I.T.S.	4.0050	4.7521	6.2426	6.4517
10.	Post-I.T.S.	1.8556	0.9964	8.4507	6.9472
11.	Post-I.T.S.	7.2685	6.6712	8.3683	1.9655
12.	Post-I.T.S.	5.2581	4.7142	5.2874	4.4939
13.	Post-I.T.S.	1.5895	0.8660	9.2800	6.7669
14.	Post-I.T.S.	11.6742	7.4185	9.4378	7.0140
15.	Post-I.T.S.	1.4156	0.7095	11.3495	6.9078
16.	Post-I.T.S.	2.1391	3.3060	9.1026	6.9843
17.	Post-I.T.S.	1.2500	0.6170	8.5193	7.5052
18.	Post-I.T.S.	2.9933	3.3349	10.5174	6.8938
19.	Post-I.T.S.	2.2640	3.4026	12.7211	6.0313
20.	Post-I.T.S.	10.0561	6.4834	12.8481	5.8069
21.	Post-I.T.S.	1.9059	1.0181	12.5478	6.3283
22.	Post-I.T.S.	1.4416	0.7192	8.5844	6.9789
23.	Post-I.T.S.	5.7767	5.8522	13.6782	4.9639
24.	Post-I.T.S.	2.2877	3.5044	12.2025	6.3748
25.	Post-I.T.S.	2.7096	4.5774	8.9600	5.5320

* Pre-irradiation training sessions
** Post-irradiation testing sessions

14. Subject: No. 27

Conditioning paradigm: DiffCA

Treatment: single exposure to 300 rads gamma radiation

Days		CS+		CS-	
		X	SD	X	SD
1.	Pre-I.T.S.*	1.1480	0.4356	15.2332	3.4066
2.	Pre-I.T.S.	0.6504	0.5422	11.2770	6.1911
3.	Pre-I.T.S.	0.8590	0.6623	14.6256	3.8664
4.	Pre-I.T.S.	0.8140	0.7616	14.0308	4.9559
5.	Pre-I.T.S.	0.5507	0.2540	14.6696	4.0954
6.	radiation	0.9574	0.6931	12.3759	6.4923
7.	Post-I.T.S.**	0.9100	0.5993	15.2331	2.7643
8.	Post-I.T.S.	0.9243	1.2429	15.6400	1.6614
9.	Post-I.T.S.	0.9314	0.7457	13.1057	5.7086
10.	Post-I.T.S.	1.2214	1.3029	13.5714	4.3414
11.	Post-I.T.S.	0.9443	0.8243	15.9064	0.0494
12.	Post-I.T.S.	0.9389	0.7855	14.7810	2.8889
13.	Post-I.T.S.	1.2373	0.4294	15.0752	3.4240
14.	Post-I.T.S.	2.1973	1.0766	15.2701	3.0728
15.	Post-I.T.S.	1.6514	0.5657	14.6971	3.8800
16.	Post-I.T.S.	1.9962	3.1996	15.4991	1.5273
17.	Post-I.T.S.	1.3352	1.0527	15.1657	3.2750
18.	Post-I.T.S.	3.7925	4.5215	15.9850	0.0935

*   Pre-irradiation training sessions
** Post-irradiation testing sessions

15. Subject: No. 16

Conditioning paradigm: DiffCA

Treatment: single exposure to 300 rads gamma radiation

Days		CS+		CS-	
		X	SD	X	SD
1.	Pre-I.T.S.*	6.1036	6.7805	10.0992	6.4992
2.	Pre-I.T.S.	1.7485	1.6586	10.0390	6.7620
3.	Pre-I.T.S.	0.7526	0.5939	8.8888	7.6074
4.	Pre-I.T.S.	3.4450	5.3940	8.8281	7.5525
5.	Pre-I.T.S.	0.8590	0.5878	7.3128	7.1821
6.	Pre-I.T.S.	0.8590	0.5878	7.2687	7.1718
7.	radiation	0.2002	3.9164	10.1274	7.4589
8.	Post-I.T.S.**	1.4559	1.2308	9.2713	7.1962
9.	Post-I.T.S.	0.9956	0.7239	12.0909	6.3982
10.	Post-I.T.S.	4.9066	6.5948	11.9382	6.3074
11.	Post-I.T.S.	0.8822	0.5548	11.7700	6.6142
12.	Post-I.T.S.	1.2123	1.9920	9.6116	7.4480
13.	Post-I.T.S.	------	------	------	------
14.	Post-I.T.S.	------	------	------	------
15.	Post-I.T.S.	------	------	------	------
16.	Post-I.T.S.	------	------	------	------
17.	Post-I.T.S.	------	------	------	------
18.	Post-I.T.S.	------	------	------	------
19.	Post-I.T.S.	------	------	------	------
20.	Post-I.T.S.	------	------	------	------
21.	Post-I.T.S.	1.3389	1.0936	8.8015	7.2490
22.	Post-I.T.S.	0.8976	0.5081	4.9401	6.4671
23.	Post-I.T.S.	2.2419	3.4476	11.4285	7.1104
24.	Post-I.T.S.	0.9650	0.4484	9.2258	7.5154
25.	Post-I.T.S.	2.4482	4.5555	7.5404	7.6572

* Pre-irradiation training sessions
** Post-irradiation testing sessions

16. Subject: No. 28

Conditioning paradigm: DiffCA

Treatment: single exposure to 450 rads gamma radiation

Days		CS+		CS-	
		X	SD	X	SD
1.	Pre-I.T.S.*	2.6190	3.5124	9.3581	7.2305
2.	Pre-I.T.S.	3.2355	5.5382	10.6052	6.9479
3.	Pre-I.T.S.	2.8305	3.6890	12.5978	5.9553
4.	Pre-I.T.S.	1.7904	0.9614	8.3327	6.8401
5.	Pre-I.T.S.	3.2328	4.5698	10.3929	6.7337
6.	Pre-I.T.S.	1.8971	1.0680	11.1967	6.7188
7.	radiation	2.3489	1.8402	5.0097	5.8830
8.	Post-I.T.S.**	3.3393	4.9747	11.3431	6.4581
9.	Post-I.T.S.	2.7129	2.9175	9.9835	7.1238
10.	Post-I.T.S.	3.3972	4.5923	12.5747	5.7030
11.	Post-I.T.S.	2.1863	3.3972	12.0791	6.4060
12.	Post-I.T.S.	1.6400	0.9096	12.5140	5.6311
13.	Post-I.T.S.	2.2877	3.6057	12.2007	6.6252
14.	Post-I.T.S.	2.7094	4.9861	9.0545	7.0053
15.	Post-I.T.S.	1.5187	0.9675	9.8779	7.9656
16.	Post-I.T.S.	1.2265	0.6395	10.5008	7.0208
17.	Post-I.T.S.	3.3527	4.8425	11.0308	6.4538
18.	Post-I.T.S.	2.0929	1.3660	9.6294	7.0189
19.	Post-I.T.S.	2.8657	4.4785	12.1859	6.3236
20.	Post-I.T.S.	1.6575	0.7504	13.0964	5.4716
21.	Post-I.T.S.	3.5112	4.4234	11.7040	6.3408
22.	Post-I.T.S.	1.4509	0.6282	11.4716	0.6372
23.	Post-I.T.S.	3.3392	4.1283	12.9884	4.8032
24.	Post-I.T.S.	2.5158	3.6965	12.7861	5.5473
25.	Post-I.T.S.	3.6153	4.5290	12.6185	5.6235
26.	Post-I.T.S.	2.0083	3.4196	14.5854	14.1410
27.	Post-I.T.S.	2.8211	4.8667	12.8390	5.6471
28.	Post-I.T.S.	1.6963	1.5419	15.2617	2.8591

*   Pre-irradiation training sessions
** Post-irradiation testing sessions

17. Subject: No. 29

Conditioning paradigm: DiffCA

Treatment: single exposure to 450 rads gamma radiation

		CS+		CS-	
Days		$\overline{X}$	SD	$\overline{X}$	SD
1.	Pre-I.T.S.*	1.4340	2.0539	8.7560	7.4085
2.	Pre-I.T.S.	0.9199	0.6597	11.1472	6.8759
3.	Pre-I.T.S.	0.9199	0.4916	10.2698	7.0101
4.	Pre-I.T.S.	1.1129	0.8729	12.2386	6.0343
5.	Pre-I.T.S.	0.7396	0.5576	11.5861	6.6657
6.	Pre-I.T.S.	1.0226	0.9803	15.1622	3.4806
7.					
8.	radiation	1.3614	0.8257	14.3708	4.2285
9.	Post-I.T.S.**	1.5951	1.3516	12.5198	6.2486
10.	Post-I.T.S.	1.9680	3.2957	12.1375	5.8682
11.	Post-I.T.S.	1.4228	0.7099	13.2938	5.1412
12.	Post-I.T.S.	1.7264	1.2203	13.4313	5.3992
13.					
14.	Post-I.T.S.	2.4547	3.5379	12.0980	5.9575
15.	Post-I.T.S.	1.9771	2.1295	66.8266	7.0248
16.	Post-I.T.S.	1.6949	0.8041	7.7363	7.0490
17.	Post-I.T.S.	1.5626	0.7476	9.5145	6.2042
18.	Post-I.T.S.	1.8438	1.2495	6.3924	6.8057
19.	Post-I.T.S.	1.7052	1.2659	7.7457	6.8459
20.	Post-I.T.S.	1.6417	0.9808	8.1695	7.4152
21.					
22.	Post-I.T.S.	2.2259	3.1412	6.0584	6.6610
23.	Post-I.T.S.	1.6750	0.8595	8.5461	7.1582
24.	Post-I.T.S.	1.3873	0.9252	5.8382	6.7168
25.	Post-I.T.S.	1.6640	1.7010	10.4133	6.9010
26.	Post-I.T.S.	1.4407	1.0456	11.7043	6.4181
27.	Post-I.T.S.	1.1895	0.6177	9.4783	7.0584
28.	Post-I.T.S.	1.9397	0.9032	12.5612	5.6064
29.	Post-I.T.S.	1.8927	0.9906	10.2750	6.7966

* Pre-irradiation training sessions
** Post-irradiation testing sessions

18. Subject: No. 30

Conditioning paradigm: DiffCA

Treatment: single exposure to 450 rads gamma radiation

Days		CS+		CS−	
		X	SD	X	SD
1.	Pre-I.T.S.*	1.5489	1.0716	1.7121	1.2657
2.	Pre-I.T.S.	2.1921	2.5292	2.1450	3.4689
3.	Pre-I.T.S.	2.0132	1.4002	4.0659	5.0960
4.	Pre-I.T.S.	3.3126	3.3974	3.8814	4.4388
5.	Pre-I.T.S.	2.2098	1.9196	5.2911	5.7444
6.	radiation	1.8229	0.9074	4.8156	5.9926
7.	Post-I.T.S.**	2.2429	1.2976	10.9416	5.7062
8.	Post-I.T.S.	1.7672	1.3569	5.5752	5.8267
9.	Post-I.T.S.	2.8745	5.8670	11.4157	6.5075
10.	Post-I.T.S.	6.3197	7.6364	11.4108	7.2800
11.	Post-I.T.S.	1.6985	0.9665	10.9777	7.0836
12.	Post-I.T.S.	2.7065	3.2640	9.6723	7.0674
13.	Post-I.T.S.	1.4008	0.8782	7.4633	7.2260
14.	Post-I.T.S.	1.2407	0.7885	4.4953	6.1020
15.	Post-I.T.S.	2.4030	3.4436	9.1497	7.3974
16.	Post-I.T.S.	1.5363	1.0223	9.3203	7.4078
17.	Post-I.T.S.	1.6823	0.9864	11.2392	6.9831
18.	Post-I.T.S.	1.4960	0.8707	8.7081	6.0998
19.	Post-I.T.S.	0.9864	0.6092	7.5217	7.2542
20.	Post-I.T.S.	1.3645	1.3881	7.8402	7.2047
21.	Post-I.T.S.	1.9438	1.2281	9.8576	7.3761
22.	Post-I.T.S.	0.9769	0.5373	9.8135	6.9432
23.	Post-I.T.S.	3.5325	5.1863	11.4429	6.7135
24.	Post-I.T.S.	0.9509	0.9649	8.9473	7.4042
25.	Post-I.T.S.	0.9842	0.3745	4.4446	5.8787
26.	Post-I.T.S.	1.1308	0.8322	4.0316	5.5747

*   Pre-irradiation training sessions
** Post-irradiation testing sessions

19. Subject: No. 19

Conditioning paradigm: DiffCA

Treatment: single exposure to 600 rads gamma radiation

Days		CS+		CS-	
		X	SD	X	SD
1.	Pre-I.T.S.*	2.6158	4.4952	14.5178	4.5049
2.	Pre-I.T.S.	1.1299	0.6685	13.1657	5.3145
3.	Pre-I.T.S.	1.1186	0.6416	14.7231	4.0621
4.	Pre-I.T.S.	1.9001	3.2800	11.8173	6.5404
5.	Pre-I.T.S.	2.6400	4.2530	10.8780	6.6000
6.	radiation	2.0154	1.5069	14.3030	3.5038
7.	Post-I.T.S.**	2.2200	2.9498	12.7316	5.7876
8.	Post-I.T.S.	12.7965	5.7214	16.0000	0.0000
9.	Post-I.T.S.	2.6030	3.4369	14.8420	5.4971
10.	Post-I.T.S.	1.9048	1.9786	15.2571	3.2380
11.	Post-I.T.S.	1.1429	5.5205	8.7905	7.2241
12.	Post-I.T.S.	6.2812	6.3233	13.4938	5.4634
13.	Post-I.T.S.	1.2345	0.6284	10.5975	7.1644
14.	Post-I.T.S.	1.1456	0.4844	10.0635	7.2083
15.	Post-I.T.S.	1.3506	0.7574	11.1111	6.5670
16.	Post-I.T.S.	1.7137	2.0560	11.5631	6.7920
17.	Post-I.T.S.	1.6049	0.8478	13.1854	5.9389
18.	Post-I.T.S.	2.6230	4.3778	13.1622	5.5559
19.	Post-I.T.S.	2.0391	3.4092	14.2917	4.4689
20.	Post-I.T.S.	3.2963	4.5616	12.7071	6.0757

* Pre-irradiation training sessions
** Post-irradiation testing sessions

20. Subject: No. 21

Conditioning Paradigm: DiffCA

Treatment: single exposure to 600 rads gamma radiation

Days		CS+		CS-	
		X	SD	X	SD
1.	Pre-I.T.S.*	2.7821	3.5288	9.0093	7.3054
2.	Pre-I.T.S.	1.7057	1.2886	9.2402	6.9031
3.	Pre-I.T.S.	1.8864	1.2551	11.2439	6.7690
4.	Pre-I.T.S.	2.0400	0.8704	11.0323	6.4800
5.	Pre-I.T.S.	3.6497	4.4180	14.6195	4.3578
6.	radiation	2.5027	2.1657	8.0744	7.0521
7.	Post-I.T.S.**	1.7169	0.9162	13.6350	5.3817
8.	Post-I.T.S.	1.9001	1.4232	15.3216	2.5656
9.	Post-I.T.S.	1.8832	1.6101	13.1902	5.7099
10.	Post-I.T.S.	2.6479	3.1928	10.2696	7.0674
11.	Post-I.T.S.	2.5273	2.7871	10.3841	7.1751
12.	Post-I.T.S.	1.3215	0.6133	10.3680	7.0371
13.	Post-I.T.S.	2.5175	3.5156	11.8378	6.6054
14.	Post-I.T.S.	3.5000	4.4338	13.0434	5.8023
15.	Post-I.T.S.	1.5685	0.8083	9.1150	7.2616
16.	Post-I.T.S.	1.5711	0.7381	10.5061	6.6625
17.	Post-I.T.S.	2.4352	3.1915	9.3514	7.0808
18.	Post-I.T.S.	1.4499	0.8084	9.2776	7.4340
19.	Post-I.T.S.	1.4059	0.6801	11.2390	6.7416
20.	Post-I.T.S.	1.2522	0.4955	14.6039	4.3658
21.	Post-I.T.S.	1.5536	0.6467	10.4182	7.1318
22.	Post-I.T.S.	2.1800	1.4562	9.4993	7.0664
23.	Post-I.T.S.	2.1223	3.2325	11.0576	6.8688
24.	Post-I.T.S.	2.6553	3.4147	14.0509	4.9103
25.	Post-I.T.S.	1.5297	0.9982	10.4048	7.1193
26.	Post-I.T.S.	1.8154	0.9367	8.8699	7.3075

* Pre-irradiation training sessions

** Post-irradiation testing sessions

DAILY WEIGHTS OF 4 CONTROL AND 7 IRRADIATED RATS*

Dose	sham	10R	10R	10R	300R	450R	450R	450R	450R	600R	600R
Rate No.	#22	#20	#23	#31	#26	#18	#28	#30	#33	#21	#25
Pre-Irrad. $\bar{X}$ Wt.	395	377.5	395	403.5	414	495.5	436.5	423	432	385	510
Wt. on Irrad. day	397	374	392	399.5	413.5	495.5	437	420.5	430.5	385.5	508.5
Post-Irrad. daily Wt.											
1	412	391	396	404	393	502.5	437.5	423	428.5	387.5	512
2	409	375.5	389.5	391	389.5	480	435.5	425.5	420.5	376	496.5
3	393.5	381	384.5	396.5	397	473.5	438	415.5	422.5	382	491.5
4	397.5	378.5	396	396	408	467	439.5	413.5	423.5	371.5	487
5	404	373.5	388	396	409	469.5	437.5	402	418.5	362.5	493
6	414	375.5	393.5	399	384	464	435.5	402	414	365.5	493.5
7	414	379.5	383.5	398.5	391	465.5	431	402	414	364.5	497
8	391.5	348	377	394	396	464	432	397.5	412.5	370	487.5
9	399	343.5	383	397	395	461	422.5	397	406.5	368	495
10	390.5	349	392.5	392	402.5	462	406	397	408.5	369	484
11	397	355	389.5	391.5	409.5	460.5	417	389	414.5	367.5	485
12	403.5	338.5	391	397	410.5	449.5	421.5	386.5	412.5	356.5	488
13	396.5	351.5	384	398.5	399.5	453	423	382.5	407.5	360	484.5
14	401	346.5	381.5	382.5	396	452.5	400.5	387.5	410	346	481
15	395	342.5	379	382.5	397.5	457.5	405	385	412.5	340	487.5
16	395.5	347	381	385.5	390	462	413.5	381.5	416.5	328.5	487
17	401	339	382.5	390.5		452.5	419.5	387	406.5	337	468.5
18	395	349.5	380	375		457.5	420	394.5	394.5	342	486.5
19	395.5	347	375	377.5		462	403		396.5	351.5	474
20	392.5	346.5	379	385		452.5	403.5		395.5		
21	396.5					454	408.5				
22						461.5					

*   Measurement read to the closest 0.5 gm.

-68-