THE UNIVERSITY OF MANITOBA

THE EFFECTS OF CO^{60} IONIZING RADIATION ON CONDITIONED AND UNCONDITIONED VESTIBULAR RESPONSES

by

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A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF ARTS

DEPARTMENT OF PSYCHOLOGY

WINNIPEG, MANITOBA

OCTOBER 1971

ABSTRACT:

The effects of Co^{60} gamma irradiation on conditioned and unconditioned vestibular responses were assessed. Forty-five male albino rats were trained on a conditioned vestibular escape operant in which the subject had to respond on a lever in order to terminate trials of vestibular tilt-oscillations in a tilt chamber. Subjects were trained using one of three different vestibular stimulus intensities (.14, .20, or .33 hz tilt-cycle frequency) . Response latency from the onset of tilting was used as the primary measure of conditioned vestibular escape strength. Total session responses and the duration of lever holding were also recorded. The animals were also subjected to an unconditioned vestibular response in the form of postrotational nystagmus. After a baseline had been attained for both vestibular responses, the subjects were irradiated with either a 10 R, a 450 R, or a 900 R dose of Co^{60} gamma irradiation (whole body). Post-irradiation measures were taken for two weeks after radiation. The 450 R subjects were given a second 450 R dose 8 days after the first. It was found that changes in response latency depended on both the radiation dose and the tilt-cycle frequency, the greatest increase in response latency occurring for the highest radiation dose level and the slowest tilt rate. These results are discussed in terms of the effectiveness of the vestibular negative reinforcement. Motor deficits, and decreases in general activity or physical strength were ruled out as the primary causes of increased latency. Lever pressing responses decreased as a function of radiation dose, and there was an increase in the duration of lever holding proportional to radiation dose. Few changes were found in the unconditioned nystagmus

response, which is complete at the midbrain level, indicating that the radiation was affecting the vestibular circuits at "higher" CNS levels.

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude to Dr. M. F. Halasz for his help and guidance during this and related research in his laboratory.

I also wish to thank my other two thesis examiners, Dr. J. J. Pear and Dr. A. Holloway, for taking the time and effort to read and edit this thesis.

I also wish to thank Mr. W. Mostaway for his assistance and the use of his computer programs used in the data analysis and graphical representation.

My appreciation is also extended to Mrs. Y. Hoh and Mrs. H. McLaren for their help in conducting experimental sessions during classes and on weekends.

Appreciation is also extended to the staff of the Manitoba Cancer and Research Foundation who made available the radiation sources in the whole body room.

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CHAPTER I

STATEMENT OF THE PROBLEM:

Many experimenters in the area of radiation (Ewald, 1905; Gerstner and Kent, 1957; Kimmeldorf and Hunt, 1965, p. 146 & 177; Levy and Quastler, 1962; Livonov, 1965; Moskovskaya, 1959; Quastler, 1957, and Thielemann, 1928) note that dizziness and loss of spacial and postural orientation are symptoms of radiation exposure, especially for near lethal doses. This seems to imply that at least some portion of the vestibular sensory system is affected by ionizing radiation. As such, tasks involving vestibular stimulation may also be affected by radiation, possibly at lower doses than those required to produce the above gross symptoms, since more precise discriminative and sensory-motor interactions may be involved in such tasks.

Although many studies have been done on the effects of radiation on behaviour in conditioning paradigms employing visual or auditory stimuli, few have been done on the effects of radiation on learned tasks involving vestibular stimuli. This probably results primarily from the lack of apparatus which can deliver such stimuli in operant settings. In our laboratory, a tilt-lever apparatus for vestibulobehavioural research with rats has been developed (Halasz and Halasz, 1970). In this technique, an operant escape response is maintained using primarily vestibular stimulation as a negative reinforcer. This apparatus provides a technique which allows one to study the effects of ionizing radiation on a conditioned vestibular escape response.

Postrotational nystagmus is a well-known unconditioned response resulting from vestibular stimulation. The effect of radiation on this unconditioned response may also be assessed and compared to the effects on the conditioned response. Thus, parallel techniques are available to assay the radiation effects on a brain stem reflex and a response mediated by "higher" central nervous system levels.

CHAPTER II

GENERAL BACKGROUND: BEHAVIOURAL EFFECTS OF IONIZING RADIATION

Although gross morphological and physiological changes are associated with neo-natal and pre-natal irradiation of the central nervous system (CNS), there has been much controversy over the radiosensitivity of the adult CNS. Generally, Western researchers have considered it radioresistant while many Soviet researchers have considered it radiosensitive. Furchtgott (1963) states that in general, "histological studies tend to support the long-held view that adult neural structures are relatively insensitive to ionizing radiations .... and a considerable amount of evidence has accumulated that gross morphological changes are not discernible at such levels of radiation (LD-50 doses)" (p. 171).

Soviet investigators have dealt primarily with the functional analysis of radiation effects, i.e. electrophysiological effects, unconditioned and conditioned reflexes. English written reviews of their work are presented in articles by Stahl (1959, 1960, 1962) and a book by Lebedinskiy and Nakhil'nitskaya (1963). Most Soviet work on the effects of ionizing radiation on conditioned reflexes (CR) employ Pavlovian conditioning techniques. Radiation effects on various motor CR's, salivary and intestinal CR's, defensive CR's, and CR "sterotypes" have been reported. Orbeli (as cited by Stahl, 1959) maintains that disorders of CNS activity can be detected by the CR method when no symptoms of radiation syndrome are present. Stahl (1962) reports that Pionkovsky (1959) and Khozak (1958) state that 0.5-2.0 rads single exposures have a stimulatory effect on CR's lasting days or even months, and that

Cherkasov (1960) asserts that a single dose of 30 rads or chronic exposure at the rate of 0.1 rads per day may cause the disappearance of all CR's in some experiments. However, there is also some controversy as some experimenters such as Lomonos and Nemenov (cited from Stahl, 1959) noted only slight or insignificant alterations in certain CR's after doses in the 1000-3000 rad range. Stahl (1959) also lists other weaknesses of CR data such as a) inadequate description of instrumentation and dosimetry b) limited use of controls, c) little information on the condition of the subjects after irradiation, d) limited analysis of data, and e) failure to report negative findings. He concludes that "there is no unanimity at present as to whether the CR method shows very low level radiation alterations or whether it is a highly sensitive indicator of damage." (p. 477, 1962).

Western researchers also have found different results in the effects of radiation on behaviour. Furchtgott (1951) failed to find any difference in adult rats' maze performance after 200 or 300 rads whole body radiation (WBR). Arnold (1962) also failed to find differences between irradiated and control rats in instrumental learning and retention after 2500 rads whole head radiation (WHR).

Improved performance on maze acquisition has been found by Blair (1958) and Arnold (1962) using 5000 rads WHR and 2500 rads WHR respectively. Blair and Arnold (1956) also tested the effects of 2500 rads WHR on retention of a maze previously learned. The control rats tended to perform better than the irradiated rats on day 3 post-irradiation, but by day 25, there was a reversal and the irradiated rats were superior to the controls.

Decrements have also been found in learned performance. Decrements in discrimination learning in rats after 5000 R irradiation of the brain area have been found to depend on the post-irradiation interval (Arnold 1962). No effects were found after a 221-day-post-irradiation interval but a 323-day-post-irradiation interval revealed detrimental effects. Urmer and Brown (1960) found that 400 rads WB gamma irradiation failed to affect retention of a maze task learned before irradiation, but did cause decrements in the performance of the animals in reorganizing the pre-irradiation learned maze response series into a new response pattern. However, Furchtgott (1963), in an attempt to replicate this study, failed to find any differences.

A large number of experiments concerning the behavioural effects of radiation have been performed on rhesus monkeys. Harlow and Moon (1956) trained 23 monkeys on standard laboratory tasks in the Wisconsin General Test Apparatus (WGTA) and then administered 100 rads WB X-irradiation to 12 monkeys every 35 days until death. Irradiated subjects had a significant decrease in weight and general activity proportional to cumulative dose. However, irradiated monkeys showed no deficit in solving the most complex problems, and even showed enhancement in performance on delayed response and oddity problems on the 4th and 5th administrations. Davis, McDowell, Deter, and Steele (1956) trained 16 monkeys for 9 months on 4 object-quality discrimination, delayed response, oddity-principle, reduced cue, and 6 manipulation tests. After 400 rads WB X-irradiation, no changes in food rewarded object-displacement tasks occurred, but transitory decrements were found in hand and orally manipulated puzzles between 9 and 19 days post-irradiation. Leary and Ruch (1965), using low level doses of 50 to 400 rads WBR, also concurred that lightly motivated behaviour such as pedomotor activity, general activity, and manipulation of mechanical puzzles is more susceptible to radiation stress than highly motivated behaviour.

Brown and McDowell (1962) conducted a large number of tests over 4-5 years on rhesus monkeys exposed to control (0 rep (roentgen-equivalent-physical)), Lo (77-154 rep), or Hi (300-616 rep) doses of mixed gamma and neutron WBR. McDowell (1958) observed the responses of these monkeys to various cage and peripheral stimuli and concluded that Hi dose irradiated monkeys are less responsive to peripheral stimuli than are the controls, but are just as responsive to cage-focal-stimuli. He postulated that this reduced distractibility or narrowing of spacial span of attention of irradiated monkeys would show up in various tasks (where focalized attention is called for) as improved performance.

Irradiation facilitated performance for Hi dose monkeys in discrimination problems with reduced cues (McDowell and Brown, 1958), although the sex factor must be evaluated as irradiated females do better than males (McDowell, Brown and McTee, 1962). Irradiated subjects did not differ from controls in acquisition of a peripheral cue learning set (McDowell and Brown, 1960b) but Lo dose subjects did have a slight advantage over controls in the transfer of a single learned discrimination along a peripheral cue gradient (McDowell, 1960). The radiation effect in this task also appears to be dependent on the sex of the subject (McDowell and Brown, 1963). In still another study, (McDowell and Brown, 1960c) the chronic irradiated monkeys were found to be less susceptible to proactive inhibition than control monkeys. This again was attributed to decreased distractibility although in this case the reasoning was somewhat tenuous. No consistent differences in errors were observed between irradiated and control monkeys in oddity-reversal problems, but irradiated monkeys supposedly showed more savings, indicating superiority in problems of this type (McDowell and Brown, 1959). However, monkeys given a much higher dose of 3000 rads to the frontal association areas of the brain did more poorly on oddity-reversal problems than did control subjects or subjects that were irradiated with the same dose in the posterior association areas (McDowell, Brown and White, 1961).

A second group of monkeys was irradiated at Lo (0-299 rep), Med (355-439 rep), or Hi (512-670 rep) doses (Brown and McDowell, 1962). In a series of dot discrimination problems, the higher the dosage, the fewer the errors on the smaller dot problems (McDowell and Brown, 1962) again an indication of reduced distractibility to peripheral cues. On a single stimulus block discrimination, McDowell, Brown and Wicker, (1963) found that the response latency was increased in proportion to the radiation dose. However, when a novel non-reinforced block was introduced, less disruption of response latency was found for higher dose levels; i.e., they were less distractible.

Another series of studies was done by McDowell and Brown on monkeys irradiated with 583 rep as much as 5 years earlier. Social distractibility was measured by the disruption of free-cage behaviour in the presence of a visible but not physically accessible social stimulus in the form of another monkey. Social distractibility was found to be less for both irradiated males (McDowell and Brown, 1965d) and for irradiated females (McDowell and Brown, 1966b), compared with normal controls. On the other hand, irradiated monkeys showed greater responsiveness to inaccessible food but were less attracted to other cues (McDowell and Brown, 1965c). Irradiated monkeys took more trials to extinguish to a single object discrimination task (McDowell and Brown, 1966a). These same subjects showed greater response perseveration for non-rewarded cues (McDowell and Brown, 1965a). In another study, using radiation levels as high as 512 rep, McDowell and Brown (1965b) found that irradiated monkeys persevered at one response under constant stimulus position (do not shift response direction) more than control monkeys. This perseveration was attributed to less distractibility and as a result, less exploration. Harlow (1962) also found visual exploration to be affected by irradiation.

Many of the above studies tend to support the distractibility hypothesis. Others are equivocal and some tend to disprove it. In most cases, this is most likely due to a lack of control of the variables that control the behaviour in these tasks. Davis and Lovelace (1963) have suggested that reduced distractibility or narrowed scope of attention due to irradiation may depend on food preferences or reinforcement types. Davis (1961) reported data that supports the notion that irradiated monkeys (1100 rads WBR in 3 yearly doses) are more distractible than controls. On odd trials, the problem consisted of object-discrimination tasks, but on even trials, additional objects were introduced. Irradiated monkeys did more poorly than controls on the trials with the superfluous objects, indicating greater distractibility. Also, Riopelle (1962) found no differences between consecutive and serial discrimination problems, and concluded that chimpanzees were not less distracted when irradiated with 375 rads or 450 rads WB CO^{60} gamma irradiation. He also found that irradiated monkeys did more poorly in 4-choice oddity problems, visual acuity, and size discrimination problems. However, in an earlier study, Riopelle, Gradsky, and Ades (1956) found that irradiated monkeys (350 rads WBR single dose or 2000-4000 rads WBR fractional doses) equalled or surpassed both control groups in discrimination problems, but showed no difference in shuttle-box avoidance or delayed response problems. This superiority for discrimination problems had been attributed to increased resistance to distraction or increased tameness. Overall, Brown and Gentry (1960), using dose levels between 0 and 616 rep, showed that the tendency to learn relations between stimuli decreases as a linear function of radiation dose, supporting the hypothesis that facilitated learning by irradiated monkeys is due to restriction of attention to specific properties of rewarded stimuli, and this localization of attention has resulted in relative inattentiveness to relations between stimuli.

Although the distractibility hypothesis has been proposed for irradiated monkeys, it has not generally been applied to other animals, perhaps because the behavioural tasks are usually different. However, one study by DiMascio, Azrin, Fuller and Jetter (1956) tested delayed response performance in dogs exposed to 150 rads or 300 rads WB X-irradiation. The performance of the 300 rad group was diminished and they attributed this to reduced attention.

Most of the above studies on monkeys involved the long-term effects of radiation. One study by McDowell and Brown (1966c) measures behavioural effects before, during, and one hour after 0-800 rads WBR. They found a decline in free-cage locomotor activity, an increase in minimum response latency to a single food-reinforced test object, and an increased tendency to balk at dot discrimination problems. The threshold for noticeable effects was between 400 rads and 500 rads.

The behavioural effects appear to depend on radiation type, dosage, exposure area, age of subject, and time interval between irradiation and testing. Functional changes due to radiation also appear to be largely dependent on the type of behavioural task; i.e., certain types of behaviour are more sensitive to radiation than other types. This variable has been stressed by Burt and Ingersoll (1965), Cheng (1968), DiMascio, et al. (1956), Sancombe (1971), and Stahl (1959, 1960 & 1962). Cheng (1968) trained rats on a water-reinforced conditioned response to auditory stimuli in a Skinner box. Two tasks, delayed conditioned approach (DCA) and differential conditioned approach (DiffCA) included similar stimuli, motor skills, and measures, but DCA requires "timing" while DiffCA requires only an auditory frequency discrimination. Single doses of 300 rads, 450 rads and 600 rads WB CO^{60} irradiation showed a dose dependent increase of reaction latencies in the DCA paradigm, but had little effect on the DiffCA task. Sancombe (1971) working with the same DCA paradigm, showed that differences in the timing requirement or task difficulty was differentially sensitive to radiation effects, the longest delay times being most affected. Dimascio et al. (1956) also found the longest delay times in delayed response tests to be most affected by irradiation.

Some work has been done on the effects of ionizing radiation on various operant conditioning schedules of reinforcement (for a description of schedules, see Ferster and Skinner, 1957). Brown, Overall, Logie and Wicker (1960) trained rats on a fixed-ratio 20 (FR 20; 20 responses per reinforcement) schedule. Subjects were divided into 6 groups and exposed one hour daily to one dose of 0, 25, 50, 75, 100 or 125 rads WB X-irradiation. The response rate of the subjects averaged across days decreased as a function of radiation intensity and was related to cumulative radiation dose. Wicker and Brown (1965) demonstrated that Co^{60} radiation doses of 400 rads and 800 rads decreased lever pressing for water reinforcement on a continuous reinforcement schedule. Radiation had been delivered in 2 weekly doses and response measures taken for 4 days post-irradiation. Since Smith and Tyree (1956) and Cheng (1968) found that water consumption increases after radiation, the decrease in response rate cannot be attributed to changes in drive level. Brown (1966) trained rats on a FR 20 food reinforcement schedule. The subjects were then exposed to 100 rads/day or 300 rads every third day for a cumulative dose of 1200 rads. There was a rapid and regular decline in response rates for the 100 rad subjects, while the 300 rad subjects declined irregularly, with response rate increases on the second and third days after the first two exposures. After radiation was discontinued, the 100 rad subjects recovered rapidly, while the 300 rad subjects failed to recover.

Jarrard (1963) trained rats on a variable interval-2 min. schedule and a Sidman (nondiscriminated) avoidance schedule. They were then exposed to 0, 100, 300 or 500 rads WB X-irradiation. Although responding for food decreased, it was noted that food consumption decreased at lower doses and lasted longer than changes in the operant lever pressing response. Decreased responding on the shock avoidance schedule was found but was attributed to an unstable baseline that had not leveled out prior to irradiation. However, Brown, Blodgett, Henderson, Ritter and Pizzuto (1966) trained rats on a FR 10 food reinforcement schedule and a discriminated avoidance-escape schedule, and then exposed them to 1000, 2000, 4000 or 8000 rads WH X-irradiation. Response rate for food and the subject's ability to avoid shock decreased one hour after irradiation, suggesting a CNS rather than a gastro-intestinal effect. Although the above avoidance schedules differed in terms of the presence or absence of an exteroceptive warning stimulus, both showed decreased responding after irradiation, and thus this effect in Jarrard's experiment may have been due to irradiation in addition to the unstable baseline.

Yarullin (1959; cited from Stahl, 1960) tested conditioned avoidance in dogs and found increases in latency after a single exposure of 15 rads WBR. However, changes were cyclical and undulating, so that even after 1355 rads, the responding of 2 subjects still resembled that of ordinary dogs. Belonsky (1959; cited from Stahl, 1960) studied escape responding in rats using electric shock as an unconditioned stimulus, and an auditory conditioned stimulus. Doses from 350-750 rads WBR resulted in heightened activity of conditioned and unconditioned responses. Higher doses up to 4000 rads resulted either in a marked depression of responding, or an alteration of initial excitation and then inhibition. Meshchersky (1958; cited from Stahl, 1960) irradiated the visual cortex of rabbits with 25-200 rads mixed gamma and X-irradiation. The subjects had previously been trained on a defensive conditioned reponse to shock using light as a conditioned stimulus. The strength and accuracy of the conditioned response increased and there was improved differentiation, but response latencies were longer. Thus, many of the results of radiation effects on conditioned avoidance-escape behaviour are somewhat equivocal.

In opposition to decreased responding after radiation, Graham, Gilbert, Gold and Callahan (1962) found increases in response rate relative to the cumulative dose in old rats (15 months) given 0, 3, 30 or 300 rads/week for 4 weeks. However, the age variable must be considered.

Although all tasks involve some sensory function interaction, some behavioural tasks are specifically oriented around various sensory functions. Brown and McDowell (1960) trained monkeys on a visual acuity task to differentiate whole from broken circles. No differences were found with breaks up to 2 degrees, but with 1 degree breaks, subjects exposed to 308 and 616 rep (mixed gamma and neutron) were inferior to both control and 77-154 rep subjects. Another study (McDowell and Brown, 1960d) used the same task for monkeys irradiated 2 years earlier with 6000 rads X-irradiation to either the frontal or posterior association areas of the brain. Frontal subjects were inferior to controls on all problems indicating a general learning deficit, while the posterior subjects differed only on problems where the circle separation was 7 degrees or less, suggesting a visual acuity deficit in these animals.

In another study (Brown, Ritter, and McDowell, 1962) monkeys were trained to discriminate a white card from a white card with a black dot of various sizes (1/4 - 1/64 in. dia.). Ocular radiation of 2000 rads adversely affected the ability to discriminate the card with the 1/64 in. dia. dot from the white card. Little effect was seen 1000 rads or 500 rads doses, or for cards with larger dots. Furchtgott (1952) trained rats on a brightness discrimination in a Lashley-type jump box. After 2 or 4 days training, subjects were irradiated with either 369 or 469 rads WBR. Radiated groups showed a deficit which he attributed to changes in the receptor system.

The olfactory bulbs are especially sensitive in detecting radiation. Brust-Carmona, Kasprazak, and Gasteiger (1966) were able to train rats on a conditioned suppression paradigm (Estes and Skinner, 1941) using electric shock as the aversive stimulus and X-rays at 0.2 rads/sec. as the pre-aversive stimulus. Thus X-rays at this dose rate were able to act as a stimulus. Bulbectomized rats failed to show suppression, indicating that the olfactory bulbs appear to be the primary receptor. The radiation stimulus appears to activate the receptor directly, and not necessarily through the production of various gases such as ozone. Morris (1966) also trained rats on the conditioned suppression paradigm and determined that X-rays at dose rates as low as .004 rads/sec. can be an effective pre-aversive stimulus for the rat. In addition, Cooper (1970) demonstrated that a dose rate of 3 rads/sec. is an adequate stimulus to increase respiratory rates in lightly anesthetized or unanesthetized rats within 5 sec. of exposure. Lesions of the olfactory bulbs revealed that respiratory changes were due largely if not entirely to olfactory stimulation by X-rays.

Perhaps the most consistent radiation effect on behaviour has been the decrease in general activity. This effect has been found for rats (Arnold, 1962; Brown and White, 1960; Fields, 1957; Jarrard, 1963; and McDowell and Brown, 1960a), for rats, guinea pigs and hamsters (Castanera Jonees, and Kimmeldorf, 1959), and for monkeys (Harlow and Moon, 1956; and McDowell and Brown, 1966b). This decrease in general activity must be taken into account when assessing behavioural changes due to radiation.

Radiation has also been employed in a large number of experiments as an aversive unconditioned stimulus. In this work, it is believed that the radiation affects behaviour because of its ability to activate various sensory receptors. Saccharin taste avoidance and instrumental place avoidance have been produced by association with gamma or X-ray doses as low as 30 rads WBR (Kimmeldorf and Hunt, 1965; and Van Cleave, 1963).

Many of the above studies are somewhat equivocal. A great deal of attention has been paid to dosage parameters, the age of the subject, and other variables related to radiation procedures. However, with the exception of a few studies, little attention has been paid to the variables controlling the behaviour on which the radiation effects are assessed. Many variables such as reinforcement types and schedules, antecedent controlling stimuli, and response topography are all variables which may drastically affect the behaviour they are maintaining. Lack of control of these variables is most likely the cause of most of the inconsistencies in the above studies. In order to fully assess radiation effects on behaviour, it will be necessary to control these variables.

The above text is not intended to be a full review of radiation effects on behaviour. However, it does give a general summary and includes many of the most important sources of information and data concerning the behavioural effects due to irradiation, that must be borne in mind in interpreting obtained changes in conditioned vestibular responding.

CHAPTER III

INTRODUCTION: RADIATION AND VESTIBULAR PROCESSES

Ewald (1905) placed glass beads containing 3 mg. radium bromide through a small opening in the vicinity of the labyrinth of pigeons. Controls had glass beads without radium. In irradiated animals, he noted turning of the head and other manifestations of labyrinthectomy. According to Van Cleave (1963), Halberstaedter (1920) observed vestibular disturbances in mice after irradiation on one side of the cranium, and Thielemann (1928) found signs of disturbed equilibrium after head exposure of 4.0-7.5 kilorads of X-rays. Thielemann also found tissue damage in the cristae, but not the maculae. Chilov (1927) noted severe vestibular disturbances in the cat after 13.5-25.0 mc. of radon had been placed in the tympanic cavity. He concluded that radon disturbed the function of the semi-circular canals, the utricle and the cochlea, but did not influence the saccule. Microscopic studies established hemorrhages in the middle and inner ear as well as inflammation and degenerative changes in the receptor formation and Scarpa's ganglion.

Furchtgott (1963) cites Moskovskaya (1959) as having studied 35 human adult patients undergoing X-ray therapy. In 20% of the patients with cumulative doses less than 2500 rads, symptoms of unsteadiness of gait, weak spontaneous divergence of both hands, and a prolongation of postrotational nystagmus from an average of 25-60 sec. to 50-160 sec. were found.

Quastler (1957) found that head exposure to 7.5 kilorads X-rays resulted in alterations in the position of the head, and motor organization that included circling and somersaults. In a later study (Levy and Quastler, 1962) hamsters were exposed 8000 rads or more of X-irradiation to either the whole head or the whole body. Two well-defined acute components appeared; a general motor unrest and disturbances in space orientation. They suggested that the motor unrest was associated with irradiation of a large part of the brain, whereas the inner ear was implicated as the structure most likely responsible for acute alterations in space orientation. Histological studies corroborated this. Evidence from anatomical and histopathology studies indicated that damage was due primarily to epithelial destruction of the inner ear, but the possibility of preceding vascular damage and edema were not excluded. It was also noted that once the behavioural effects were manifested, they were irreversible for higher doses, but a rapid recovery occurred for near threshold doses. The threshold dose for motor symptoms was determined to be a single dose of 6 kilorads and more than double that for fractional doses.

Gamble, Peterson and Chandler (1968) studied the effects of 500 to 6000 rads X-irradiation focused on the inner ear. Recording cochlear microphonic potentials, they found only small decrements during the first 2 post-irradiation weeks for the 4000 rad and 5000 rad doses, inflammation having developed in the 6000 rad subjects. The stria vascularis and hair cells of the organ of corti appeared to be most susceptible to morphologic change and are thought to account for the moderate but definite depression of function. The vestibular system was considered even more resistant than the cochlea.

Keleman (1963-64) delivered 300 to 5000 rads WBR to rats. He found that in the semi-circular canals, the crista, inclusive of the cupula, proved relatively resistant, only beginning to disintegrate between 1000 rads and 2000 rads. Hemorrhage was considered the primary source of damage, but compression of the endolymphatic space due to perilymphatic edema was a standard finding beyond 400-500 rads.

Although it appears that morphological and histological effects of radiation on the labyrinth require relatively high doses, alterations in functional processes involving vestibular stimulation may occur at much lower doses. This implies that either radiation of the vestibular system can produce behavioural changes without gross morphological or histological changes, or that radiation is primarily affecting some other part of the CNS involved in the vestibular behavioural function; e.g. the midbrain, cerebellum or cortex.

Only a few experiments have been done involving vestibular stimulation in conditioning situations, and only a portion of these have employed radiation as a variable. Lebedinskiy and Nakhil'nitskaya (1963) note that Petelina (1957) used rotary stimulation as a conditioned stimulus in a conditioned secretory reflex. After 400 rads WBR, the strength of the positive conditioned reflex was reduced on days 2-3, 7-9, 19-22 and 27-28 after radiation. On intervening days, the conditioned responses were somewhat increased but often did not reach the pre-irradiation level.

Barnes (1966, 1967) tested the effects of pulsed ionizing radiation on monkeys' vestibulobehavioural performance on the primate equilibrium platform (PEP). Twelve rhesus monkeys were trained to maintain a platform-horizontal position by means of a joy-stick in order to avoid an electric shock. Deviations greater than 14 degrees from horizontal resulted in the delivery of a 10 ma. shock. The speed of rotation could be varied and was used at two different levels in this study. Subjects were trained to maintain the horizontal position, with the platform speed changed before each 3 min. trial. Time per trial spent in the horizontal and the number of errors (deviations beyond 14°) were the primary measures. After a baseline performance was obtained, subjects were subjected to an average mid-head tissue dose of 2420 rads mixed gamma and neutron radiation in a microsecond pulse. A rather general performance decrement occurred 2-4 min. after the burst and slowly disappeared during the first 20 min. There were individual differences as some subjects were totally incapacitated while others were much less affected. He concluded that the equilibrium-maintaining function, whatever it may include, is radiosensitive and worthy of further study. The next study (1968) used a modified PEP in which the monkeys had to track incoming signals that tilted the platform in various patterns, rather than merely maintain the horizontal position by responding to overcorrections. The subjects received either 1000 rad or 2500 rad doses in a procedure similar to the one above, and were tested for either 1 or 3 hours post-irradiation. Only 2 of 13 1000 rad subjects showed a significant early response decrement, whereas the higher dose produced results similar to the first study. Thus dose-level responses were apparent, 1000 rads being near threshold. Visual stimuli were not controlled for, but pilot studies indicated that the "integrity of the visual modality is practically, if not entirely, unnecessary for the maintenance of performance capability on the PEP." (p.7). However, this is yet to be fully tested. It is not clear whether changes in response to the unconditioned properties of the stimulation played a role in these effects. Also, other dosage and exposure parameters as well as longer post-irradiation intervals remain to be investigated.

Riccio and Thach (1968) demonstrated that rotation produced response suppression in an ongoing operant response maintained by fixed-interval, variable-interval, fixed-ratio, or variable-ratio schedules of reinforcement. The magnitude of behavioural suppression was found to be a function of the rotary stimulus intensity. Centrifugal forces were minimized by placing the chamber over the centre of rotation. Food satiation and impaired motor capacity were also ruled out as causes of response suppression. The fact that the rotatory stimulus suppressed responding suggests that it may be aversive. In an earlier study (Riccio, Igarashi and Eskin, 1966), it was found that reduced motor activity due to rotation was greatly attenuated in subjects with damaged labyrinths. Thus the immediate effective stimulus was considered to be "complex accelerational forces acting on the semi-circular canals" (Riccio and Thach, 1968, p.479).

The aversive properties of vestibular stimulation have been taken advantage of in a technique for vestibulobehavioural research with rats in an operant setting (Halasz and Halasz, 1970; Halasz and Lindsay, 1971). In this technique, conditioned vestibular escape (CVE) may be established when externally initiated tilt oscillations of a chamber are terminated by a rat's bar press. Thus tilt-oscillations here function as an aversive stimulus maintaining the operant rather than a conditioned stimulus or a discriminative stimulus as in the previously mentioned vestibular response studies by Petelina and Barnes. CVE strength is measured as response latency following onset of tilting. Some proprioceptive stimuli are also most probably involved. The CVE paradigm is being used in this study to assess the effects of Co^{60} ionizing radiation on conditioned vestibular responding for a 2 week period following irradiation.

The CVE paradigm differs from many of the escape-avoidance tasks described in the general introduction. The subject cannot avoid the aversive vestibular stimulus, only escape from it. More important, the aversive stimulus is not a "painful" electric shock, but only a vestibular stimulus. Since the negative reinforcer maintaining the response is different, radiation effects may also be different. Radiation-induced changes in the "pain response" are thus not confounded with the vestibular aspects of the task.

Postrotational nystagmus is employed as an unconditioned vestibular response (UCVR). This UCVR was used as a comparison to the CVE response. Petelina (1957) observed that the duration of postrotational nystagmus in cats was reduced on the second day after 400 rads WBR. This decrease continued to the 8th or 9th day. A period of more prolonged nystagmus followed. Then, 18-19 days after radiation, the duration once again became shorter, this last effect being resistant with no return to normal after 30 days post-irradiation. Moskovskaya, as previously noted, found prolongation in the duration of postrotational nystagmus in humans receiving less than 2500 rads cumulative dose while undergoing X-ray therapy. However, the dosage was fractional and the time between radiation and testing varied. Farber and Tabakova (1959) showed that changes in the threshold sensitivity of the vestibular analyzer as measured by postrotational nystagmus after a single 50 rad dose, is to a large extent a function of initial sensitivity of the vestibular analyzer. Thus individual differences in radiation effects on nystagmus are present.

The present study looks at the effects of 10 rad, 450 rad and 900 rad doses of Co^{60} irradiation on the CVE response in the tilt-box apparatus and an UCVR in the form of postrotational nystagmus. If the UCVR is found to be as sensitive as the CVE response to radiation, then it will henceforth be unnecessary to go through the problems of the operant training of the subjects in order to fully study radiation effects on the vestibular system. On the other hand, if greater or different radiation effects are obtained for the CVE than for the UCVR, the specific radiosensitivity of "higher" vestibular circuits may be indicated.

CHAPTER IV

Subjects:

The subjects (Ss) consisted of 45 male albino Holtzman rats, 55 to 65 days old at the beginning of training and 85 to 100 days old when irradiated. Between sessions, the Ss were housed in individual commercial steel cages in the department's rat colony. Food and water were freely available in the home cages.

Apparatus:

The test chamber for the conditioned response to vestibular stimulation consisted of a tilt-lever apparatus or tilt-box (Halasz and Halasz, 1970). This test chamber (23.5cm(l) X 17.5 cm.(w) X 20.0 cm. (h)) was constructed from an ordinary individual rat cage that was mounted on a shaft and bearings. The cage was able to rotate about a horizontal axis which extended through the panel on which the lever manipulandum was mounted (Fig. 1). The lever manipulandum was 12.7 cm. wide and extended 2.3 cm. from the front panel. It was located 6.5 cm. above the chamber grid floor. A force of 23 gm. was required to activate the lever microswitch. The top of the chamber was covered by a hinged Plexiglass lid. The tilt-box shaft and bearings were attached to a plywood box which housed the tilt chamber. An air piston and cog wheels that caused the shaft to rotate were attached to the outside of this plywood housing. A speaker that produced white noise to mask any auditory cues associated with the tilting was also attached to the plywood housing.

Tilting of the tilt-box was controlled by logic modules and air controls in an adjoining room. Full control was available over the

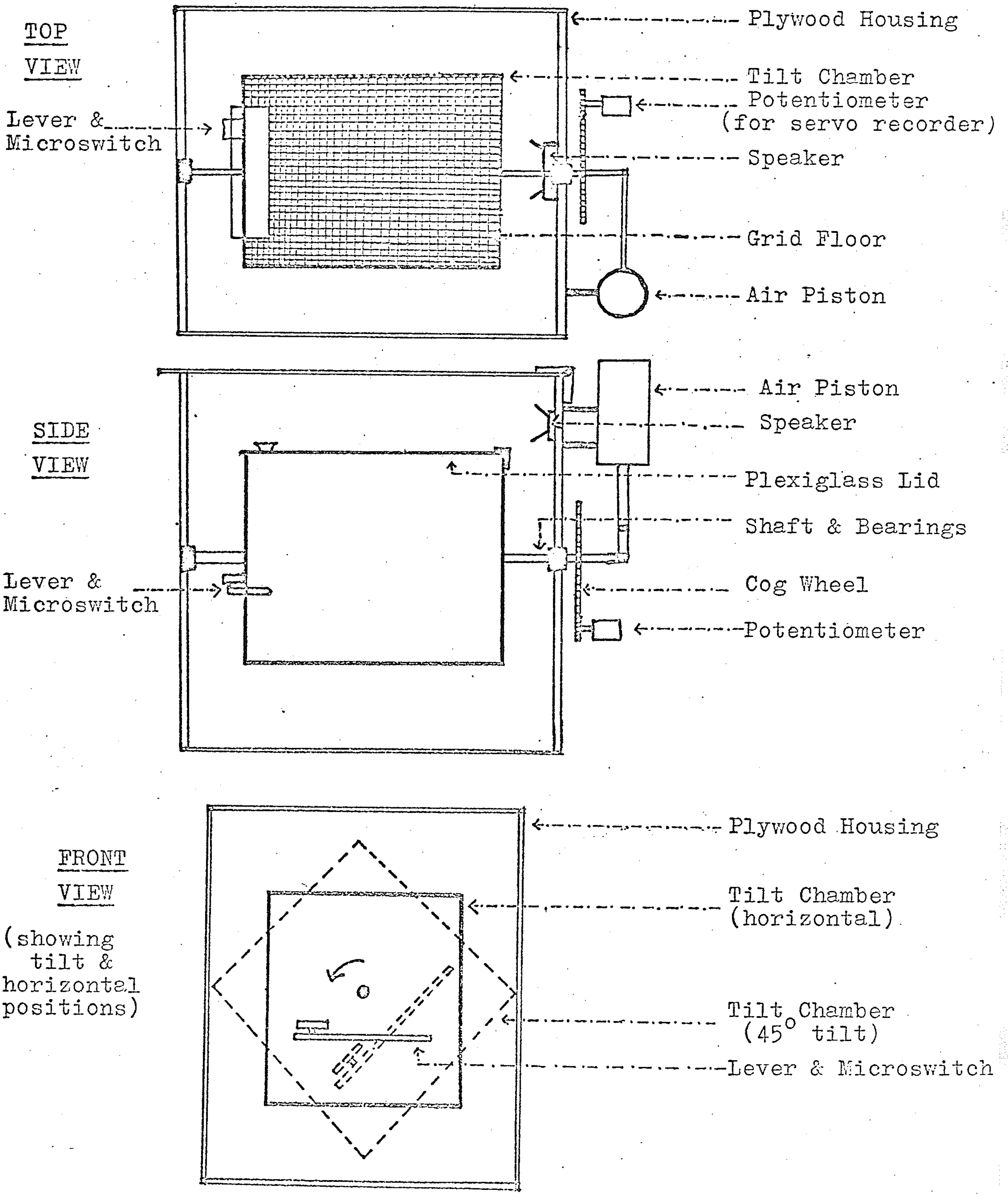


Figure 1. Top, side, and front schematic diagrams of the Tilt-box apparatus.

following parameters:

a) angular excursion from horizontal (to one side only), maximum arc of 45°

b) rate of tilt and reset, independently adjusted by air controls.

c) tilt-reset cycle frequency

d) proportion of cycle at maximum and minimum angular excursion (dwell times)

Discrete trials of tilting were initiated externally by a tape programmer in conjunction with the logic modules, and were terminated by the subject (S) pressing the lever in the tilt-box. The tape that initiated the trials was punched with 24 holes that were spaced randomly (from random number tables) with a mean intertrial interval of 1.4 min. The total number of lever pressing responses and the total time duration that the lever was pressed down by the S during the session were recorded respectively by a counter and running time meter. Oscillations of the tilt-box were also recorded graphically by means of a Heathkit proportional servo recorder receiving as input a signal from a potentiometer driven by the rotation shaft of the tilt-box.

Postrotational nystagmus was used as the UCVR. The restraining apparatus consisted of a commercial Plexiglass rat restrainer that had been slightly modified so that the S's head projected through an aperture in the anterior end. The rotating apparatus itself consisted of a rotary pursuitmeter with a black rotating platform that could be rotated at speeds of 30rpm or 60rpm. The rat restraining apparatus was attached to the top of the platform so that the centre of the rat's body was approximately over the centre of rotation. The rotation was applied to the S in darkness to ensure that the nystagmus was vestibular in origin. A stopwatch was used to record the duration of the postrotational nystagmus.

Procedure:

a) Pre-irradiation Training

By manipulation of the various tilt parameters, three different tilt conditions were used in this study:

1. .33 hz(cycles/sec.) cycle frequency (fast tilt rate; i.e. FTR) consists of 1 sec. tilt, a 1 sec. reset, and ½ sec. dwell times at both horizontal and tilt positions.
2. .20 hz. cycle frequency (medium tilt rate; i.e. MTR)-- consists of a 2 sec. tilt, a 2 sec. reset, and ½ sec. dwell times at both horizontal and tilt positions.
3. .14 hz cycle frequency (slow tilt rate; i.e. STR)-- consists of a 3 sec. tilt, a 3 sec. reset, and ½ sec. dwell times at both horizontal and tilt positions.

In previous work, it has been found that the .14 hz cycle frequency is close to the threshold value for aversive vestibular stimulation for most rats. The .33 hz cycle frequency, on the other hand, was a relatively rapid tilt rate nearing the physical capacity of the apparatus. The ½ sec. dwell times were slightly variable both within a given cycle frequency and between different cycle frequencies.

The first few training sessions varied in duration and the number of trials administered. No direct shaping procedures were involved. The animal was simply placed in the chamber and the tilting started. For the first few sessions, a Formica floor was usually placed over the grid floor. This prevented the S from clinging to the grid, increasing the probability that he would move about during the tilting and accidentally press the lever that causes the tilting to cease, and thus be reinforced for responding. The temporary solid floor was then removed and the remainder of the sessions were then administered using the grid floor. The training was continued until a fairly stable session-to-session mean response latency was attained. The sessions for the last 2 weeks of pre-irradiation training consisted of 20 trials each. One session was administered each day. The mean response latency for the 20 trials, the total number of responses per session, the total duration of lever holding per session, and the ratio of the last two measures (average duration of a lever press) were recorded for each session. These measures for the last 5 sessions immediately prior to irradiation were used as the baseline.

For the postrotational nystagmus measurement, each S was given one daily session in the nystagmus rotation device subsequent to its tilt-box session. Each nystagmus session consisted of 4 trails; 2 trials at the 30rpm rotation speed and 2 trials at the 60rpm rotation speed. The trials were presented in the order: a) 30rpm b) 60rpm c) 60rpm d) 30rpm. The two trials at a given rotation speed were averaged. A trial consisted of 1 min. of rotation in nearly total darkness. When the 1 min. of rotation was completed, the rotation was stopped sharply. At the same time, a light was turned on to illuminate the S, and a stop-watch was started. The rat's pupils were observed and the duration of the nystagmus was recorded. Trials were separated by a 1 min. intertrial interval. These daily nystagmus sessions were administered 10 days prior to irradiation, the first 5 days being used to habituate the S to the situation, and the last 5 days being used as a baseline.

The 45 Ss were run in 5 sets over the period from September, 1970 until May, 1971. Each set contained 9 Ss, one from each tilt-radiation condition. The initial training, baseline, and post-irradiation measurements for each set took approximately 2 months.

b) Radiation Procedures

Irradiation was carried out at the Manitoba Cancer Treatment and Research Foundation. The Ss were transported by automobile a total of 16 miles to and from the irradiation centre. The Ss were irradiated by whole body exposure to a Co^{60} gamma source. The dose rate varied from 5.2 to 5.7 R/min. over the 8 month time period for the 15 in. source-to-subject distance used. The animals were irradiated at one of three different dose levels: 10 rads (low level; i.e. control), 450 rads, and 900 rads (approximately the LD-50-30 dose). Because of the time involved in transporting and irradiating the animals, no experimental sessions were administered on the day of irradiation.

c) Post-irradiation Measures

The first post-irradiation measures were administered 24 hours after exposure. A 20-trial session in the tilt-box followed by a 4-trial determination of the postrotational nystagmus was given for 14 days (or until death occurred). By the end of the first week, the 450 rad animals had fully recovered to the original baseline. Thus, these animals were given a second 450 rad dose (900 rads fractionated total dose) after 7 days of tilt-box testing; i.e., 8 days after the first dose.

CHAPTER V

RESULTS:

The tilt-box data was analyzed primarily in terms of response latency as a function of tilt-cycle frequency (vestibular stimulus intensity) and radiation dose. With 3 different levels of each, 9 different experimental conditions were possible. Five subjects (Ss) were in each condition.

For the postrotational nystagmus measures, all Ss receiving the same radiation dose were considered together. Postrotational nystagmus duration measures were obtained from each S with 30 and 60 rpm stimulation. The raw data for all response measures for each S is presented in Appendix A.

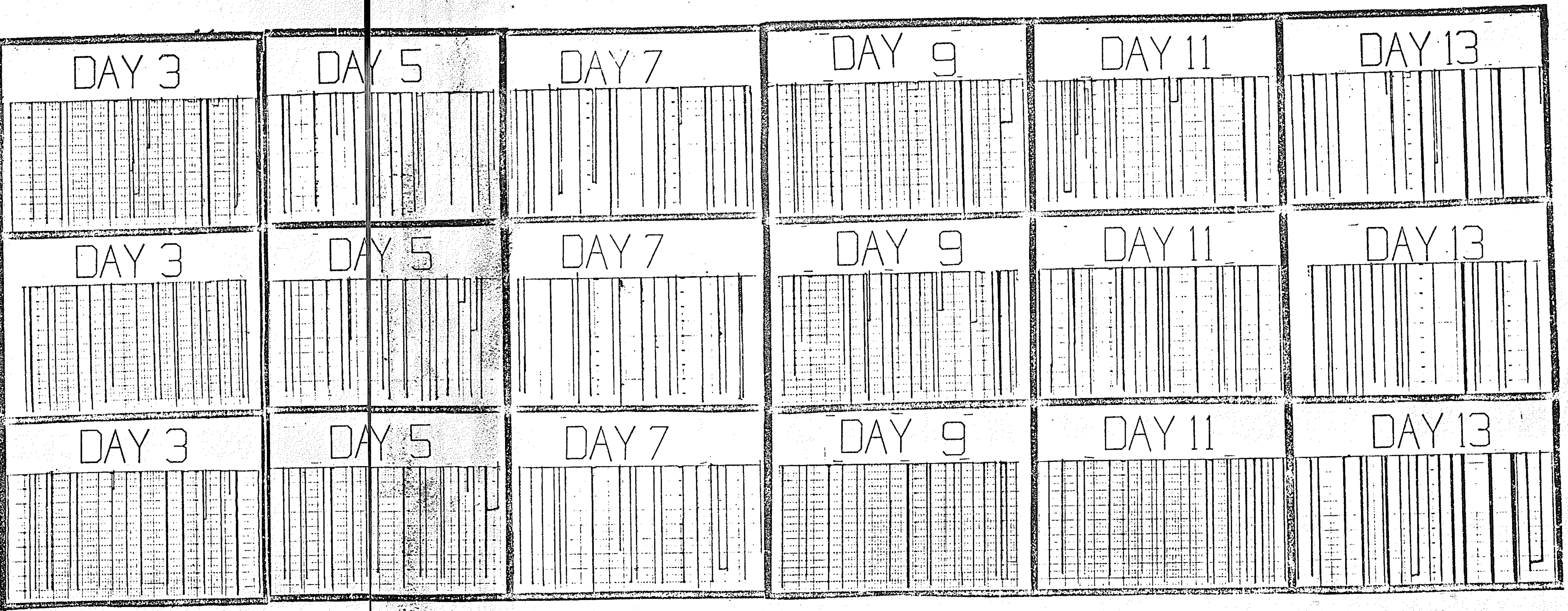
During the 2 post-irradiation weeks, a number of rats exposed to the higher radiation doses died:

- fast tilt rate (FTR), 450 rads -- 1 S died 12 days after the first 450 rad dose; i.e., 4 days after the second 450 rad dose.
- fast tilt rate (FTR), 900 rads -- 3 Ss died; one 9 days post-irradiation, and two 12 days post-irradiation.
- medium tilt rate (MTR), 900 rads -- 3 Ss died; one 7 days post-irradiation, one 11 days post-irradiation, and one 12 days post-irradiation.
- slow tilt rate (STR), 900 rads -- 4 Ss died; two 10 days post-irradiation, and two 11 days post-irradiation.
- one control (10 rads) S on the MTR developed respiratory disease and so only 12 days of data post-irradiation were obtained from it.

Weights of the Ss were also recorded and it was noted that there was a decrease in weight for most Ss that was proportional to cumulative radiation dose.

The behaviour of each subject was assessed in terms of its pre-irradiation baseline. The mean of each response measure over the 5 sessions preceding radiation was considered as the baseline. Response measures for each S were then calculated as a difference (Δ) from the pre-irradiation baseline or as a % of the pre-irradiation baseline. Group measures (means) were derived from the individual Δ or % response measures. Since the 450 rad Ss were given a second 450 rad dose on day 8 after the first dose, they were not given any tilt-box or nystagmus sessions on this day, and so day 8 was not plotted on any graphs for these Ss.

Figures 2, 3 and 4 illustrate raw servo records for typical individual Ss on the fast, medium and slow tilt rates respectively. Each S's records should be assessed in relation to its pre-irradiation baseline record. Each pen oscillation mark on the record corresponds to one tilt-cycle, and each group of oscillations corresponds to one trial. It should be noted that with the FTR (.33 hz) (Fig. 2), radiation had little effect on the S's performance. The 10 rad control, the 450 rad and the 900 rad Ss all exhibited very little change after radiation. On the other hand, dose dependent radiation effects were readily apparent on the STR (.14 hz) (Fig. 4). Assessing each S in relation to its baseline, it should be noted that little change occurred for the STR 10 rad Ss. However, the STR 900 rad S had a decrement (longer response latencies) in performance on day 4, with a slight but not full recovery on day 6-7, followed by a much greater decrement on days 9-11. The STR S had



rad individual Ss on the
3 seconds.

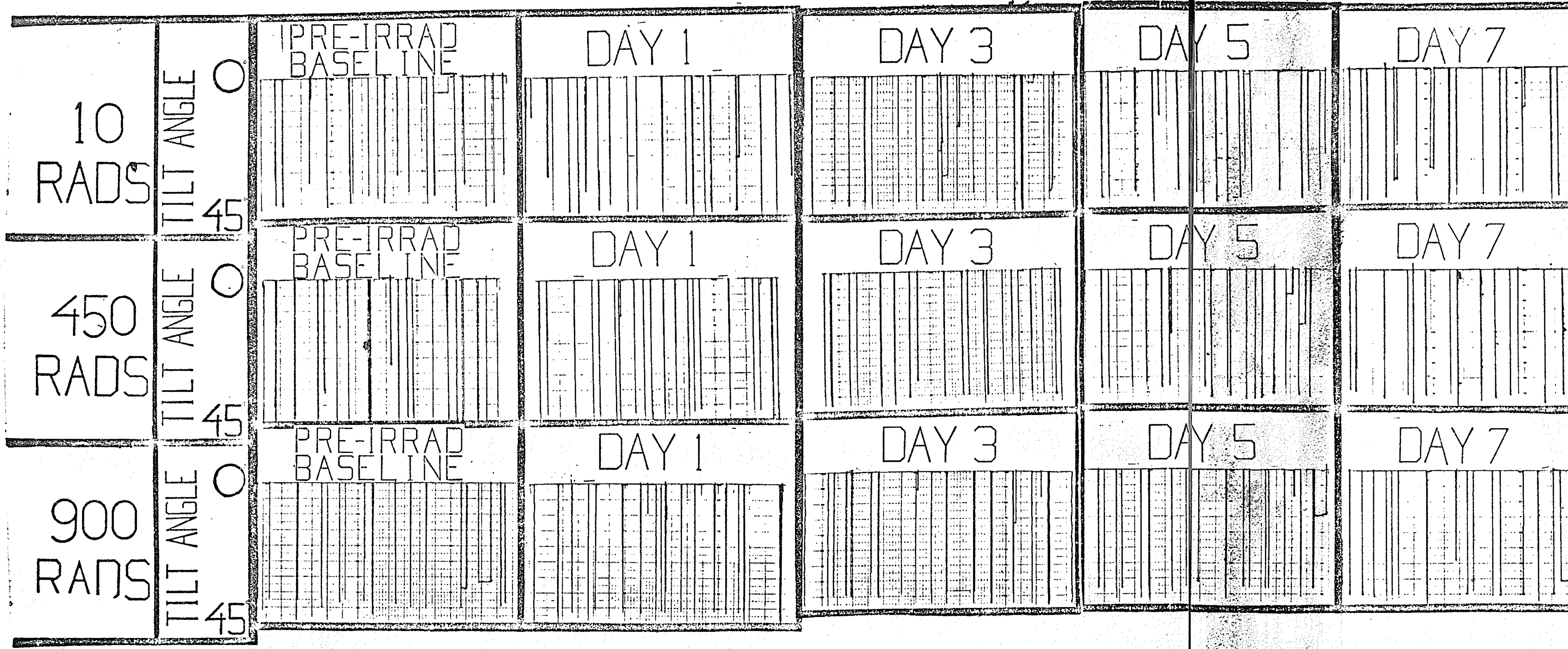
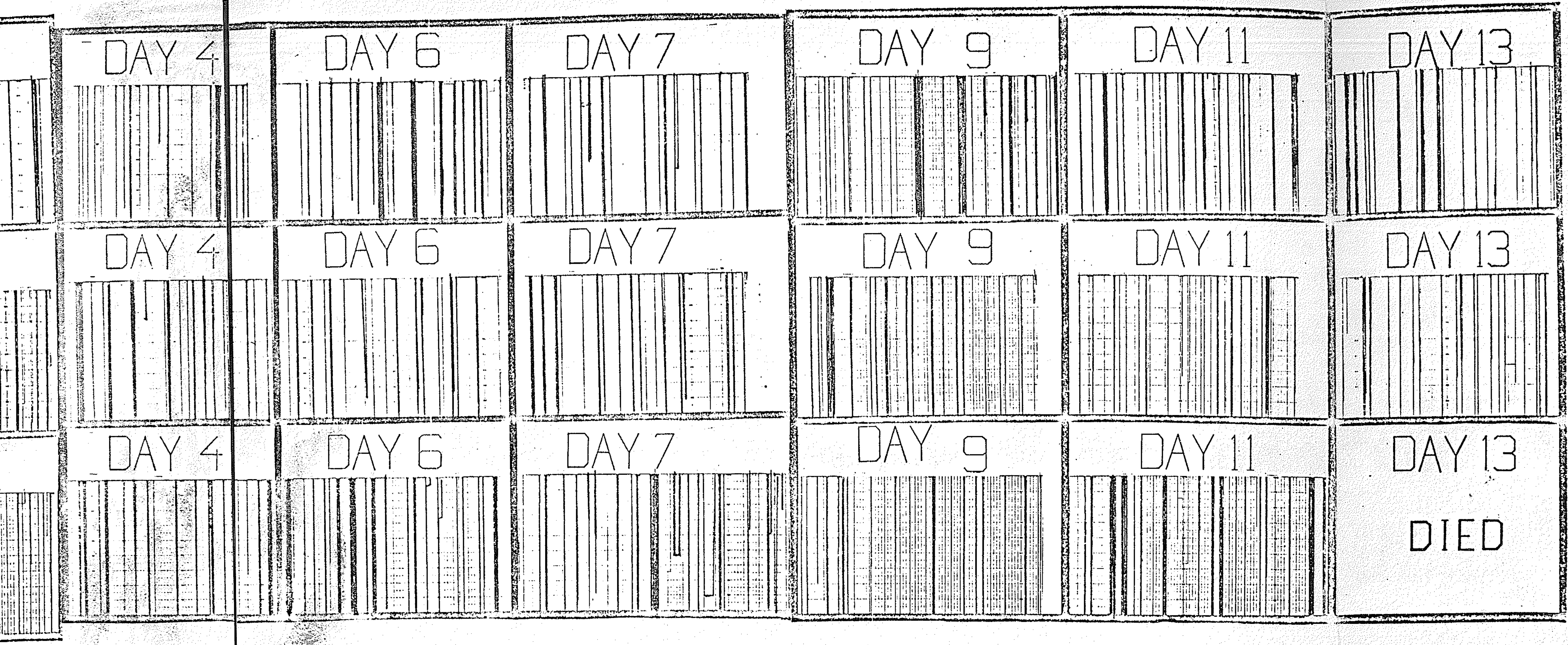


Figure 2. Tilt-box servo records for the 10 rad, 450 rad, and the 900 rad individual Ss on the fast tilt rate. Each pen oscillation corresponds to one tilt-cycle = 3 seconds.


DAY 4
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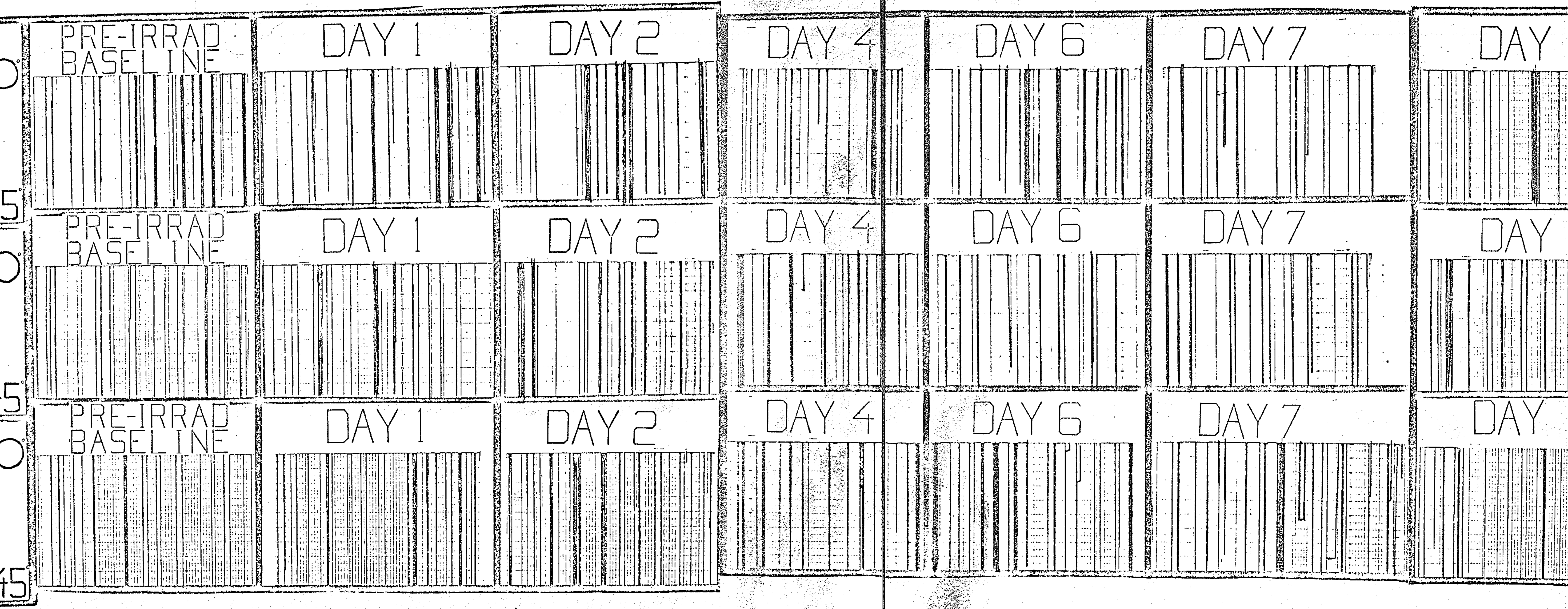

ox servo records for the 10 rad, 450 rad, and 900 rad individual Ss on the
e. Each pen oscillation corresponds to one tilt-cycle = 5 seconds.

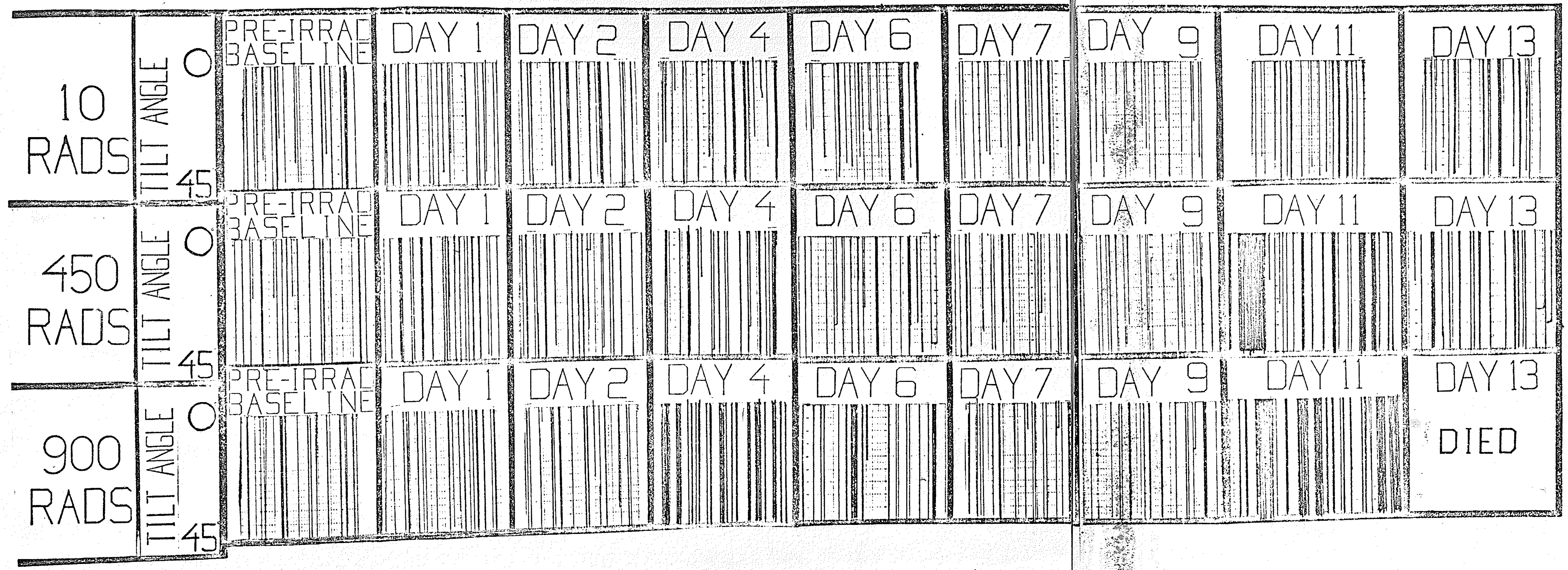

Figure 4. Tilt-box servo records for the 10 rad, 450 rad, and 900 rad individual Ss on the slow tilt rate. Each pen oscillation corresponds to one tilt-cycle = 7 seconds.

a slight decrement on day 4 followed by a return to baseline on day 6-7. After a second 450 rad dose on day 8, longer response latencies were again produced. The MTR (.20 hz) Ss (Fig. 3) exhibited effects that were intermediate between the FTR and STR radiation effects.

Since the absolute value of the individual Ss' baselines were different (but the absolute change from this baseline after radiation did not depend on the pre-irradiation level), the session mean response latency measure for each S was expressed as a difference from its own pre-irradiation baseline (Δ) in order to allow a more valid comparison of the radiation effects. An analysis of variance for these Δ mean response latency measures is presented in Table 1. The analysis of variance was calculated for only the first 7 days post-irradiation. After this, some of the high radiation exposure Ss had died and the groups became depleted. There is a significant Radiation dose effect ($p < .01$) and a significant Radiation X Tilt-cycle frequency interaction ($p < .01$), indicating that the radiation effect is dependent on the intensity of the vestibular unconditioned stimulus (tilt rate): i.e.

		Tilt-cycle Frequency		
		STR(.14 hz)	MTR(.20 hz)	FTR(.33 hz)
Radiation Dose	10 rads	0.037	0.103	-0.011
	450 rads	-0.443	2.760	-0.003
	900 rads	19.763	8.440	2.911

Mean response latencies are expressed in sec.

There is also a significant Day effect ($p < .05$) in this problem and a significant Radiation dose X Day interaction ($p < .05$), i.e.

TABLE 1

Analysis of Variance: Δ Mean Response Latency Tilt-box Data for the First 7 Days Post-irradiation

Source	DF	SS	MS	F
Tilt-cycle frequency(T)	2	0.12	0.06	0.98
Radiation dose(R)	2	1.82	0.91	15.15**
T x R	4	0.96	0.24	3.98**
Error 1	36	2.16	0.06	
Day(D)	6	0.39	0.07	2.64*
T x D	12	0.27	0.02	0.91
R x D	12	0.58	0.05	1.96*
T x R x D	24	0.44	0.02	0.74
Error 2	216	5.38	0.02	
Total	314	12.13		

* $p < .05$
** $p < .01$

Raw Δ mean latency data was transformed to log(x - 15.0) to meet the assumption for homogeneity of variance.

All analysis of variance computations in this thesis were done by means of the "Mixed factorial designs computer program" by F. Chebib.

		Day						
		1	2	3	4	5	6	7
Radiation Dose	10 rads	0.793	-0.027	0.460	-0.113	-0.820	-0.140	0.147
	450 rads	-0.527	-0.293	2.067	2.753	0.713	0.880	-0.193
	900 rads	2.560	3.107	5.133	13.693	20.240	11.647	16.220

Mean response latencies are expressed in sec.

Dispensing with the statistical analysis and dealing with the data per se; changes in the Δ mean response latency over days for the FTR, MTR, and STR groups are plotted in figures 5, 6 and 7 respectively. For the FTR (Fig. 5), there is virtually no difference between the 10 rad control and the 450 rad groups, while a small post-irradiation increase in response latency appears for the 900 rad group. For the STR (Fig. 7), a dose dependent radiation effect is much more apparent. The two 450 rad doses (900 rads fractional) did not exhibit as great an effect as the single 900 rad dose. The dependency of the radiation effects on the tilt-cycle frequency is illustrated in Fig. 8. Here, the 900 rad groups for the fast, medium and slow tilt rates are presented. It is obvious that the radiation effect on the mean response latency depended on the tilt-cycle frequency of the tilt-box, the greatest effect appearing for the lowest unconditioned stimulus value (STR).

Postrotational nystagmus measures were also calculated as a difference from pre-irradiation baseline. Analysis of variance for the first 7 days post-irradiation revealed no significant differences for either the 30 rpm or the 60rpm nystagmus. Day to day changes in the nystagmus durations are presented in figures 9 and 10. Consistent dose dependent

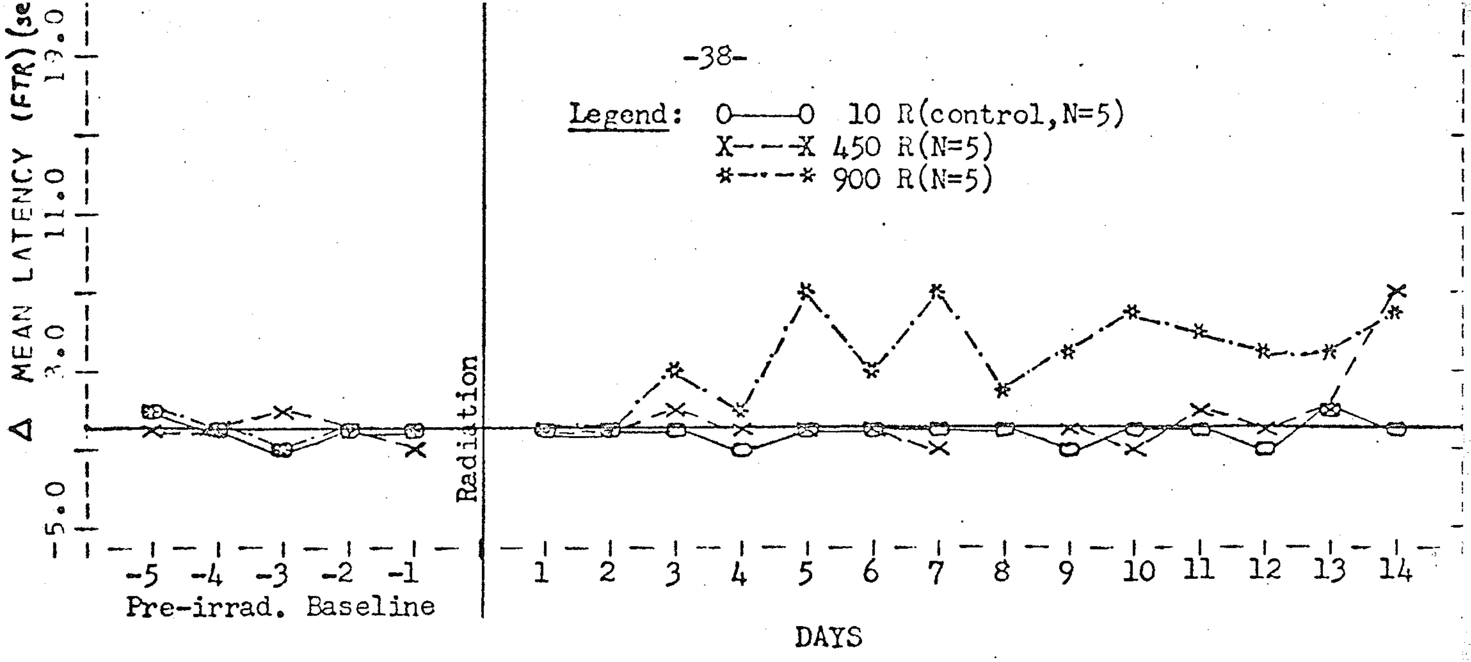

Figure 5. Difference from baseline (Δ) for the mean response latency for the fast tilt rate as a function of radiation dose.

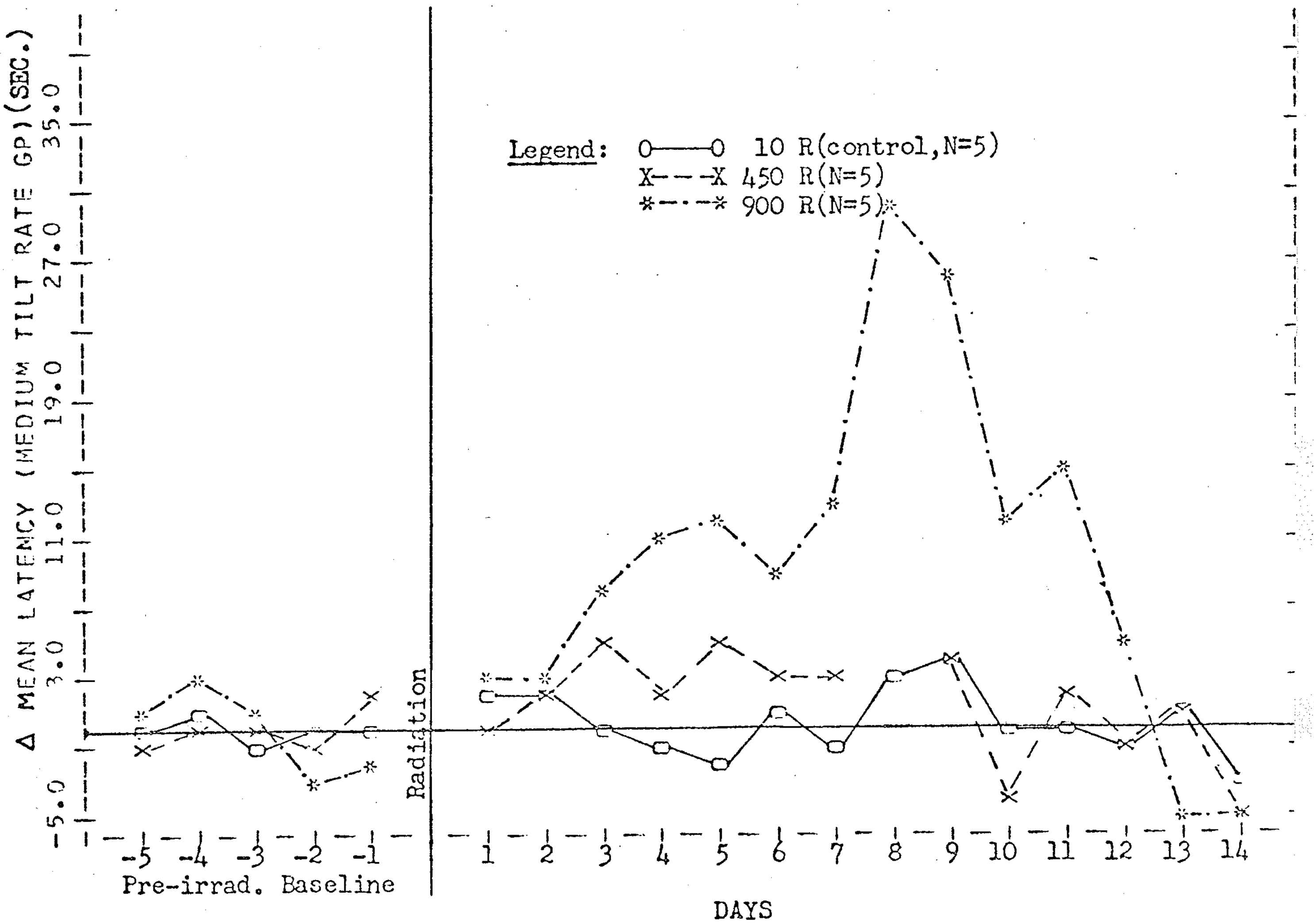

Figure 6. Difference from baseline (Δ) for the mean response latency for the medium tilt rate as a function of radiation dose.

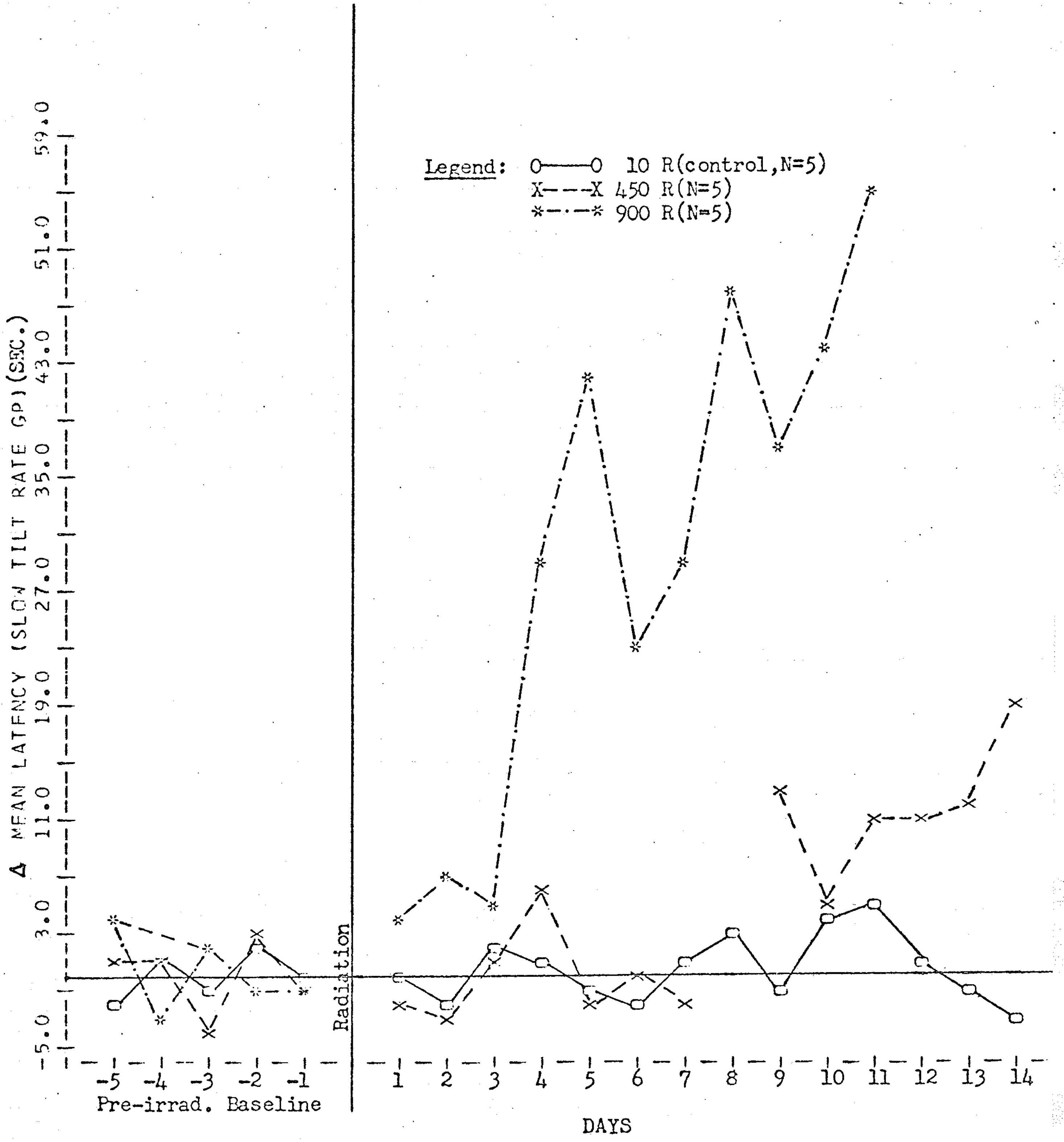

Figure 7. Difference from baseline (Δ) for the mean response latency for the slow t rate as a function of radiation dose. The last 3 days for 900 R were not plotted as all subjects except one had died.

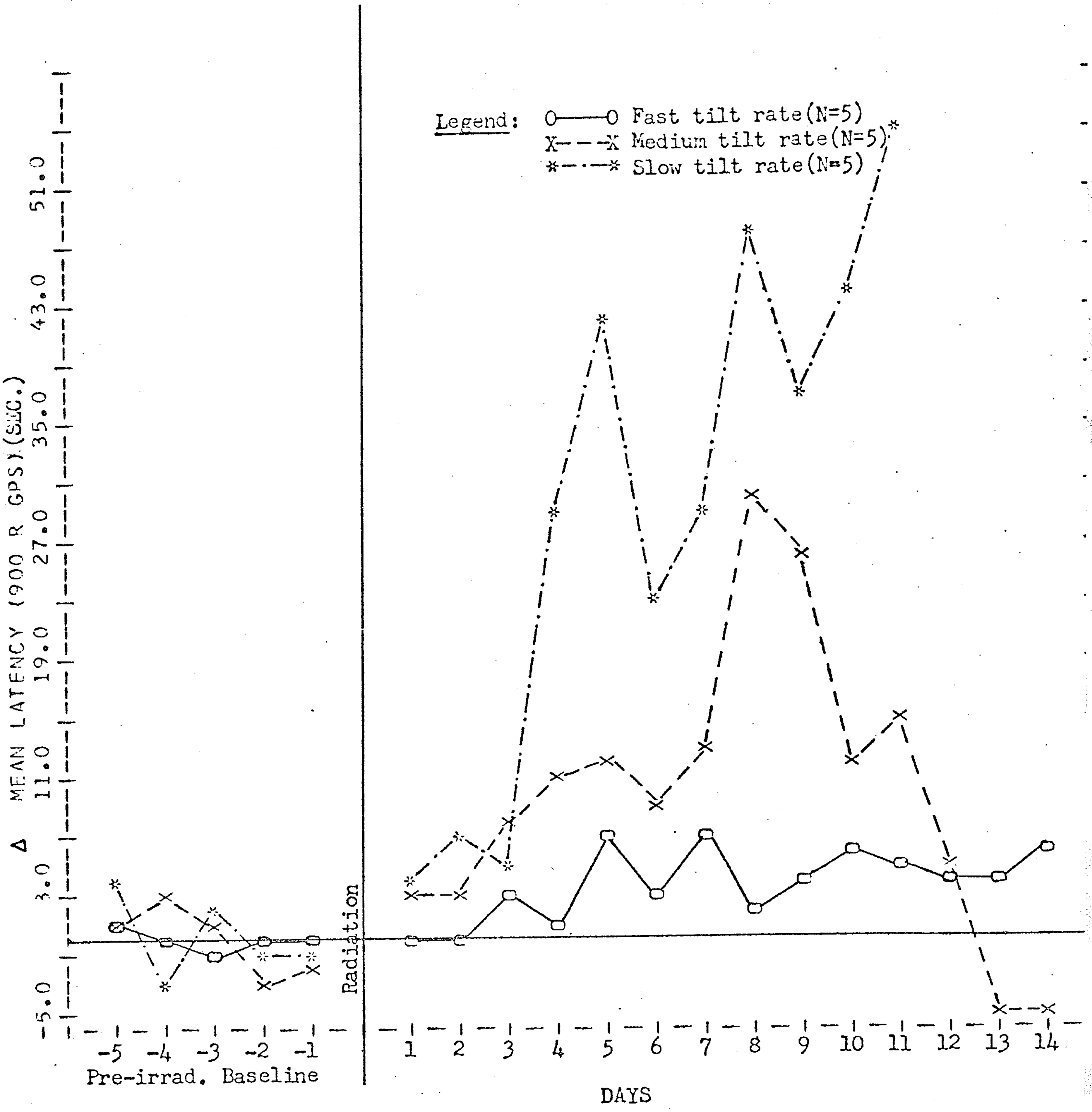

Figure 8. Difference from baseline (Δ) for the mean response latency for the 900 R radiation dose as a function of tilt-cycle frequency(stimulus intensity). The last 3 days for the slow tilt rate were not plotted as all subjects except one had died.

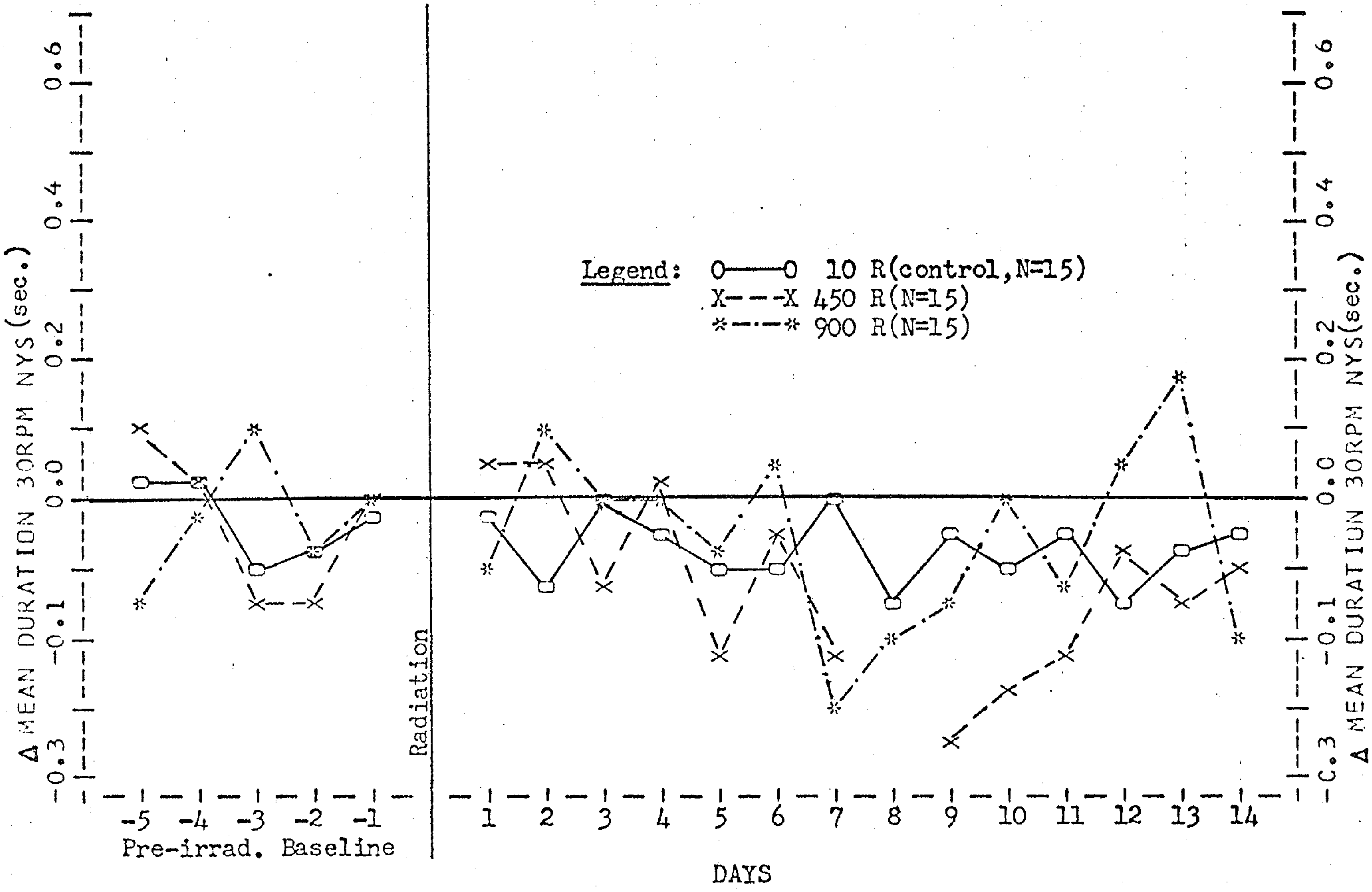

Figure 9. Differences from baseline (Δ) for the mean duration of the 30 rpm post-rotational nystagmus as a function of radiation dose.

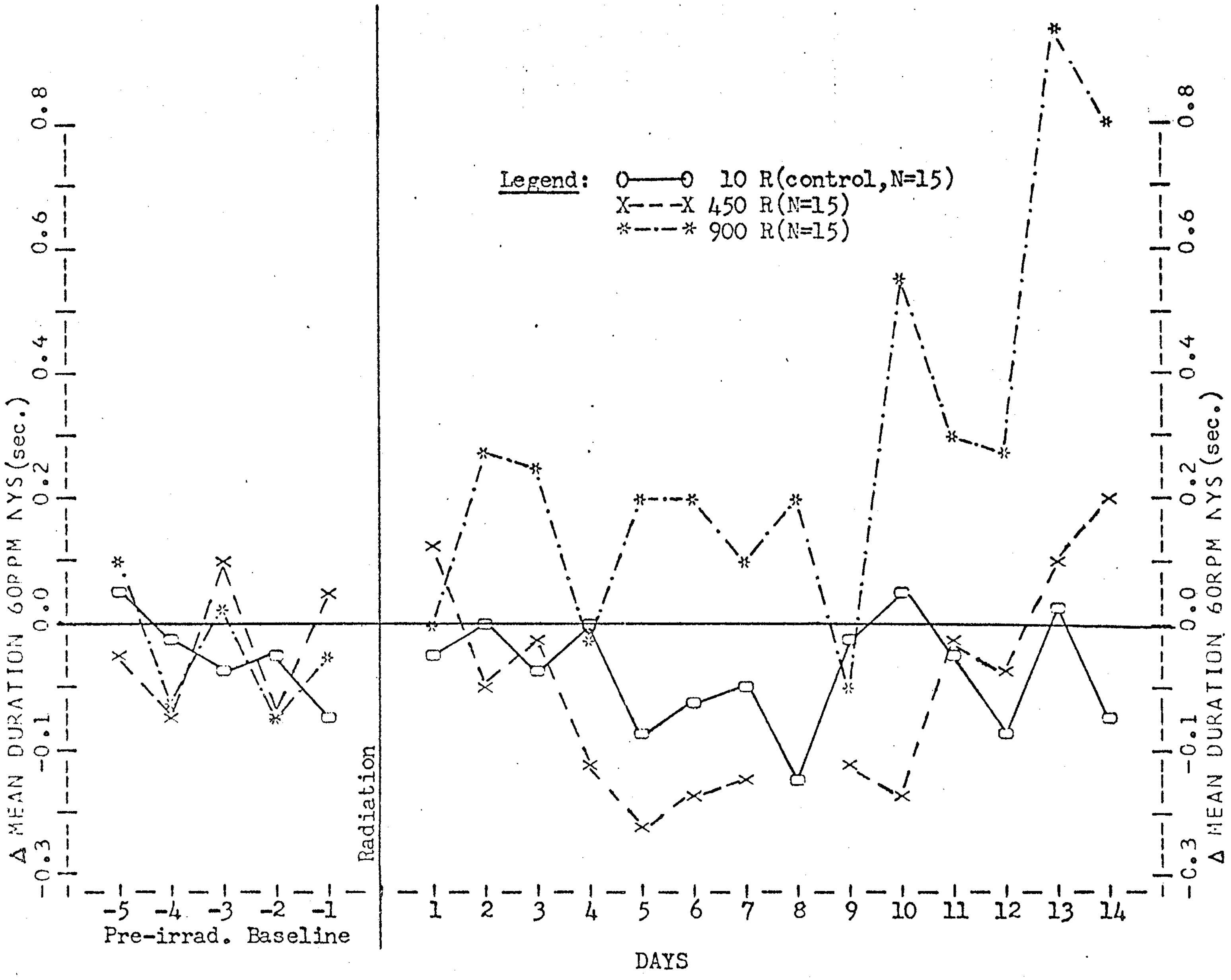

Figure 10: Differences from baseline (Δ) for the mean duration of the 60 rpm post-rotational nystagmus as a function of radiation dose.

radiation trends were not apparent, with the exception of the duration of the 60rpm postrotational nystagmus for the 900 rad group which appeared to increase after day 10. However, this increase was primarily due to increases in only 4 or 5 of the 15 Ss.

In order to compare the radiation effects on the conditioned and unconditioned vestibular responses, the Δ mean response latencies from the tilt-box and the Δ mean duration of the postrotational nystagmus were correlated. Each Pearson correlation co-efficient was calculated from these two measurement pairs for the 5 Ss within one tilt-radiation condition for each day; i.e., 5 pairs. There were no consistent correlational trends between the radiation effect on the vestibular reflex and the conditioned vestibular response. However, this data (if one wishes to see it) is presented in fugures 11, 12 and 13 for the 30rpm postrotational nystagmus and figures 14, 15 and 16 for the 60rpm postrotational nystagmus.

The analysis of variance for the first 7 days for the total number of lever pressing responses per session is presented in Table 2. Since the baseline for this response measure varied from S to S, and in addition, the radiation effect depended on the original baseline level, this measure was calculated as a % of the pre-irradiation baseline for each daily session. A significant Radiation dose effect ($p < .01$) and a significant post-irradiation Day effect ($p < .01$) and a significant Radiation dose X Day interaction ($p < .01$) were found, i.e.:

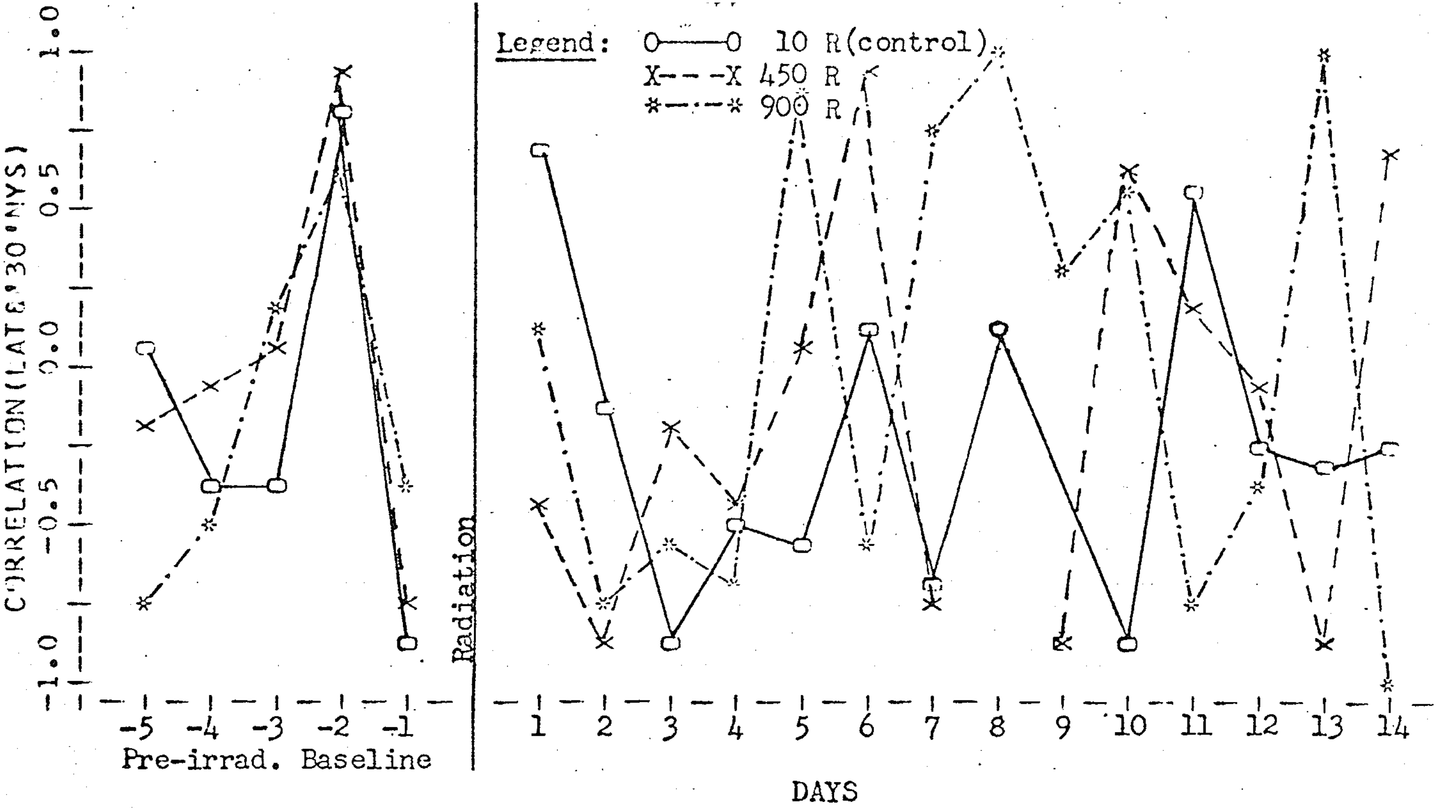

Figure 11. Correlation between Δ mean response latency for the fast tilt rate and the Δ mean duration of the 30rpm postrotational nystagmus.

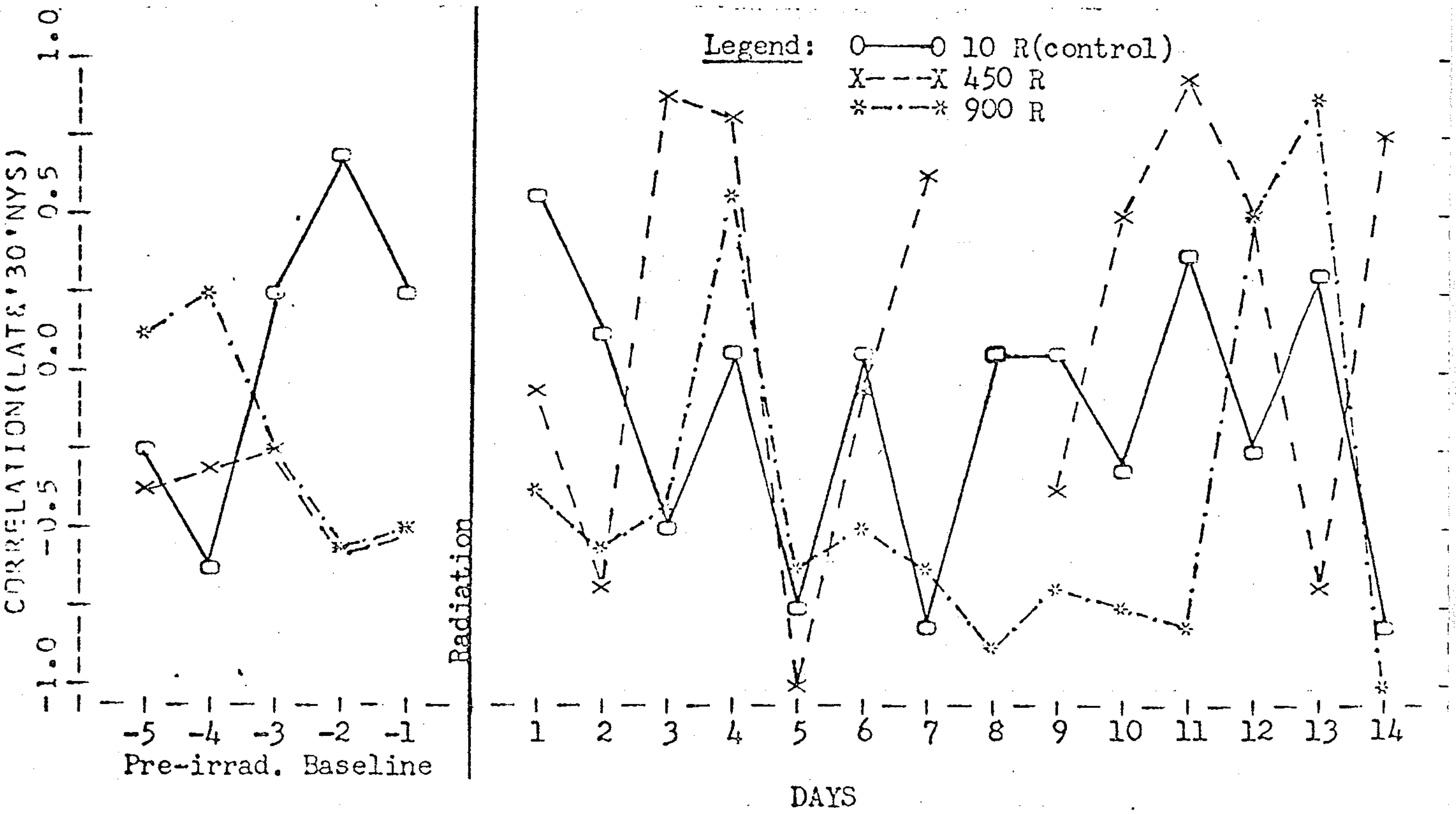

Figure 12. Correlation between Δ mean response latency for the medium tilt rate and the Δ mean duration of the 30rpm postrotational nystagmus.

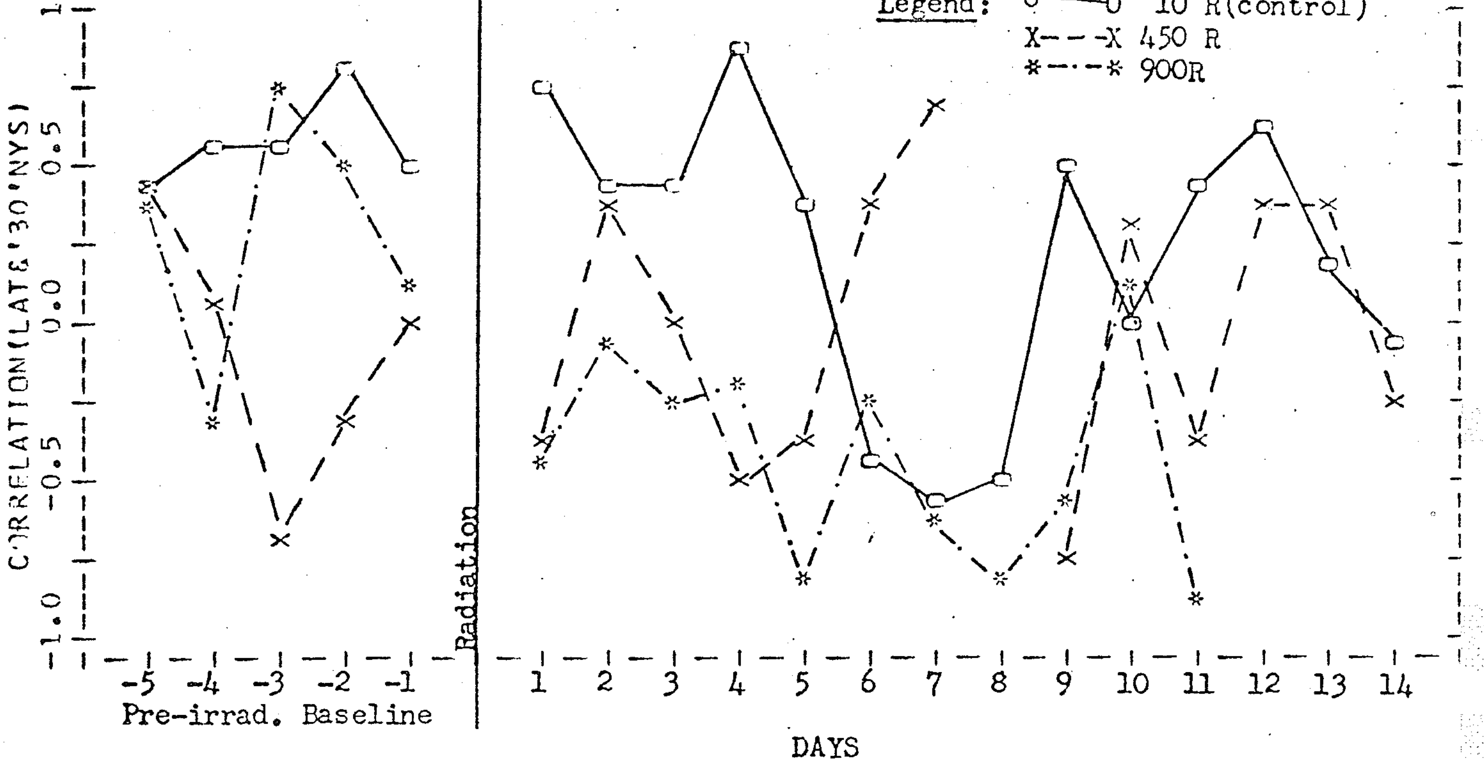

Figure 13. Correlation between Δ mean response latency for the slow tilt rate and the Δ mean duration of the 30 rpm postational nystagmus.

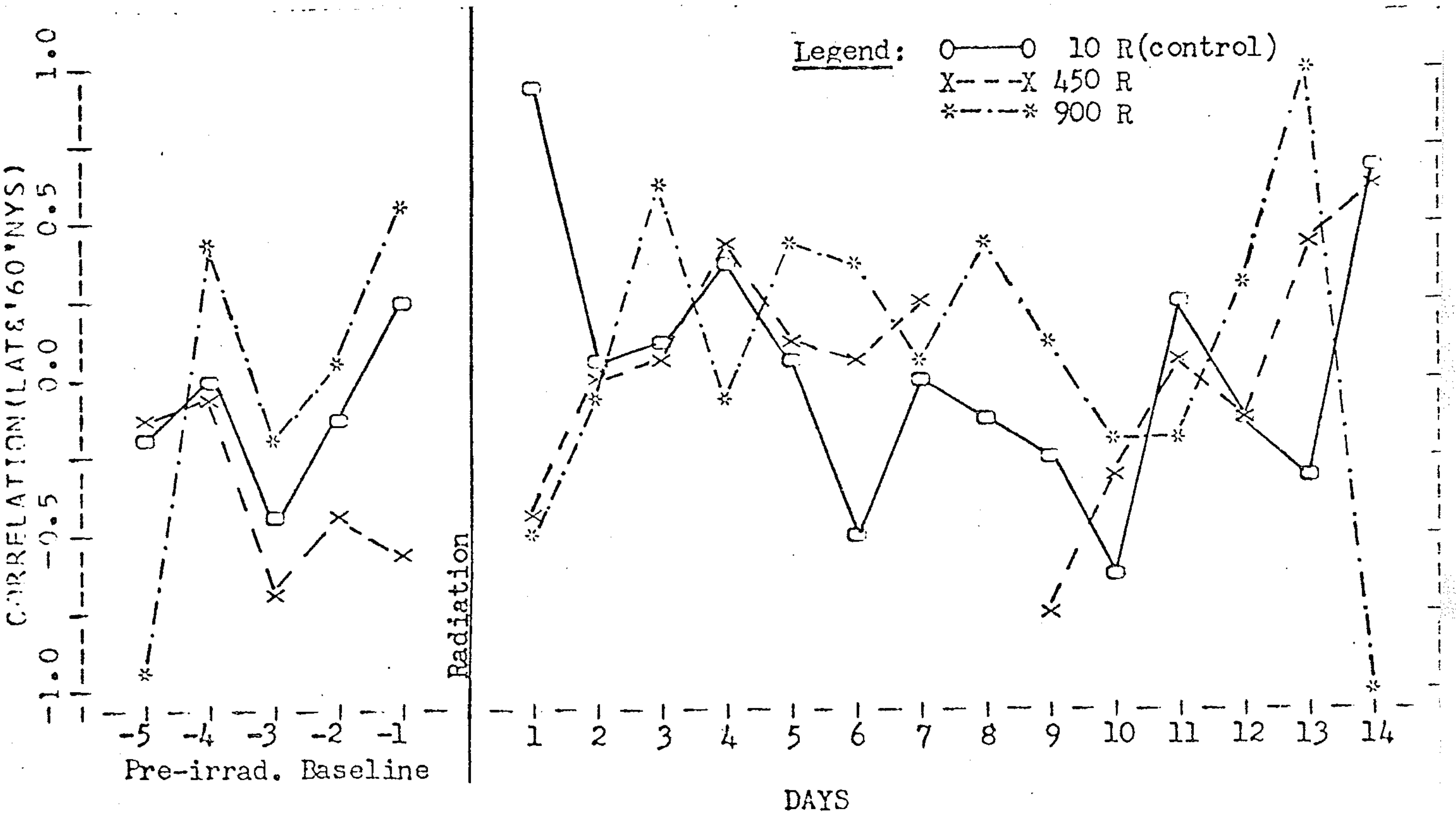

Figure 14. Correlation between Δ mean response latency for the fast tilt rate and the Δ mean duration of the 60rpm postrotational nystagmus.

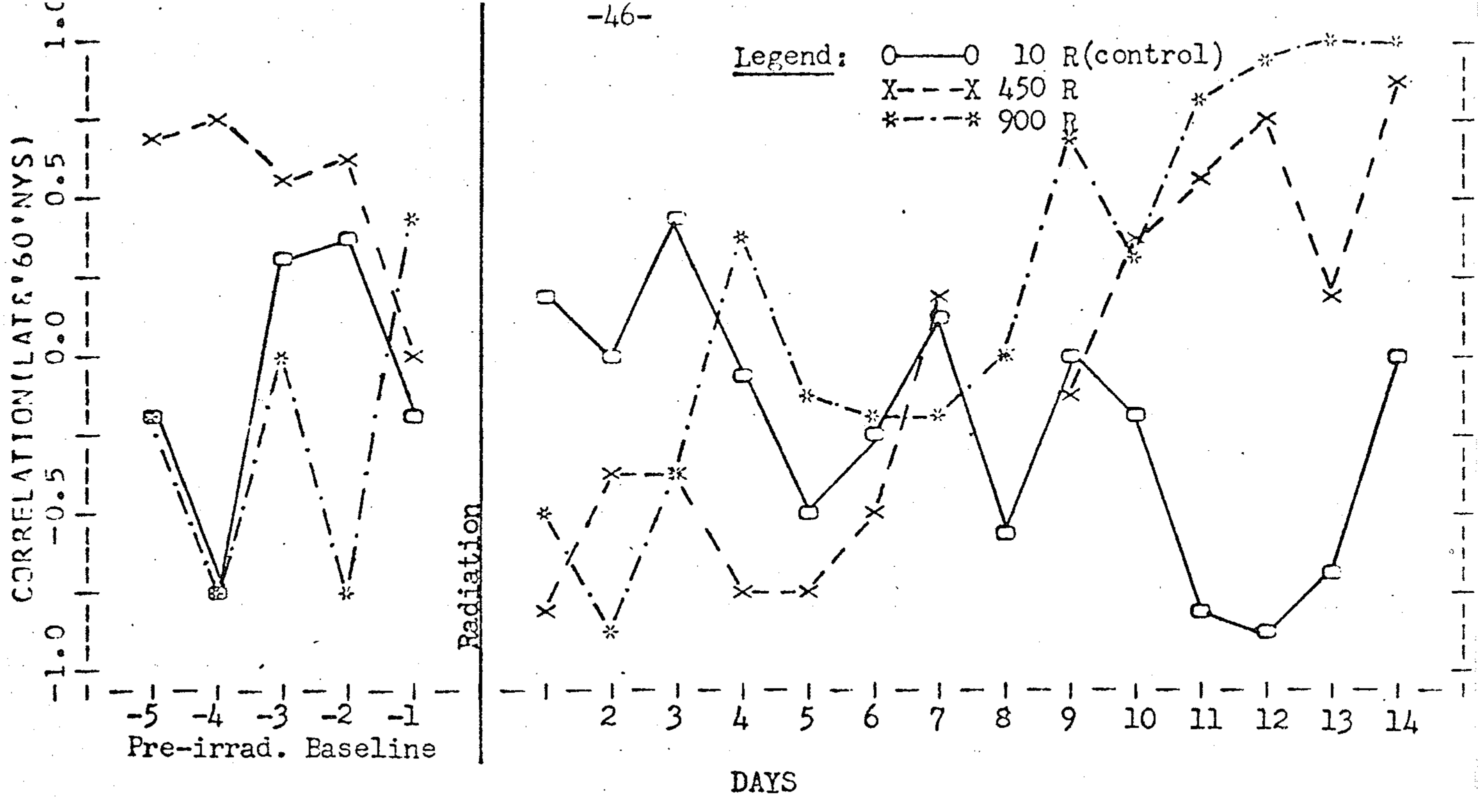

Figure 15. Correlation between Δ mean response latency for the medium tilt rate and the Δ mean duration of the 60rpm postrotational nystagmus.

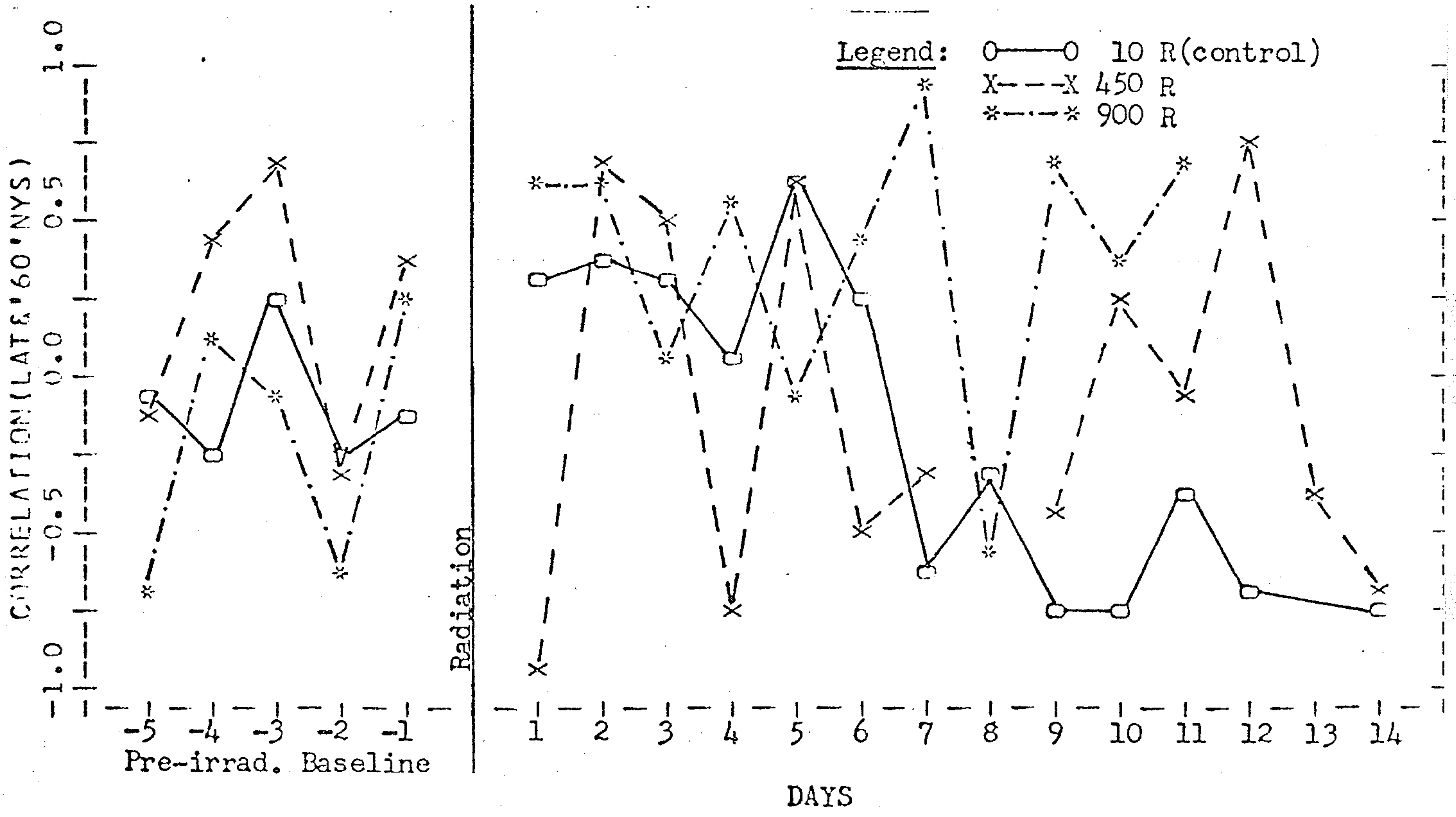

Figure 16. Correlation between Δ mean response latency for the slow tilt rate and the Δ mean duration of the 60 rpm postrotational nystagmus.

TABLE 2

Analysis of Variance: Total Number of Lever Presses per Session Data (expressed as % of pre-irrad. baseline) for the First 7 Days Post-irradiation

Source	DF	SS	MS	F
Tilt-cycle frequency(T)	2	756.31	378.15	0.25
Radiation dose(R)	2	22220.45	11110.22	7.35**
T x R	4	3839.08	959.77	0.64
Error 1	36	54416.62	1511.57	
Day(D)	6	8527.41	1421.24	3.33**
T x D	12	3721.70	310.14	0.73
R x D	12	13272.74	1106.06	2.59**
T x R x D	24	9977.32	415.72	0.98
Error 2	216	92134.31	426.55	
Total	314	208860.06		

** $p < .01$

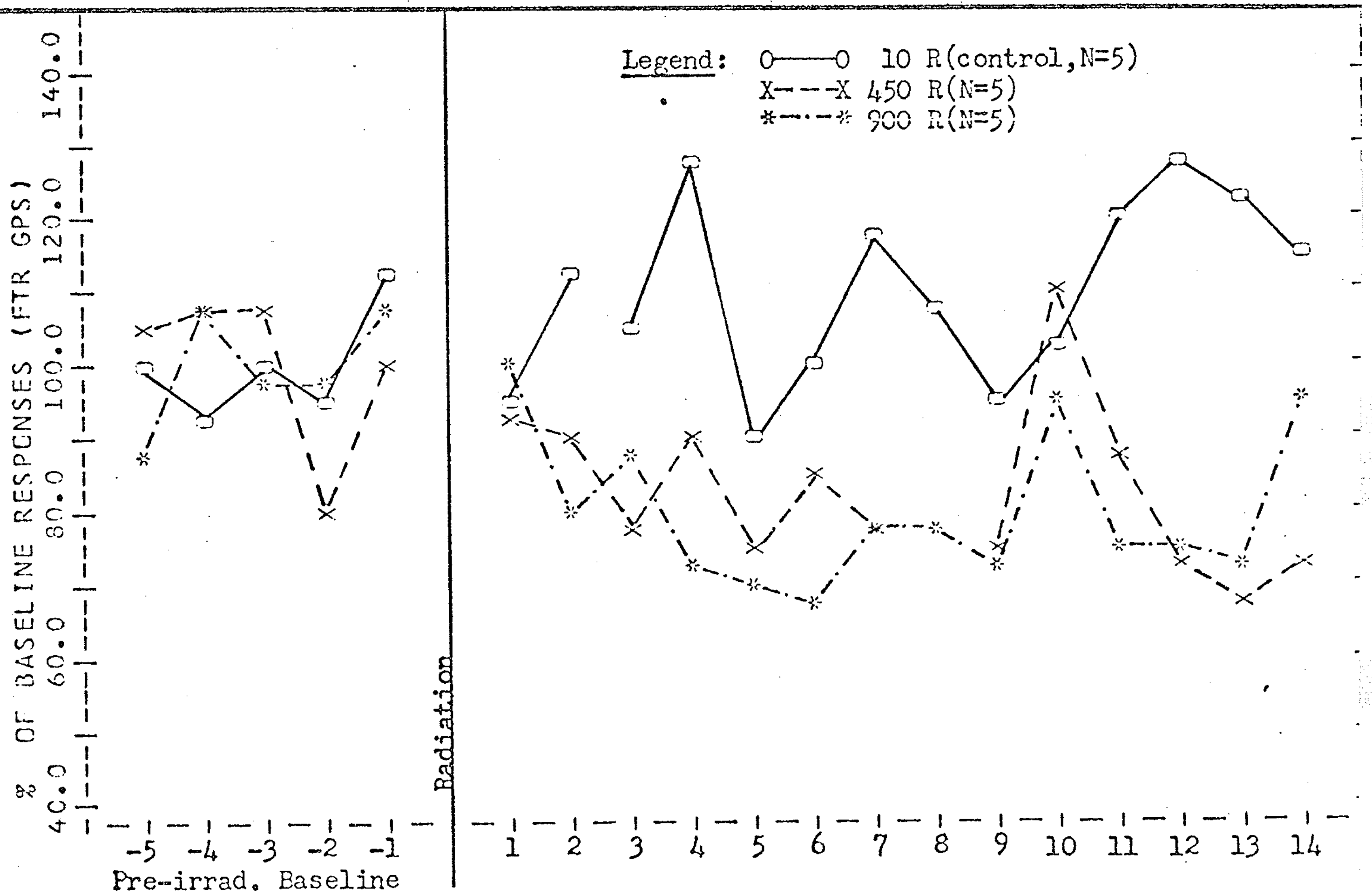

Figure 17. Day to day changes in the total number of lever pressing responses per session for the fast tilt rate (FTR) as a function of radiation dose. Measures are expressed as a % of pre-irradiation baseline.

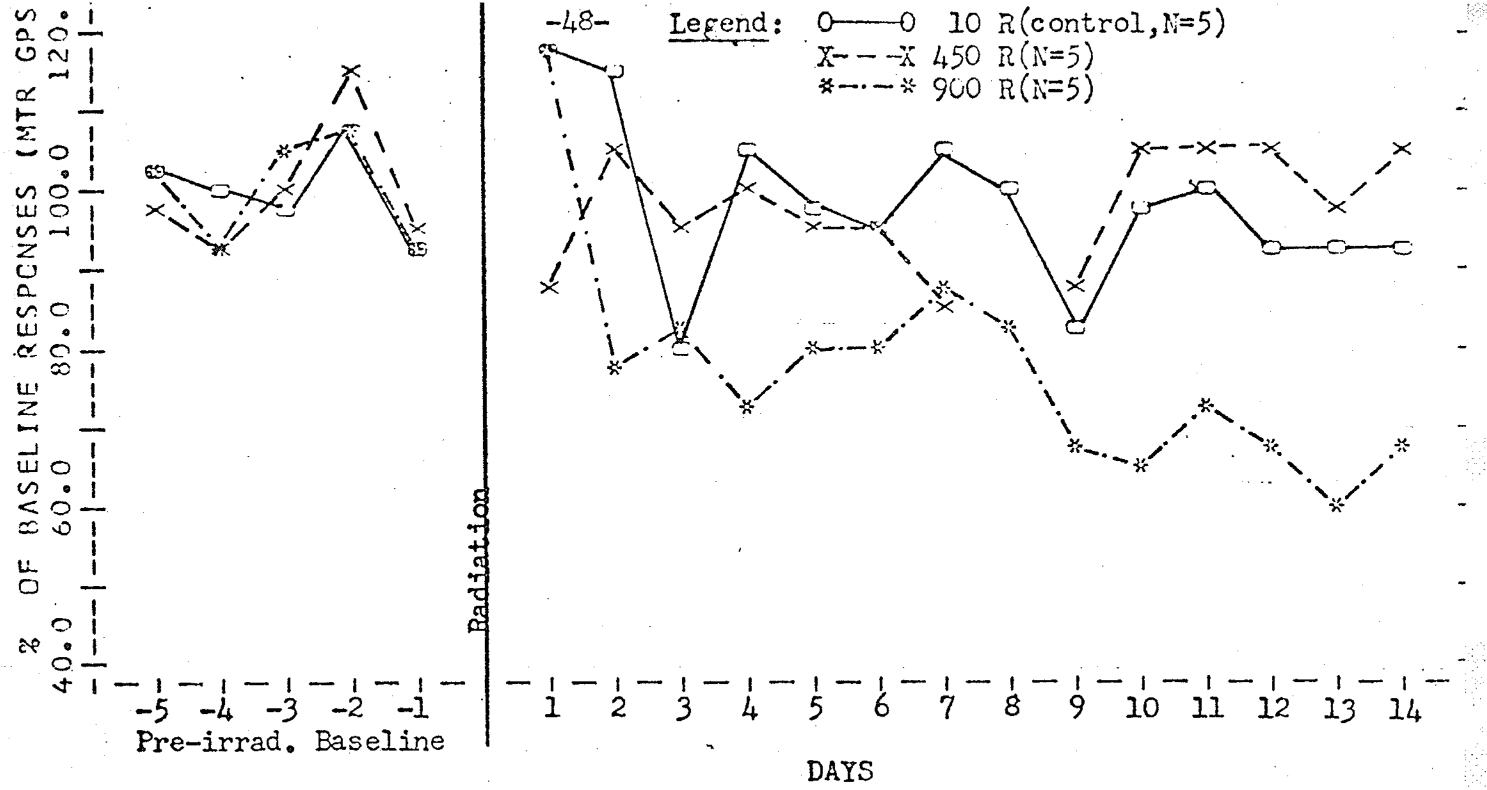

Figure 18. Day to day changes in the total number of lever pressing responses per session for the medium tilt rate (MTR) as a function of radiation dose. Measures are expressed as a % of pre-irradiation baseline.

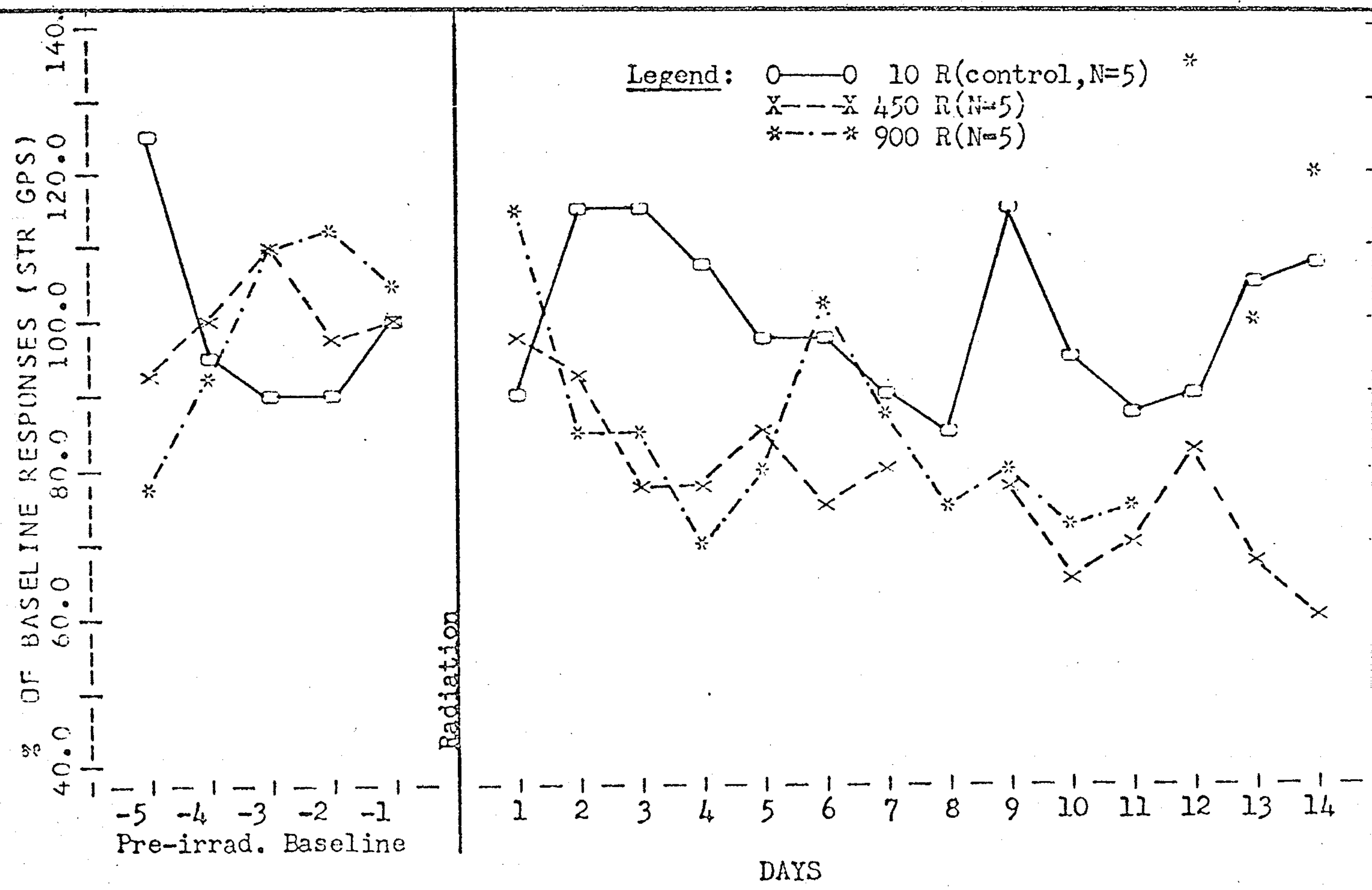

Figure 19. Day to day changes in the total number of lever pressing responses per session for the slow tilt rate (STR) as a function of radiation dose. Measures are expressed as a % of pre-irradiation baseline.

		DAY						
		1	2	3	4	5	6	7
Radiation Dose	10 rads	101%	114%	100%	113%	95%	98%	104%
	450 rads	93%	95%	83%	89%	85%	85%	81%
	900 rads	111%	82%	85%	72%	77%	83%	84%

Decreases in total lever pressing responses after radiation were not dependent on the tilt-cycle frequency. Day to day changes in the total number of responses per session (expressed as a % of pre-irradiation baseline) are presented in figures 17, 18 and 19 for the fast, medium and slow tilt rates respectively. Decreases in lever pressing began 2-3 days post-irradiation for the 900 rad groups and continued throughout the 14 day test period. Although decreases were observed on some days for the 450 rad *S*s, these changes were not consistent.

The total duration of lever holding per session was also calculated as a % of the pre-irradiation baseline. An analysis of variance for this data is presented in Table 3. A significant Radiation dose effect was found ($p < .01$). Tilt-cycle frequency and Day variables were not significant. Day to day changes in this reponse measure are presented in figures 20, 21 and 22 for the fast, medium, and slow tilt rates respectively. For the 900 rad groups, increases in lever holding began 1-2 days post-irradiation and continued at a high level for the remainder of the 14 day test period, although this initial increase began to subside for the 900 rad fast and medium tilt rates. For the 450 rad groups, there was an increase in lever holding on day 2 after the first 450 rad dose followed by a return to baseline. After the second 450 rad dose, there was a much larger sustained increase in the duration of lever holding per session.

The average duration of a single lever press for each session (Total duration of lever holding/total number of lever presses) was calculated as a % of pre-irradiation baseline. An analysis of variance for this data for the first 7 days post-irradiation is presented in Table 4. Again a significant Radiation dose effect was found ($p < .01$). Increases in the average duration of a lever press were not found to depend on the tilt-cycle frequency or the days after radiation. Day to day changes in this measure are presented in Figures 23, 24 and 25 for the fast, medium and slow tilt rates respectively. Results were substantially the same as those for the total duration of lever holding. However, this asserts the fact that the total duration of lever holding increase cannot be attributed to increased responding.

TABLE 3

Analysis of Variance: Total Duration of Lever Holding Data (expressed as % of pre-irrad. baseline) for the First 7 Days Post-irradiation

Source	DF	SS	MS	F
Tilt-cycle frequency (T)	2	31753.12	15876.56	0.33
Radiation dose (R)	2	771939.06	385969.50	8.04**
T x R	4	96459.68	24114.92	0.50
Error 1	36	1728448.00	48012.44	
Day (D)	6	87386.56	14564.42	1.53
T x D	12	57237.50	4769.78	0.50
R x D	12	76615.31	6384.60	0.67
T x R x D	24	164919.50	6871.64	0.72
Error 2	216	2056133.00	9519.13	
Total	314	5070844.00		

** $p < .01$

TABLE 4

Analysis of Variance: Average Duration of a Lever Press Data (expressed as % of pre-irrad. baseline) for the First 7 Days Post-irradiation

Source	DF	SS	MS	F
Tilt-cycle frequency (T)	2	68520.56	34260.28	0.44
Radiation dose (R)	2	1362024.00	681012.00	8.81**
T x R	4	213735.38	53433.84	0.69
Error 1	36	2782722.00	77297.81	
Day (D)	6	81490.88	13581.81	1.06
T x D	12	67258.81	5604.90	0.44
R x D	12	151307.56	12608.96	0.99
T x R x D	24	224249.50	9343.73	0.73
Error 2	216	2765284.00	12802.24	
Total	314	7716549.00		

** $p < .01$

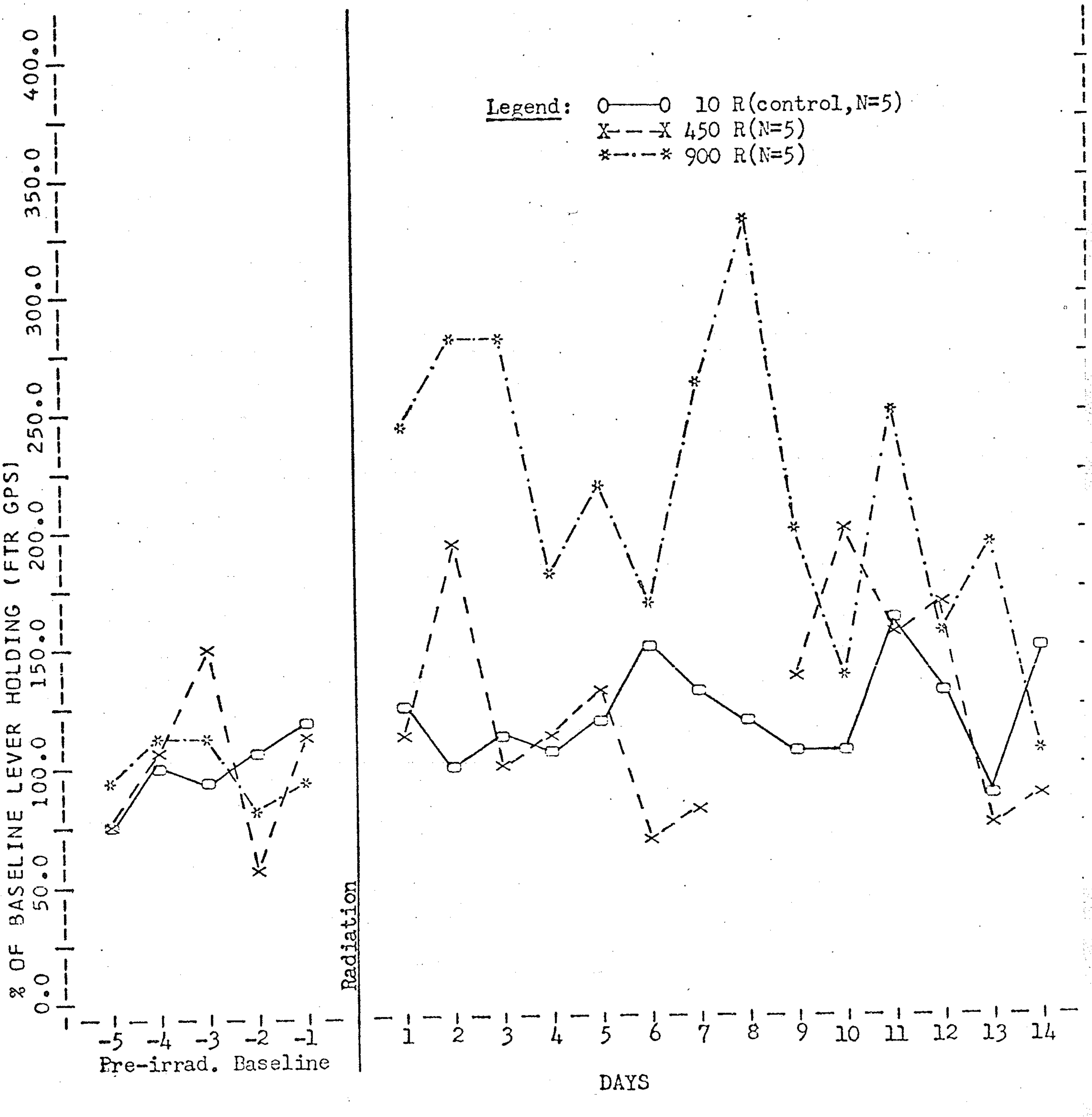

Figure 20. Day to day changes in tot l duration of lever holding per session for the fast tilt rate (FTR) as a function of radiation dose. Measures are expressed as a % of pre-irradiation baseline.

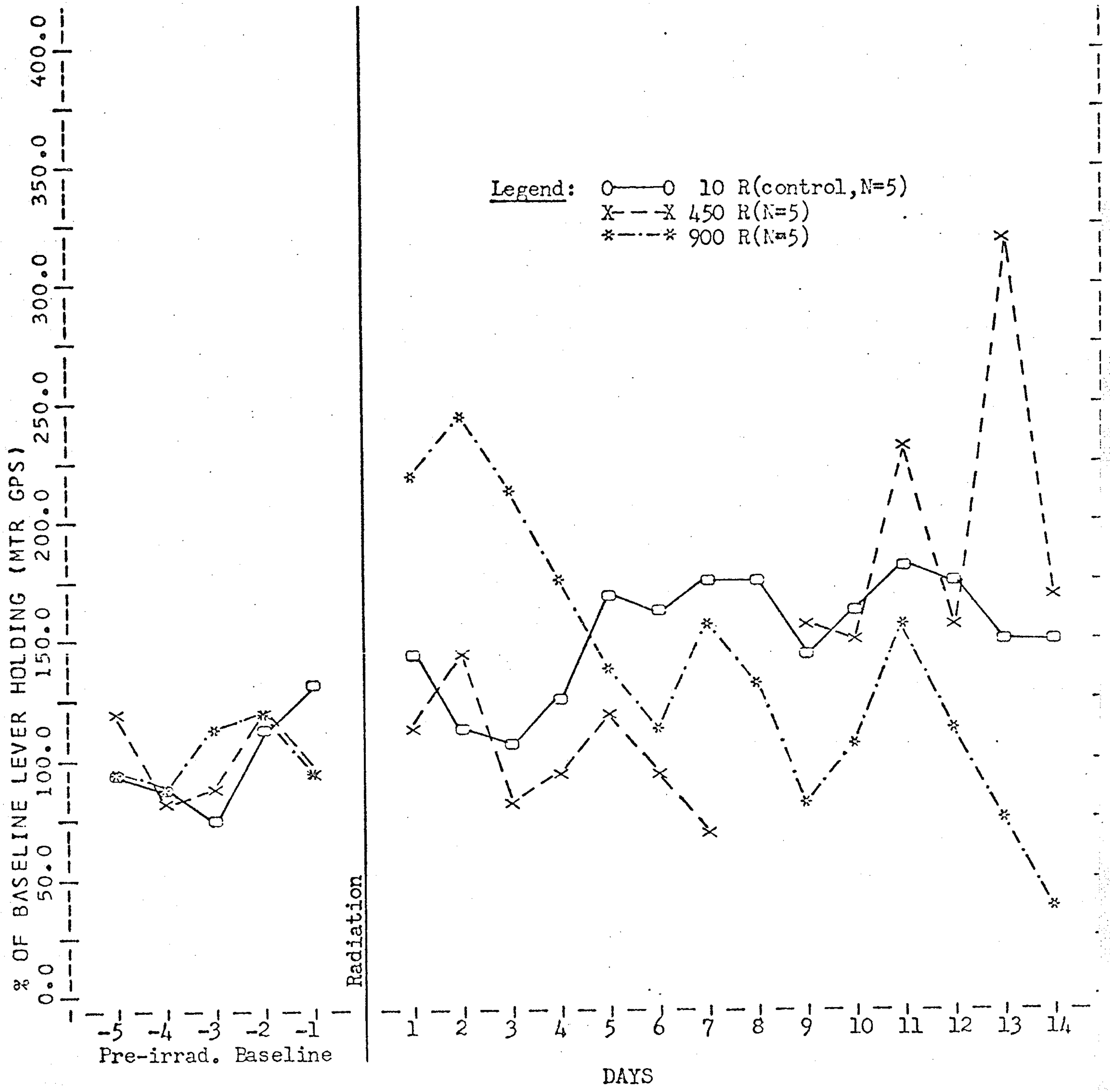

Figure 21. Day to day changes in the total duration of lever holding per session for the medium tilt rate (MTR) as a function of radiation dose. Measures are expressed as a % of pre-irradiation baseline.

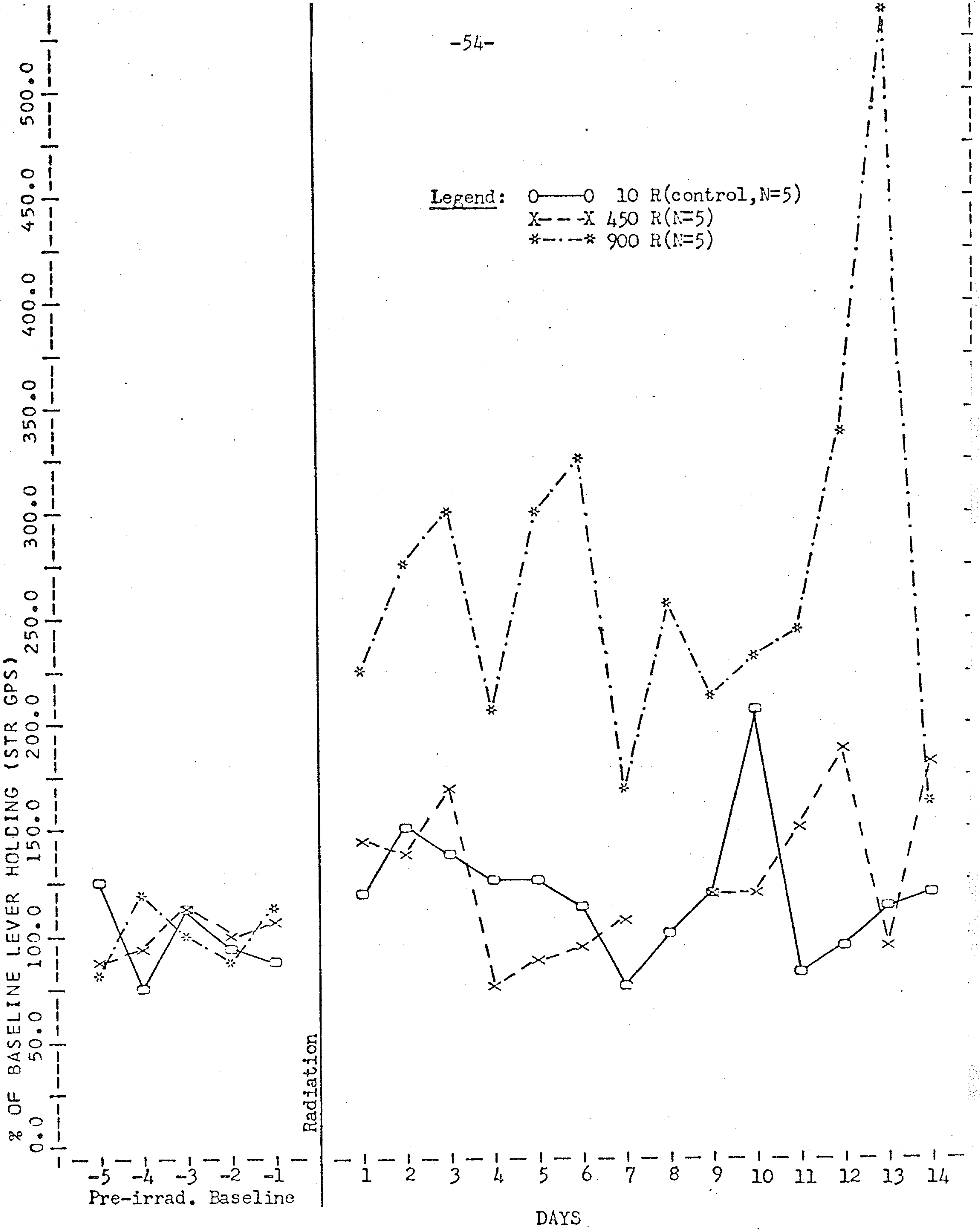

Figure 22. Day to day changes in the total duration of lever holding per session for the slow tilt rate (STR) as a function of radiation dose. Measures are expressed as a % of pre-irradiation baseline.

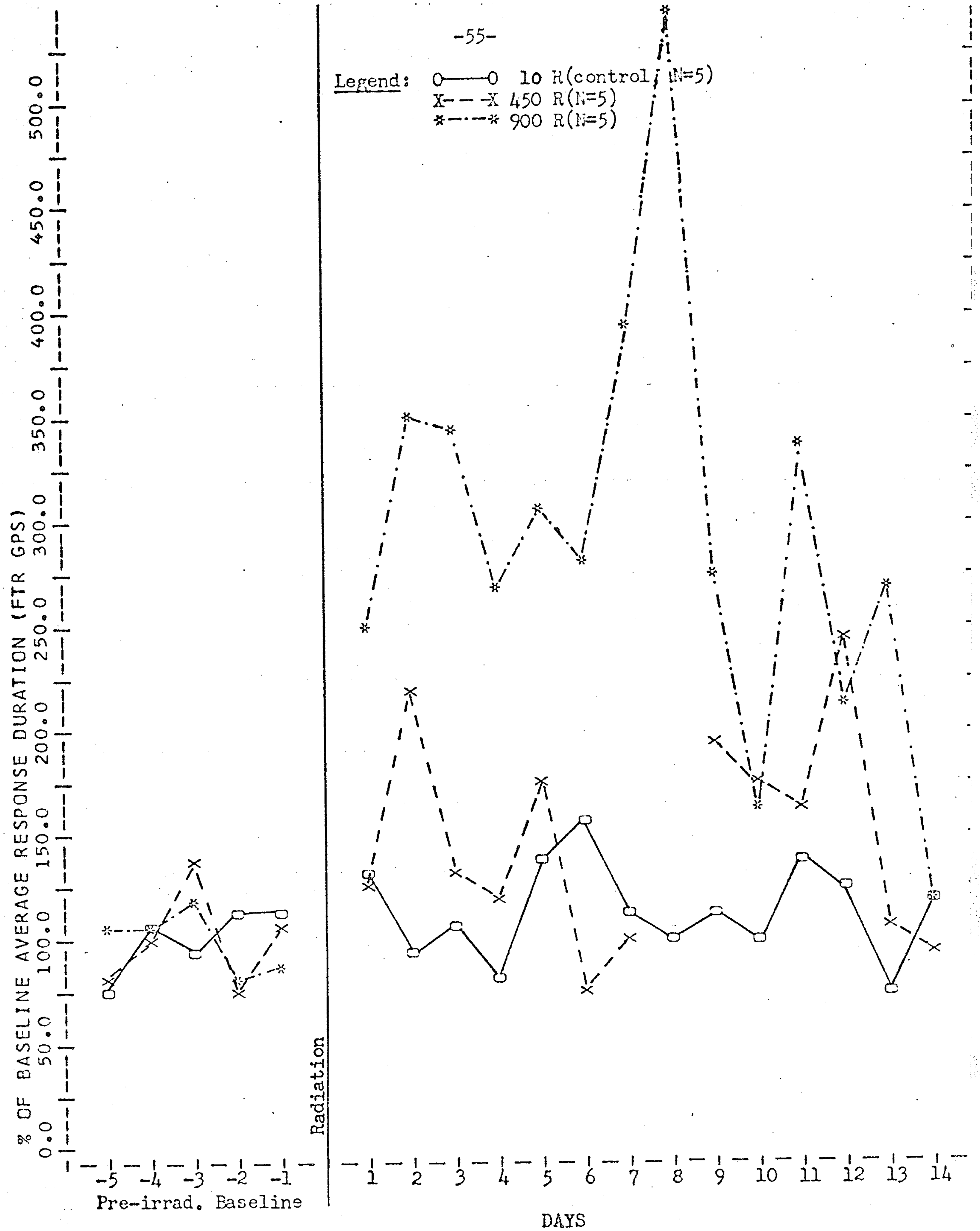

Figure 23. Day to day changes in the average response duration per session for the fast tilt rate (FTR) as a function of radiation dose. Measures are expressed as a % of pre-irradiation baseline.

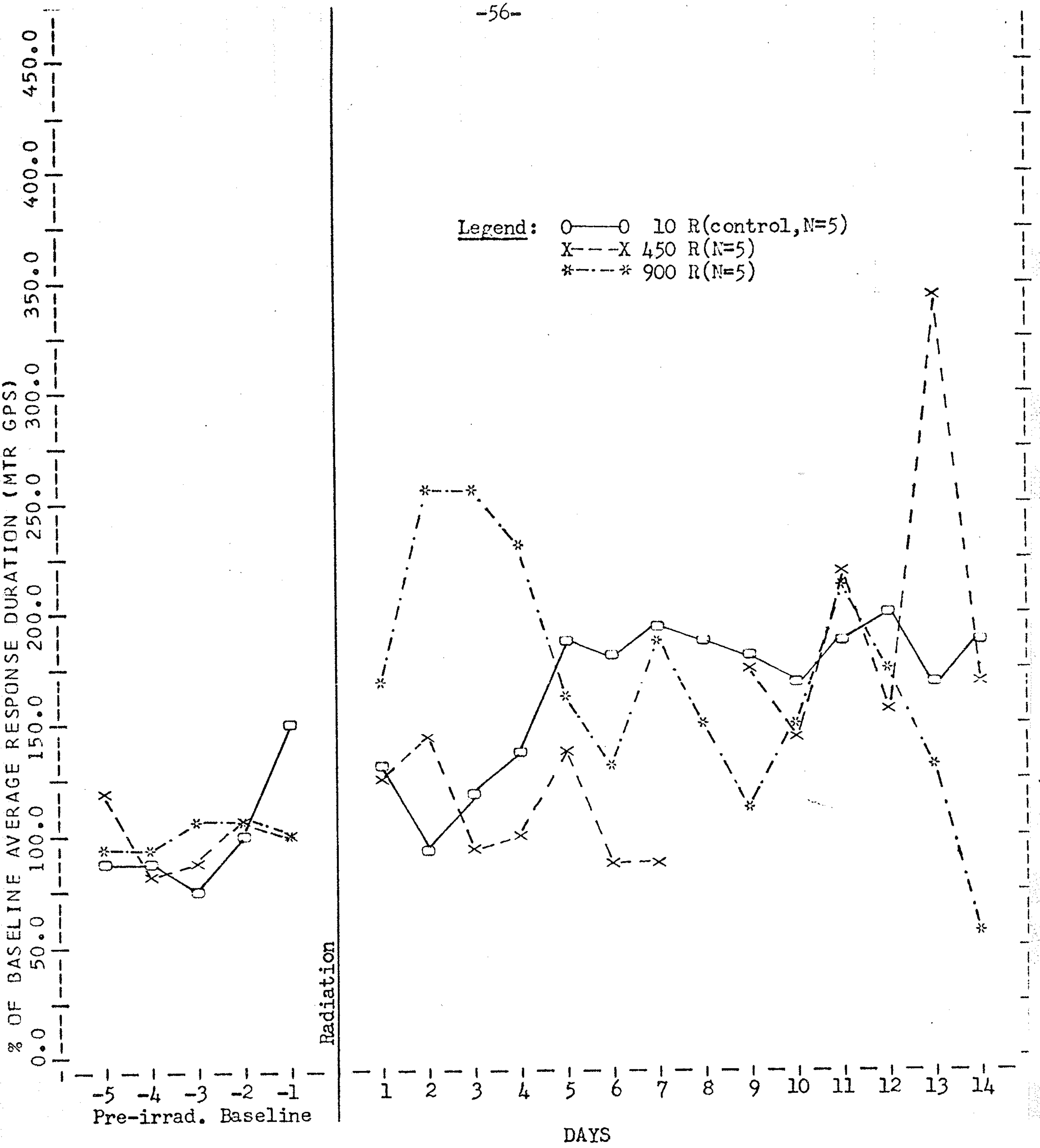

Figure 24. Day to day changes in the average response duration per session for the medium tilt rate (MTR) as a function of radiation dose. Measures are expressed as a % of pre-irradiation baseline.

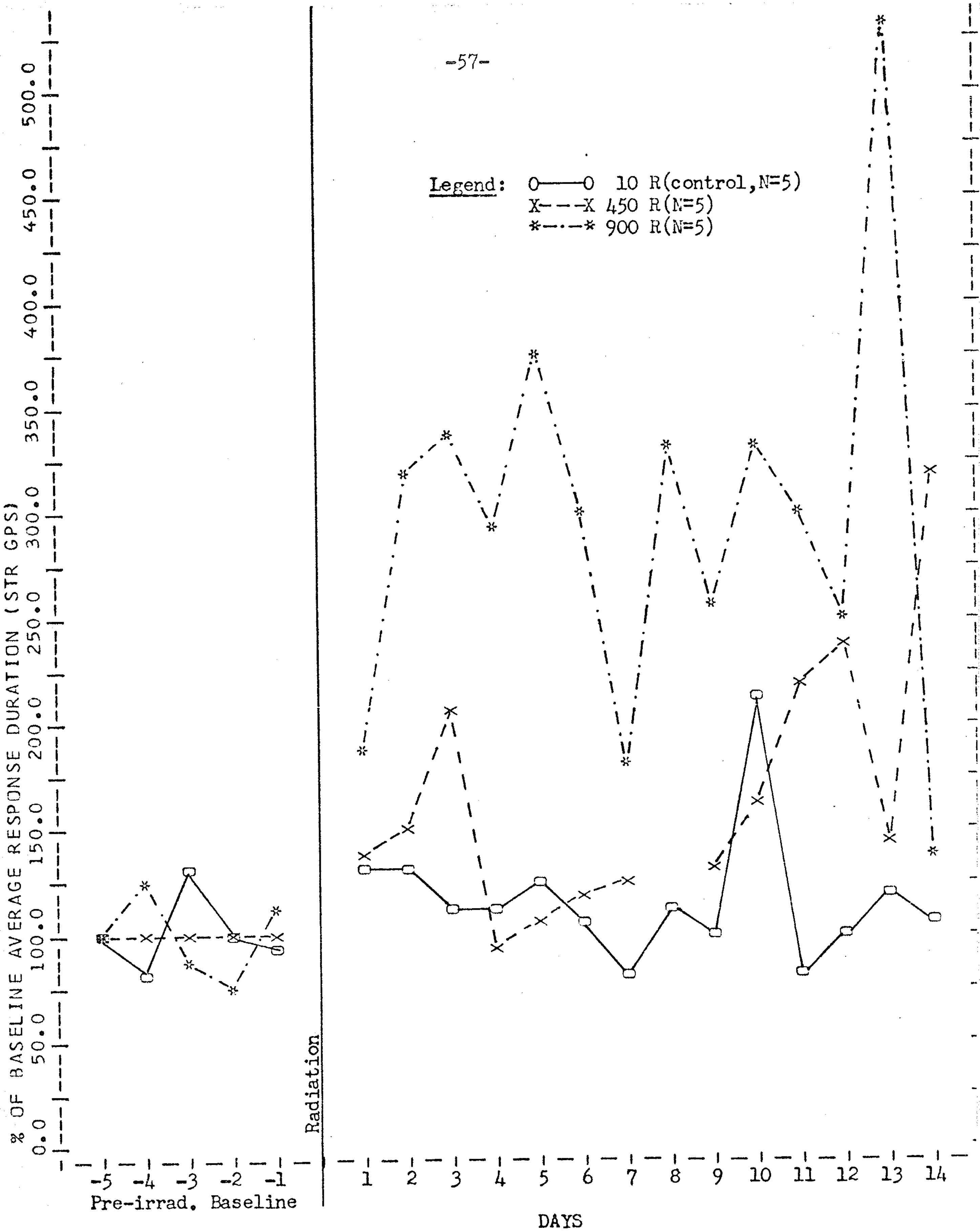

Figure 25. Day to day changes in the average response duration per session for the slow tilt rate (STR) as a function of radiation dose. Measures are expressed as a % of pre-irradiation baseline.

CHAPTER VI

DISCUSSION AND CONCLUSION:

The conditioned vestibular escape behaviour (CVE) in the tilt-box was much more radiosensitive than the nystagmus unconditioned vestibular response (UCVR). The increases in response latency found in this study are consistant with those found in avoidance-escape paradigms using electric shock as the negative reinforcer or unconditioned stimulus(US) (Yarullin, 1959; Belonski, 1959; and Meshchersky, 1958), despite the fact that the US in the CVE problem is not "painful". The changes in response latency occurred during the period of acute radiation sickness and also later during the hematopoetic disturbances(second post-irradiation week). However, these changes in response latency, depending as they do on the tilt-cycle frequency, cannot be attributed wholly to changes general activity, physical strength, or other non-specific debility present during this period

Dependence of the radiation increase of CVE latency on the tilt-cycle frequency can be interpreted in terms of effective negative reinforcement. On the fast tilt rate, the vestibular negative reinforcement may have been so intense as to be able to maintain responding at a near baseline level despite radiation effects. The behaviour on the slow tilt rate, in which the aversive stimulus may be near the threshold for maintenance of CVE, is much more susceptible to radiation disturbance. Thus the degree to which radiation affects this conditioned vestibular response may be largely dependent on the aversive level of the vestibular stimulus.

Gastro-intestinal effects after radiation often result in lowered food consumption and weight loss. However, since the CVE behaviour was not maintained by food reinforcement, such changes should have had minimal effects on this behaviour. Behavioural changes also occurred in cases where there was little or no weight loss. It might be argued that a decrease in food consumption might have caused the S to become so weak that he was not able to perform the required lever pressing response adequately. It should be noted, however, that the Ss on the fast tilt rate had the strength to continue to respond at a near baseline level even though they received the same radiation dose as Ss on the slow tilt rate that exhibited large increases in response latency.

A similar argument can be used to discount a general motor deficit from radiation as the cause of increased response latency. The fast tilt rate tilts the Ss more rapidly than the slow tilt rate and it would appear that that more motor coordination would be required to respond in the fast tilt rate condition. Yet, little decrement occurred for these animals. Thus it seems very unlikely that the increased response latency on the slow tilt rate was due to a motor deficit. This same argument can be used to discount a decrease in general activity as the cause of increased response latency. If the decrease in general activity that often results after radiation is producing longer response latencies, then it should produce longer response latencies equally on all tilt rates, not just the slow tilt rate.

The nystagmus response was affected very little by the radiation doses employed. This is not consistant with either Petelina (1957) who found decreases after radiation or Moskovskaya (1959) who found increases.

However, Petelina used cats and had found cyclic increases and decreases. Moskovskaya used human subjects undergoing radiation therapy and so doses were fractional, and times between radiation and testing also varied. The method of obtaining postrotational nystagmus in this study was somewhat crude due to the equipment available. A light that had to be turned on to record nystagmus duration (instead of total darkness all the time), and a restrainer in which the rat could turn its head somewhat would result in shorter and more variable postrotational nystagmus durations than if darkness and a well fixed head position were used throughout (Guedry, 1965). However, to compensate to some extent, a pre-irradiation nystagmus baseline was established using the above method, and post-irradiation measures were assessed in relation to this. Deviations from this baseline were small. Since the nystagmus response is complete at the midbrain and cerebellar levels, it would seem that a lack of change in this response would indicate that little functional radiation impairment of neural processes had occurred at these levels. Thus, the changes in CVE behaviour are probably due to radiation effects on "higher" vestibular circuits. Besides the well-known cerebellar circuits, a cortical projection area for vestibular sensation has recently been found in the monkey (Schwarz and Fredrickson, 1971). If such an area is also available in the rat, radiation may be affecting a cortical link of the conditioned response. Since the CVE response is maintained by primarily vestibular stimuli, then depressed function of the cortical projection cells that receive this stimulus input may result in changes in the behaviour maintained by it. Analagously, deficits in visual acuity performance after radiation of the posterior association areas of the brain (McDowell and Brown, 1960d), and deficits in avoidance conditioned responses using a visual conditioned stimulus and an electric shock unconditioned stimulus after irradiation of the visual cortex (Meshchersky, 1958) have been found.

Decreases in the number of responses per session was a general effect independent of the tilt-cycle frequency and dependent only on the radiation dose level. Decreases in responding have been found for shock escape using an auditory CS (Belonsky, 1959), for Sidman avoidance (Jarrard, 1963), for discriminated avoidance-escape (Brown, Blodgett, Henderson, Ritter, Pizzuto, 1966), and various positively reinforced (food or water) responses (Brown, 1956; Brown, Overall, Logie, and Wicker, 1960; Jarrard, 1963; and Wicker and Brown, 1965).

The increase in lever holding appears sooner than the other effects i.e. the first day after radiation. This perseveration in lever holding continued despite the fact that holding the lever down did not prevent the occurrence of the next trial. Response perseveration after radiation has been found in other tasks not involving vestibular stimulation (McDowell and Brown, 1965b; 1965c; and 1965d).

The 2-phase effect in the response latency changes for the 900 Rad Ss , i.e..an initial increase in response latency (days 2-5) followed by a partial return to baseline and then a second increase in response latency (after day9) are probably best explained by the accompanying post-irradiation stages. The first effect occurrs primarily during the stage of acute radiation sickness while the second effect occurs at the start of the stage of hematopoetic disturbances due to irradiation.

This study tested the effects of a control, a sublethal, and near lethal doses (10 rads, 450 rads and 900 rads respectively) of Co^{60} gamma irradiation on conditioned and unconditioned vestibular responses. Although the unconditioned vestibular response is essentially unaffected and damage to the vestibular apparatus thus does not seem apparent at the dose levels employed, the conditioned vestibular response is readily affected, even at the 450 rad level, especially at the low stimulus intensity values. In conclusion, it can be stated that the conditioned vestibular escape response is much more radiosensitive than the unconditioned vestibular nystagmus response. The dependence of the radiation effects on the intensity of the vestibular negative reinforcing stimulus that maintains the conditioned vestibular escape behaviour implies that the changes in the conditioned vestibular escape latency are not primarily due to non-specific factors such as a decrease in general activity, decreased physical strength, or other motor deficits. The lack of change in the unconditioned nystagmus response which is complete at the midbrain level also implies that "higher" vestibular circuits (possibly cortical projection areas or other cortical centers involved in the conditioned vestibular response) are the ones primarily affected.

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APPENDIX A

Daily session data for the individual S for the 5 pre-irradiation baseline days and the 14 post-irradiation days for the following response measures:

a) Mean and standard deviation (S.D.) of the response latency over the 20 trial session (sec.).

b) Total number of responses per session.

c) Total duration of lever holding per session (sec.).

d) Mean duration of the postrotational nystagmus for the 2 trials at 30rpm and the 2 trials at 60rpm.(sec.).

SUBJECT # 1 TILT CYCLE FREQUENCY .33cps (fast) RADIATION DOSE 10 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	6.1	3.3	31	42.6	5.1	7.4
Baseline	7.1	4.0	25	43.9	5.2	7.9
Baseline	5.7	3.4	29	24.6	4.8	7.6
Baseline	4.8	2.3	29	56.8	4.8	6.8
Baseline	5.2	2.3	35	66.5	5.0	6.8
Radiation	single exposure of 10 R					
1	6.3	4.2	32	66.6	4.9	7.2
2	6.7	4.8	33	44.5	5.0	7.4
3	4.0	1.7	33	43.5	5.0	7.5
4	6.1	3.1	42	48.2	4.5	7.3
5	5.9	5.4	31	80.6	4.6	6.6
6	5.5	4.1	33	29.5	4.5	6.8
7	7.4	5.6	32	39.5	4.3	7.0
8	5.1	2.8	37	57.0	4.4	6.2
9	7.2	4.6	28	24.7	4.8	7.4
10	5.3	2.6	20	19.5	4.6	6.8
11	5.5	5.0	33	56.8	4.6	6.5
12	6.6	2.7	34	83.5	4.4	7.1
13	6.4	4.3	43	41.1	4.7	7.3
14	6.9	4.4	23	32.3	4.6	7.4

SUBJECT # 2 TILT CYCLE FREQUENCY .33cps (fast) RADIATION DOSE 10 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	6.0	7.5	44	148.1	3.6	7.2
Baseline	6.9	4.9	36	115.8	3.9	7.6
Baseline	7.0	4.3	45	263.5	4.3	7.0
Baseline	6.9	4.1	32	191.9	4.0	7.5
Baseline	7.0	5.9	35	159.4	3.9	7.2
Radiation	single exposure of 10 R					
1	5.2	2.6	33	196.1	3.4	6.8
2	6.0	3.7	51	150.7	3.9	7.1
3	6.5	6.4	40	243.5	4.0	7.1
4	5.3	3.2	51	130.8	4.4	7.1
5	7.1	3.6	30	170.1	3.8	7.4
6	8.3	6.8	33	242.1	4.3	7.0
7	6.0	5.4	34	137.3	4.2	7.1
8	5.6	4.0	36	57.2	4.1	7.6
9	5.5	4.1	37	63.8	4.1	7.7
10	7.0	4.1	43	98.7	3.6	6.6
11	7.5	4.9	46	111.6	4.1	6.9
12	6.1	3.6	36	139.5	4.0	7.3
13	8.9	6.0	46	89.3	3.8	7.0
14	5.9	3.1	33	103.9	3.9	6.9

SUBJECT # 3 TILT CYCLE FREQUENCY .33cps (fast) RADIATION DOSE 10 R

DAY	LATENCY(sec.)		TOTAL RESPONSES	DURATION(sec.) of LEVER HOLDING	NYSTAGMUS	
	MEAN	S.D.			30rpm	60rpm
Baseline	8.1	5.5	43	120.8	4.2	7.0
Baseline	5.6	8.1	43	133.0	4.8	6.9
Baseline	5.9	4.1	35	401.8	3.9	7.4
Baseline	4.3	3.7	41	451.0	4.0	7.4
Baseline	4.6	2.9	69	347.1	4.4	6.7
Radiation	single exposure of 10 R					
1	4.7	3.4	45	346.3	4.3	6.9
2	8.0	7.7	35	335.7	4.1	6.9
3	6.3	4.3	47	361.1	4.2	7.5
4	4.1	2.4	48	294.4	4.1	7.0
5	4.6	2.3	35	433.5	4.7	6.8
6	5.4	3.7	53	195.1	4.2	7.2
7	6.0	3.8	80	351.1	5.0	7.1
8	6.1	4.5	56	607.2	3.9	6.5
9	4.2	2.0	33	584.0	4.6	8.1
10	4.7	4.0	62	492.3	4.4	8.3
11	5.2	5.3	51	662.4	4.5	7.5
12	3.4	1.7	82	524.4	4.0	6.9
13	8.8	9.9	44	320.0	4.4	7.8
14	6.5	6.2	49	459.9	4.2	6.6

SUBJECT # 4 TILT CYCLE FREQUENCY .33cps (fast) RADIATION DOSE 10 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	6.5	3.9	27	16.0	4.4	7.0
Baseline	6.5	3.9	27	113.0	3.6	6.2
Baseline	4.1	2.2	34	83.7	4.5	7.8
Baseline	7.7	5.4	27	51.3	4.4	7.0
Baseline	4.9	2.1	30	57.4	4.7	7.5
Radiation	single exposure of 10 R					
1	7.8	5.9	25	81.7	4.3	7.1
2	4.6	2.3	49	80.0	4.0	7.2
3	4.4	3.0	33	38.8	4.4	7.2
4	4.5	2.3	38	48.2	4.2	6.9
5	7.0	3.9	32	21.2	4.2	6.7
6	4.4	2.7	27	48.9	4.6	7.2
7	5.0	7.4	29	127.9	4.4	6.9
8	6.7	3.6	23	30.0	4.6	6.9
9	4.3	2.7	28	41.4	4.6	6.9
10	4.3	2.7	29	47.8	4.7	8.0
11	6.4	4.0	30	131.5	4.8	8.3
12	5.6	4.4	34	46.5	4.5	6.5
13	4.5	2.7	34	40.6	4.7	8.0
14	9.1	7.8	43	157.8	4.3	7.7

SUBJECT # 5 TILT CYCLE FREQUENCY .33cps (fast) RADIATION DOSE 10 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	6.5	3.3	30	48.3	5.1	7.7
Baseline	6.7	8.5	30	30.4	5.2	7.3
Baseline	5.3	2.4	34	35.0	4.9	7.3
Baseline	5.3	2.3	34	24.8	4.8	7.5
Baseline	8.9	7.1	29	55.6	4.6	7.5
Radiation	single exposure 10 R					
1	8.1	6.3	31	43.1	5.1	7.6
2	7.7	6.1	23	20.5	4.6	8.0
3	7.5	4.8	27	46.3	4.7	7.5
4	6.3	5.0	38	61.5	4.9	7.2
5	6.9	3.3	26	54.8	5.1	7.5
6	6.5	5.6	30	152.4	4.4	7.3
7	8.3	8.4	35	44.9	4.6	7.4
8	6.3	4.7	37	69.5	4.6	7.6
9	5.9	3.9	34	58.0	4.8	7.7
10	7.3	4.9	31	67.2	4.5	7.5
11	5.4	4.1	47	64.2	4.8	7.3
12	6.3	3.5	40	55.7	4.4	7.4
13	7.5	5.9	41	45.6	4.4	7.2
14	4.7	3.6	50	59.5	5.0	7.4

SUBJECT # 6 TILT CYCLE FREQUENCY .33cps (fast) RADIATION DOSE 2X450 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	7.2	3.5	32	54.5	4.8	8.4
Baseline	7.9	4.2	39	126.7	5.6	8.3
Baseline	8.0	5.3	39	136.7	5.2	8.2
Baseline	8.1	5.5	25	93.6	5.2	7.8
Baseline	4.9	2.8	42	217.4	5.2	8.0
Radiation	first exposure of 450 R					
1	10.1	6.0	29	94.2	5.2	8.1
2	9,2	4.6	30	225.2	4.9	8.0
3	7.5	2.7	25	135.9	5.3	8.4
4	8.2	4.0	29	136.0	5.1	7.5
5	6.6	1.7	30	109.0	4.6	6.8
6	6.8	2.8	35	155.0	5.1	7.5
7	7.4	4.1	37	187.4	4.6	7.4
8	second radiation exposure of 450 R					
9	8.8	5.7	33	204.5	4.3	6.9
10	8.8	5.5	35	334.1	5.4	7.1
11	10.7	9.8	33	204.7	4.6	7.1
12	9.4	6.5	24	697.9	5.3	7.0
13	----------	----------	----------	----------	----------	----------
14				Died		

SUBJECT # 7 TILT CYCLE FREQUENCY .33cps (fast) RADIATION DOSE 2x450 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	13.1	8.3	26	109.2	4.0	7.0
Baseline	9.5	5.5	36	175.5	4.0	6.5
Baseline	12.1	20.1	32	192.3	3.9	6.9
Baseline	10.6	5.0	30	94.6	3.9	6.7
Baseline	6.7	2.9	32	111.4	4.3	6.8
Radiation	first exposure of 450 R					
1	7.5	6.9	39	138.9	4.4	7.3
2	10.0	5.3	34	67.5	4.1	6.9
3	10.6	10.1	26	82.3	4.3	6.7
4	6.6	4.1	35	77.1	4.0	6.4
5	7.8	6.1	25	91.8	4.3	6.8
6	9.3	10.9	30	90.5	3.8	6.6
7	7.5	5.4	28	72.4	4.0	6.3
8	second radiation exposure of 450 R					
9	7.8	8.4	26	118.3	4.2	7.1
10	5.3	2.8	48	234.5	3.2	6.6
11	10.4	7.8	31	134.7	4.3	7.0
12	7.7	4.0	33	112.3	4.1	6.4
13	7.5	2.8	26	54.9	4.4	6.1
14	11.1	6.3	28	108.2	4.1	7.3

SUBJECT # 8 TILT CYCLE FREQUENCY .33cps (fast) RADIATION DOSE 2x450 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	4.4	2.7	75	54.3	4.5	6.6
Baseline	4.6	2.4	55	37.5	3.8	6.1
Baseline	4.0	1.5	54	90.0	3.8	6.5
Baseline	4.0	1.4	35	37.7	3.6	6.1
Baseline	5.3	4.3	51	93.8	3.8	6.2
Radiation	first exposure of 450 R					
1	6.5	2.6	33	68.8	3.8	5.8
2	4.6	1.9	44	243.0	3.8	5.8
3	6.7	3.9	43	55.1	3.8	6.3
4	5.9	2.6	53	129.4	3.9	6.2
5	4.3	1.3	34	156.9	3.7	6.0
6	4.9	2.0	44	32.0	4.0	6.2
7	3.7	2.0	27	45.8	3.8	6.5
8	second radiation exposure of 450 R					
9	4.4	2.7	32	191.0	3.7	6.2
10	5.0	2.5	32	67.4	3.8	6.4
11	8.5	3.3	21	21.8	4.4	6.8
12	5.4	2.4	21	20.5	4.0	7.1
13	7.7	5.6	21	25.5	3.8	6.1
14	21.8	18.9	20	11.1	4.8	8.1

SUBJECT # 9 TILT CYCLE FREQUENCY .33cps (fast) RADIATION DOSE 2X450 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	5.1	3.3	40	45.2	4.9	8.0
Baseline	3.1	1.6	37	53.5	4.4	8.2
Baseline	6.6	5.2	31	96.5	4.9	8.1
Baseline	6.6	3.4	23	34.2	4.6	7.5
Baseline	5.1	1.8	35	75.0	4.3	7.8
Radiation	first exposure of 450 R					
1	5.7	2.0	40	118.3	5.3	8.8
2	4.3	2.0	26	55.1	5.0	7.7
3	5.6	3.8	26	85.4	4.5	7.7
4	6.9	5.8	25	52.4	4.4	7.9
5	5.3	3.4	29	98.8	4.4	7.7
6	5.3	4.4	27	48.7	4.5	7.8
7	4.8	4.9	23	47.6	4.5	8.4
8	second exposure of 450 R					
9	5.1	3.7	20	32.8	4.2	7.5
10	5.3	2.2	21	26.5	3.9	7.8
11	4.5	2.5	25	98.2	4.1	7.1
12	5.9	1.8	24	49.6	4.3	7.5
13	6.9	3.2	26	87.4	4.3	8.0
14	12.3	12.2	35	137.8	4.3	7.4

SUBJECT # 10   TILT CYCLE FREQUENCY .33 cps (fast)   RADIATION DOSE 2x450 R

DAY	LATENCY(sec.)		TOTAL RESPONSES	DURATION(sec.) of LEVER HOLDING	NYSTAGMUS	
	MEAN	S.D.			30rpm	60rpm
Baseline	4.1	2.7	34	108.6	3.9	7.1
Baseline	4.2	3.4	33	207.4	4.3	6.8
Baseline	3.7	2.6	48	293.0	4.4	7.2
Baseline	4.7	3.7	35	48.5	4.2	6.8
Baseline	4.1	2.0	27	46.2	4.3	6.3
Radiation	first exposure of 450 R					
1	3.6	1.4	28	139.7	4.3	6.9
2	4.3	2.7	36	375.5	4.4	7.0
3	4.0	1.8	28	158.8	4.0	7.0
4	5.2	2.4	28	105.2	3.7	7.2
5	5.6	3.8	23	112.3	4.7	7.1
6	5.0	3.0	24	45.1	4.2	6.4
7	3.7	1.6	28	63.0	4.1	7.1
8	second exposure of 450 R					
9	3.8	2.4	30	128.5	4.2	7.3
10	3.0	2.2	58	559.3	4.2	7.0
11	3.6	2.5	45	441.1	4.1	6.9
12	4.3	1.8	29	151.7	4.0	6.6
13	4.6	1.6	26	120.7	4.3	7.5
14	6.4	6.9	22	46.9	4.4	7.4

SUBJECT # 11 TILT CYCLE FREQUENCY .33cps (fast) RADIATION DOSE 900 R

DAY	LATENCY(sec.) MEAN	S.D.	TOTAL RESPONSES	DURATION(sec.) of LEVER HOLDING	NYSTAGMUS 30rpm	60rpm
Baseline	3.8	2.0	27	113.2	5.0	9.0
Baseline	4.3	2.1	35	56.7	5.3	9.4
Baseline	4.7	2.8	32	64.2	6.4	10.1
Baseline	3.6	1.8	25	36.0	5.2	8.4
Baseline	3.8	1.4	27	51.2	5.0	9.1
Radiation	single exposure of 900 R					
1	3.4	1.9	28	218.1	5.9	10.1
2	4.5	2.0	31	115.2	5.4	8.8
3	3.9	2.1	54	277.6	5.8	8.4
4	5.2	3.1	23	42.4	5.1	8.2
5	8.6	5.0	28	186.9	5.6	8.3
6	4.0	3.4	25	67.8	5.5	7.9
7	4.4	2.9	24	33.6	5.0	8.4
8	4.5	3.9	26	34.8	5.1	8.3
9	4.3	2.5	24	71.4	5.3	8.1
10	4.5	3.5	33	40.1	5.2	8.3
11	5.5	3.1	22	26.1	5.5	8.4
12	7.7	4.2	23	112.1	5.5	8.5
13						
14			Died			

SUBJECT # 12 TILT CYCLE FREQUENCY .33cps (fast) RADIATION DOSE 900 R

DAY	LATENCY(sec.)		TOTAL RESPONSES	DURATION(sec.) of LEVER HOLDING	NYSTAGMUS	
	MEAN	S.D.			30rpm	60rpm
Baseline	6.5	5.3	48	155.5	3.6	6.7
Baseline	5.1	2.9	66	210.8	4.0	6.5
Baseline	6.8	4.4	53	191.1	3.9	7.5
Baseline	5.2	2.6	52	151.9	3.7	6.7
Baseline	5.8	2.2	40	107.2	3.4	6.6
Radiation	single exposure of 900R					
1	6.3	3.3	35	123.6	3.6	6.0
2	5.6	2.6	23	168.2	3.8	7.5
3	10.8	11.6	24	178.1	3.7	7.0
4	6.5	4.1	24	89.4	3.9	6.9
5	9.5	7.5	24	114.1	3.5	6.0
6	11.4	8.3	22	233.8	3.3	6.6
7	7.8	4.8	25	114.1	3.8	6.8
8	8.1	6.5	29	333.4	3.9	6.5
9	7.8	3.5	22	119.6	3.4	7.1
10						
11						
12			Died			
13						
14						

SUBJECT # 13 **TILT CYCLE FREQUENCY** .33cps (fast) **RADIATION DOSE** 900 R

DAY	LATENCY(sec.) MEAN	LATENCY(sec.) S.D.	TOTAL RESPONSES	DURATION(sec.) of LEVER HOLDING	NYSTAGMUS 30rpm	NYSTAGMUS 60rpm
Baseline	17.5	13.2	24	208.6	3.9	6.3
Baseline	12.1	5.5	38	226.6	4.2	5.5
Baseline	10.2	6.9	25	184.6	4.6	7.9
Baseline	15.6	7.2	23	127.5	4.5	6.7
Baseline	16.1	9.3	31	272.4	3.7	7.3
Radiation	single exposure of 900 R					
1	11.2	9.4	35	498.2	4.0	8.1
2	10.8	7.6	27	395.3	4.6	7.2
3	18.3	9.9	24	470.3	4.0	8.8
4	12.2	9.7	31	336,5	5.2	7.1
5	37.3	63.8	26	477.1	5.0	8.2
6	17.6	6.4	21	283.1	4.8	8.0
7	47.1	79.7	27	489.6	4.4	7.3
8	16.6	12.6	28	199.6	4.4	8.1
9	21.1	32.8	29	352.2	4.5	7.4
10	33.7	36.2	34	377.3	4.7	7.5
11	23.1	20.6	24	425.6	3.5	5.9
12	11.1	7.4	30	353.6	4.4	6.0
13	11.7	5.3	25	390.6	4.1	5.6
14	22.7	9.6	31	119.5	3.4	6.0

SUBJECT # 14 TILT CYCLE FREQUENCY .33cps (fast) RADIATION DOSE 900 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	5.2	3.7	31	65.7	3.9	7.4
Baseline	3.5	1.6	31	309.0	4.2	7.6
Baseline	3.6	1.5	30	220.3	4.6	7.1
Baseline	3.2	0.9	29	45.0	4.2	7.2
Baseline	3.9	2.4	59	123.8	4.8	7.2
Radiation	single exposure of 900 R					
1	5.6	3.6	50	350.4	4.4	7.9
2	4.2	2.1	30	790.0	4.6	7.6
3	7.6	4.5	22	536.5	4.6	9.6
4	6.4	4.5	25	275.4	4.7	8.2
5	5.0	2.8	21	282.3	4.2	8.2
6	3.9	1.7	27	145.4	4.6	7.9
7	3.8	2.5	37	154.1	4.1	7.9
8	3.7	2.4	30	450.4	4.0	8.3
9	5.3	4.7	21	155.1	4.1	8.7
10	4.0	2.3	27	112.5	4.7	11.9
11	6.3	3.2	25	25.6	5.3	10.1
12	9.0	6.3	20	199.0	4.6	11.0
13	13.5	8.8	20	302.1	5.2	12.4
14	8.2	6.8	29	238.1	4.9	11.3

SUBJECT # 15 TILT CYCLE FREQUENCY .33 cps (fast) RADIATION DOSE 900R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	3.9	2.7	43	37.7	4.7	7.5
Baseline	6.6	5.3	39	26.2	4.5	6.8
Baseline	3.5	3.1	54	74.9	4.6	6.7
Baseline	4.1	2.8	76	110.5	4.8	7.5
Baseline	4.3	2.2	51	67.8	4.5	7.7
Radiation	single exposure of 900 R					
1	6.1	4.9	41	210.1	4.5	7.6
2	5.9	5.4	39	262.7	4.4	7.9
3	7.8	5.1	34	178.6	5.0	7.7
4	6.4	4.2	33	284.4	4.6	6.7
5	7.2	4.9	31	196.4	4.9	8.1
6	9.7	8.7	30	222.8	4.4	8.0
7	3.9	2.9	33	545.2	4.4	8.6
8	8.7	8.0	29	627.8	5.1	8.6
9	11.9	8.9	41	347.7	4.3	7.1
10	8.0	6.1	35	141.9	4.3	7.5
11	11.7	9.4	39	463.1	4.5	8.9
12	16.7	12.0	31	87.0	4.6	7.6
13						
14			Died			

SUBJECT # 16 TILT CYCLE FREQUENCY .20cps (medium) RADIATION DOSE 10 R

DAY	LATENCY(sec.) MEAN	LATENCY(sec.) S.D.	TOTAL RESPONSES	DURATION(sec.) of LEVER HOLDING	NYSTAGMUS 30rpm	NYSTAGMUS 60rpm
Baseline	21.9	24.7	23	64.4	5.5	9.3
Baseline	13.5	13.5	26	166.5	5.3	8.6
Baseline	10.8	8.6	30	169.6	4.8	8.1
Baseline	9.0	6.8	35	206.4	4.8	7.9
Baseline	13.7	9.2	30	162.6	4.7	8.4
Radiation	single exposure of 10 R					
1	17.5	10.8	37	230.5	5.3	8.3
2	11.1	10.9	32	208.6	5.6	8.8
3	16.0	18.9	29	143.2	5.0	9.3
4	14.4	22.6	31	145.8	5.4	8.4
5	10.1	8.4	36	131.8	4.3	8.0
6	9.0	7.3	27	176.2	4.8	8.8
7	11.9	8.0	24	157.1	5.7	7.6
8	20.9	21.3	29	126.6	5.0	7.8
9	14.7	17.1	27	109.8	4.5	7.9
10	14.9	20.5	36	160.3	4.9	9.0
11	12.9	11.7	38	137.9	4.6	8.2
12	12.2	9.4	28	106.6	4.8	8.4
13	19.8	31.4	30	111.4	4.9	8.1
14	9.1	12.5	32	98.8	4.6	8.4

SUBJECT # 17 TILT CYCLE FREQUENCY .20cps (medium) RADIATION DOSE 10 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	11.2	7.3	45	141.2	4.1	7.4
Baseline	9.3	9.5	61	118.6	4.5	7.6
Baseline	9.1	5.9	45	58.4	4.3	7.0
Baseline	6.1	3.9	64	236.8	4.2	6.7
Baseline	13.7	7.7	51	91.7	4.2	6.9
Radiation	single exposure of 10 R					
1	12.9	12.2	57	87.0	4.4	7.2
2	16.3	12.8	43	87.3	4.1	7.2
3	7.0	5.8	36	53.3	4.2	6.7
4	8.9	10.6	52	52.7	4.5	7.0
5	10.4	7.5	42	59.5	4.2	7.1
6	12.2	12.2	34	201.6	4.2	7.6
7	8.9	6.8	37	77.8	4.2	7.4
8	10.6	7.4	53	167.2	4.3	7.1
9	15.3	19.2	39	105.9	4.4	7.4
10	13.0	12.6	37	62.3	4.5	7.4
11	11.7	11.2	46	116.8	4.3	6.3
12	8.7	5.4	45	136.7	4.3	6.8
13	12.4	8.6	43	80.9	4.4	7.8
14	14.4	10.9	39	38.8	4.3	7.0

SUBJECT # 18 TILT CYCLE FREQUENCY .20cps (medium) RADIATION DOSE 10 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	13.4	12.6	47	71.5	3.9	6.5
Baseline	23.4	18.1	40	31.1	3.9	6.1
Baseline	20.4	15.6	35	44.1	3.4	6.0
Baseline	30.4	27.8	34	38.8	4.0	6.1
Baseline	19.1	16.6	41	56.2	3.3	6.4
Radiation	single exposure of 10 R					
1	21.1	21.0	29	77.8	3.8	5.9
2	27.9	16.9	36	44.8	3.4	6.6
3	13.0	8.0	34	88.3	3.9	5.9
4	17.4	10.7	31	150.2	3.8	6.4
5	20.7	16.8	33	272.4	3.8	6.8
6	28.4	13.6	28	97.2	3.4	6.2
7	18.9	10.4	31	217.6	3.9	6.3
8	31.3	30.6	32	162.8	3.5	5.9
9	28.8	27.8	30	215.1	3.4	7.2
10	14.6	17.7	37	205.3	3.8	5.6
11	17.8	16.0	30	166.0	3.5	5.9
12	15.3	10.1	30	195.0	4.1	6.0
13	13.1	10.6	35	215.0	4.0	6.1
14	14.0	11.4	30	230.1	3.8	7.2

SUBJECT # 19 TILT CYCLE FREQUENCY .20cps (medium) RADIATION DOSE 10 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	14.9	22.1	53	310.5	4.2	7.6
Baseline	17.9	17.5	44	361.5	4.1	7.3
Baseline	15.3	8.7	39	161.6	4.3	7.4
Baseline	14.7	16.2	48	353.8	4.2	7.7
Baseline	15.1	15.7	27	594.0	4.5	6.9
Radiation	single exposure of 10 R					
1	17.3	17.6	70	344.1	4.4	7.2
2	14.9	16.0	80	648.6	3.8	7.1
3	21.4	18.8	23	46.6	3.7	7.5
4	16.9	9.6	62	196.5	4.5	7.4
5	13.1	8.6	41	307.0	4.1	7.7
6	16.9	23.7	50	330.4	4.5	7.0
7	17.1	14.1	71	316.3	4.0	7.4
8	14.6	13.4	48	264.7	4.0	7.1
9	21.4	22.4	31	92.2	4.0	7.3
10	17.8	23.8	45	280.0	4.2	6.8
11	15.8	12.4	33	315.2	4.5	6.9
12	20.5	21.6	36	284.2	4.3	7.0
13	18.0	16.8	41	99.1	4.0	7.0
14	11.7	8.5	46	93.7	4.2	6.8

SUBJECT # 20 **TILT CYCLE FREQUENCY** .20cps (medium) **RADIATION DOSE** 10 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	4.8	2.8	29	80.2	4.1	7.6
Baseline	3.9	1.5	24	99.4	4.2	7.0
Baseline	3.0	1.4	34	101.1	4.0	6.5
Baseline	3.3	1.5	28	60.5	4.3	6.8
Baseline	4.2	1.7	25	229.9	4.1	7.7
Radiation	single exposure of 10 R					
1	3.6	2.3	32	266.5	3.8	7.1
2	3.8	1.8	27	90.2	4.4	7.7
3	4.5	2.3	27	225.6	4.6	6.4
4	3.7	1.6	28	154.4	4.8	7.5
5	3.7	1.8	30	76.8	3.6	6.1
6	4.0	2.4	37	275.4	4.4	7.1
7	3.2	1.6	35	182.0	4.3	6.0
8	4.1	1.7	30	290.1	3.7	7.4
9	4.9	3.4	26	97.1	4.3	7.3
10	5.5	5.4	25	182.5	3.4	6.7
11	4.2	4.0	35	327.5	3.7	7.4
12	3.3	2.9	32	256.5	4.0	7.1
13						
14			DIED			

SUBJECT # 21   TILT CYCLE FREQUENCY .20cps (medium)   RADIATION DOSE 2x450 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	28.8	30.5	38	412.9	5.7	7.6
Baseline	30.1	27.1	30	429.6	5.3	7.2
Baseline	30.2	42.6	31	461.6	4.8	7.8
Baseline	34.5	37.8	76	1026.4	4.8	8.4
Baseline	37.5	36.2	32	695.8	4.7	8.0
Radiation	first exposure of 450 R					
1	26.2	24.0	35	360.2	5.3	8.0
2	23.1	35.0	45	479.9	5.6	7.4
3	37.4	43.8	37	718.1	5.0	7.0
4	36.3	36.0	36	677.2	5.4	6.3
5	56.1	49.1	37	648.8	4.3	6.3
6	45.5	36.1	39	412.5	5.0	6.5
7	36.4	50.4	33	222.5	4.7	6.7
8	second radiation exposure of 450 R					
9	40.3	46.8	32	696.2	3.8	6.2
10	18.4	13.9	37	650.6	4.7	6.6
11	27.5	39.2	38	880.1	4.4	6.1
12	26.1	29.5	46	1054.0	4.8	6.9
13	31.2	46.4	44	180.0	4.8	7.2
14	10.0	7.6	52	471.2	4.7	6.4

SUBJECT # 22 TILT CYCLE FREQUENCY .20cps (medium) RADIATION DOSE 2x450 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	19.3	13.3	36	88.1	4.5	7.3
Baseline	23.5	20.1	27	33.7	4.7	7.5
Baseline	18.2	23.2	42	67.5	4.4	6.7
Baseline	18.1	16.4	33	63.2	4.0	7.5
Baseline	24.1	19.0	30	60.2	4.6	7.0
Radiation	first exposure of 450 R					
1	17.1	16.6	29	90.1	4.4	7.0
2	33.4	38.4	37	187.3	4.4	6.6
3	31.2	28.1	27	43.3	4.6	6.6
4	13.3	9.9	26	26.0	4.2	7.2
5	18.7	14.9	23	132.5	4.1	6.7
6	22.6	30.3	25	38.0	4.0	7.0
7	21.2	19.3	24	73.8	4.0	7.3
8	second radiation exposure of 450 R					
9	26.2	20.7	25	95.9	3.8	7.5
10	14.0	12.7	30	121.2	4.1	7.4
11	32.2	36.9	33	317.8	4.6	7.7
12	21.3	31.9	30	136.4	4.2	8.2
13	31.2	53.5	32	715.4	4.1	7.4
14	21.5	27.8	35	120.8	4.2	7.3

SUBJECT # 23 TILT CYCLE FREQUENCY .20cps (medium) RADIATION DOSE 2x450 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	9.2	4.6	36	185.3	4.8	8.3
Baseline	6.1	6.6	28	48.3	4.5	8.0
Baseline	8.0	6.2	43	110.8	4.3	8.3
Baseline	5.5	4.2	35	136.1	4.3	8.5
Baseline	7.4	5.7	38	149.3	5.1	8.9
Radiation	first exposure of 450 R					
1	13.6	12.2	27	124.9	4.9	7.5
2	11.2	11.5	32	69.6	4.5	7.8
3	16.4	14.2	30	77.2	4.4	8.0
4	11.6	14.3	48	141.9	5.1	8.0
5	8.2	10.2	32	67.1	4.3	7.6
6	7.6	5.0	40	81.2	5.0	6.9
7	8.3	7.6	33	105.9	4.5	7.8
8	second radiation exposure of 450 R					
9	13.3	12.4	35	153.7	4.6	8.1
10	13.1	20.9	47	154.2	4.8	8.0
11	8.0	6.6	30	87.4	4.3	7.6
12	7.6	11.8	31	186.6	5.0	8.8
13	7.1	4.1	28	168.0	4.7	9.2
14	6.6	3.2	29	186.7	4.7	8.1

SUBJECT # 24 TILT CYCLE FREQUENCY .20cps (medium) RADIATION DOSE 2x450 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	7.4	6.3	28	125.1	4.8	8.1
Baseline	5.7	3.3	38	118.8	4.9	7.9
Baseline	7.3	7.2	29	118.6	4.6	8.6
Baseline	6.4	3.4	29	68.7	4.1	7.9
Baseline	6.9	4.2	35	84.9	4.3	7.8
Radiation	first exposure of 450 R					
1	4.9	1.4	35	136.5	3.9	7.5
2	5.0	2.2	44	192.0	4.6	7.7
3	5.8	3.2	46	57.9	4.0	7.6
4	13.6	12.0	39	101.6	4.7	6.6
5	5.8	3.6	36	78.2	4.3	7.4
6	6.9	7.0	24	48.8	3.8	7.6
7	7.9	12.1	36	82.9	3.6	6.9
8	second exposure of 450 R					
9	5.9	2.3	36	217.5	3.9	7.0
10	5.0	2.1	38	118.5	3.8	7.3
11	7.3	5.1	38	163.3	4.0	9.3
12	5.8	2.1	29	72.8	4.6	9.0
13	6.3	5.1	32	156.0	4.6	8.6
14	7.3	3.1	33	196.0	4.8	8.5

SUBJECT # 25 TILT CYCLE FREQUENCY .20cps (medium) RADIATION DOSE 2x450 R

DAY	LATENCY(sec.)		TOTAL RESPONSES	DURATION(sec.) of LEVER HOLDING	NYSTAGMUS	
	MEAN	S.D.			30rpm	60rpm
Baseline	7.8	4.5	40	233.2	4.4	6.7
Baseline	14.2	15.2	43	267.7	3.9	7.0
Baseline	13.4	10.0	33	114.2	3.7	7.3
Baseline	7.0	8.0	41	314.3	4.0	6.9
Baseline	14.4	16.8	33	125.3	3.4	7.4
Radiation	first exposure of 450 R					
1	14.9	19.3	33	254.0	3.4	6.8
2	15.7	25.5	28	240.0	4.0	6.9
3	10.9	13.2	27	211.9	3.5	6.9
4	15.6	21.5	28	234.7	4.2	6.3
5	12.6	12.1	45	286.2	3.7	7.2
6	10.6	7.8	45	463.9	4.2	7.3
7	17.7	19.7	25	75.3	4.1	7.1
8	second radiation exposure of 450 R					
9	13.0	9.0	31	356.3	4.0	7.2
10	9.7	7.7	38	417.6	3.4	6.9
11	13.4	17.0	52	559.6	3.4	6.4
12	11.1	7.1	57	363.8	3.7	6.7
13	5.3	4.3	41	280.1	4.2	7.0
14	9.6	7.6	40	500.7	3.9	6.4

SUBJECT # 26 **TILT CYCLE FREQUENCY** .20cps (medium) **RADIATION DOSE** 900 R

DAY	LATENCY(sec.) MEAN	 S.D.	TOTAL RESPONSES	DURATION(sec.) of LEVER HOLDING	NYSTAGMUS 30rpm	 60rpm
Baseline	24.2	24.7	36	340.1	5.1	7.2
Baseline	33.8	28.8	43	184.8	4.5	7.6
Baseline	23.5	18.6	49	197.5	5.2	8.4
Baseline	17.6	15.7	49	209.7	5.3	8.4
Baseline	24.9	31.7	28	83.4	5.4	8.7
Radiation	single exposure of 900 R					
1	31.4	34.9	44	184.7	5.6	8.1
2	18.8	20.2	34	111.4	5.6	9.5
3	36.7	31.7	35	189.0	4.6	7.0
4	26.4	36.1	33	62.2	5.3	8.5
5	28.4	29.1	24	73.5	4.9	7.0
6	19.3	20.0	33	157.8	5.0	7.7
7	34.4	66.1	37	69.4	4.1	6.7
8	20.8	17.1	32	80.2	4.8	7.6
9	23.7	29.2	32	81.6	4.9	6.9
10	20.3	23.4	26	85.3	4.7	7.0
11	30.9	33.6	25	97.3	4.6	6.7
12	13.0	8.0	34	140.0	4.9	6.8
13	18.3	16.1	29	162.6	4.8	6.5
14	16.0	9.5	33	79.7	5.2	7.4

SUBJECT # 27 TILT CYCLE FREQUENCY .20cps (medium) RADIATION DOSE 900 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	24.5	21.1	40	100.0	4.9	7.2
Baseline	26.4	51.3	44	145.1	5.3	6.6
Baseline	23.8	22.5	49	101.1	4.9	7.2
Baseline	14.4	9.5	37	157.6	5.2	7.4
Baseline	12.0	10.6	31	260.7	5.4	6.9
Radiation	single exposure of 900 R					
1	12.1	21.3	63	730.8	5.4	7.4
2	10.1	7.2	38	1445.1	5.2	8.2
3	24.0	29.9	41	551.8	5.7	7.7
4	58.0	71.3	34	584.4	5.5	7.9
5	67.1	91.9	44	450.5	4.8	6.9
6	60.0	80.6	43	360.4	4.9	7.2
7	72.1	120.6	36	182.4	4.3	6.8
8	134.2	224.4	37	447.2	4.3	6.5
9	125.5	107.0	28	288.0	4.5	7.1
10	67.8	91.8	27	349.9	4.0	6.9
11	64.1	57.3	41	316.2	4.1	7.7
12	------------	------------	------------	------------	------------	------------
13			Died			
14						

SUBJECT # 28 TILT CYCLE FREQUENCY .20cps (medium) RADIATION DOSE 900 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	12.1	8.8	48	143.1	3.7	6.8
Baseline	7.4	4.6	28	70.8	3.6	6.4
Baseline	9.5	5.6	48	147.0	3.7	6.1
Baseline	8.6	8.1	42	132.2	4.0	6.5
Baseline	8.7	6.1	52	125.3	4.0	6.1
Radiation	single exposure of 900 R					
1	14.6	15.5	59	190.4	4.2	6.2
2	11.3	9.7	30	100.2	3.7	5.9
3	8.9	4.6	31	362.9	3.8	5.8
4	19.1	16.3	26	351.4	3.6	5.7
5	14.3	12.5	33	176.2	3.7	5.8
6	17.4	16.7	35	199.1	4.2	5.9
7	13.6	14.3	36	520.9	3.9	7.2
8	12.9	16.5	40	82.9	3.8	5.6
9	10.0	6.2	33	89.3	3.7	5.6
10	14.0	10.1	31	150.9	4.2	5.9
11	19.5	14.5	30	382.6	4.0	6.0
12	34.3	40.5	21	119.7	4.0	6.1
13						
14			Died			

SUBJECT # 29 TILT CYCLE FREQUENCY .20cps (medium) RADIATION DOSE 900 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	13.1	12.5	61	103.8	4.1	7.4
Baseline	12.3	12.5	62	179.0	3.5	6.8
Baseline	13.8	9.3	39	94.7	4.0	7.2
Baseline	10.1	14.3	85	317.4	3.3	6.5
Baseline	9.9	9.6	66	140.3	3.8	6.8
Radiation	single exposure of 900 R					
1	25.1	24.3	50	167.7	3.1	6.3
2	40.3	39.7	25	65.4	3.6	5.9
3	31.1	36.2	34	239.2	3.7	6.5
4	12.4	10.7	35	93.0	3.8	6.3
5	12.0	13.7	46	109.5	4.0	7.4
6	15.0	15.3	29	83.0	4.0	7.0
7	11.4	8.3	39	184.2	4.2	7.7
8	16.2	11.2	45	224.7	3.8	6.4
9	9.4	11.0	31	43.2	4.3	6.7
10	11.0	11.2	39	59.8	4.4	7.1
11	12.4	8.3	35	118.6	4.3	6.4
12	12.5	9.1	47	296.9	4.1	6.4
13	8.3	6.6	30	121.1	4.4	6.9
14	10.2	10.9	35	55.4	3.5	6.6

SUBJECT # 30 TILT CYCLE FREQUENCY .20cps (medium) RADIATION DOSE 900 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	5.0	4.4	31	61.8	4.9	8.4
Baseline	6.4	4.5	21	84.6	4.7	8.1
Baseline	7.3	6.8	30	227.7	4.4	8.3
Baseline	5.2	4.2	24	79.7	4.1	7.3
Baseline	7.0	4.4	24	66.5	4.6	8.1
Radiation	single exposure of 900 R					
1	5.6	4.2	28	269.0	4.2	7.3
2	6.5	4.9	27	96.0	4.5	8.6
3	9.3	7.3	25	168.8	4.8	8.4
4	10.8	7.0	22	114.7	4.3	9.1
5	11.4	7.3	21	162.5	4.7	9.7
6	5.3	3.1	21	39.3	5.1	10.4
7	7.2	5.5	29	99.5	5.0	7.4
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10			DIED			
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SUBJECT # 31 TILT CYCLE FREQUENCY .14cps (slow) RADIATION DOSE 10 R

DAY	LATENCY(sec.) MEAN	LATENCY(sec.) S.D.	TOTAL RESPONSES	DURATION(sec.) of LEVER HOLDING	NYSTAGMUS 30rpm	NYSTAGMUS 60rpm
Baseline	17.1	20.4	50	83.9	4.7	6.5
Baseline	25.9	25.4	46	107.0	4.7	6.8
Baseline	20.0	18.5	47	38.8	4.4	6.6
Baseline	38.6	56.5	42	76.1	5.1	6.6
Baseline	28.3	26.1	46	119.2	5.2	6.9
Radiation	single exposure of 10 R					
1	29.0	21.9	38	173.6	5.4	7.1
2	21.1	23.2	56	65.2	4.9	6.9
3	39.9	56.9	41	72.5	5.1	7.3
4	35.2	40.2	48	162.0	4.8	7.2
5	18.9	10.0	41	166.6	4.8	6.6
6	18.2	20.0	55	207.7	4.8	6.5
7	28.7	25.3	58	95.0	4.3	7.0
8	32.7	36.8	57	136.6	4.6	6.7
9	21.7	16.9	68	151.0	4.7	6.9
10	36.5	38.3	46	163.1	4.9	6.9
11	34.7	35.7	41	58.4	5.0	6.8
12	28.9	27.7	46	68.1	4.6	6.5
13	26.3	18.0	78	94.0	4.4	6.3
14	21.0	18.8	68	121.4	4.7	6.6

SUBJECT # 32 TILT CYCLE FREQUENCY .14cps (slow) RADIATION DOSE 10 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	15.5	14.1	36	79.2	4.3	7.1
Baseline	26.8	30.2	26	81.3	4.4	6.9
Baseline	21.6	30.7	26	171.3	3.7	6.6
Baseline	26.4	25.1	25	85.1	3.9	7.6
Baseline	16.3	11.0	33	56.7	4.2	6.6
Radiation	single exposure of 10 R					
1	15.0	10.3	21	46.3	3.8	7.0
2	9.6	5.7	53	220.2	4.1	6.6
3	18.7	23.2	24	87.6	3.9	6.8
4	18.6	19.5	30	104.0	3.6	6.7
5	21.2	26.2	28	68.3	3.5	6.8
6	22.9	28.1	31	69.8	4.0	6.7
7	27.6	31.3	26	74.8	4.0	6.2
8	26.7	19.4	23	55.4	4.0	6.3
9	20.4	16.2	23	36.1	4.1	6.3
10	30.2	40.1	25	119.3	3.9	6.7
11	35.5	30.3	33	62.3	4.2	6.8
12	21.9	18.4	30	84.1	4.0	7.1
13	15.1	9.4	24	124.3	4.0	7.0
14	15.7	12.9	32	123.9	4.3	7.1

SUBJECT # 33 TILT CYCLE FREQUENCY .14cps (slow) RADIATION DOSE 10 R

DAY	LATENCY(sec.)		TOTAL RESPONSES	DURATION(sec.) of LEVER HOLDING	NYSTAGMUS	
	MEAN	S.D.			30rpm	60rpm
Baseline	10.9	10.7	61	90.5	4.1	7.6
Baseline	7.2	4.8	25	28.5	4.0	7.6
Baseline	6.3	4.7	52	58.5	4.1	7.4
Baseline	8.2	6.7	30	47.1	4.1	6.9
Baseline	8.6	12.0	47	44.8	3.9	7.0
Radiation	single exposure of 10 R					
1	10.7	9.1	42	62.7	4.3	7.5
2	11.3	11.6	38	34.0	4.5	6.7
3	12.6	18.2	55	128.6	4.1	6.2
4	11.0	13.8	44	47.6	4.0	6.9
5	13.4	18.8	33	48.4	4.7	7.7
6	8.9	12.5	35	40.9	4.1	7.2
7	7.6	7.6	30	30.6	4.4	7.7
8	7.6	16.6	28	49.5	4.1	7.4
9	4.7	4.7	44	77.0	4.4	7.0
10	13.8	14.6	34	212.3	4.4	7.4
11	13.0	12.3	35	27.2	4.1	7.1
12	8.3	10.6	30	42.3	4.2	7.2
13	12.1	14.3	32	88.3	4.3	6.8
14	16.0	13.8	33	41.5	4.1	6.7

SUBJECT # 34 TILT CYCLE FREQUENCY .14cps (slow) RADIATION DOSE 10 R

DAY	LATENCY(sec.)		TOTAL RESPONSES	DURATION(sec.) of LEVER HOLDING	NYSTAGMUS	
	MEAN	S.D.			30rpm	60rpm
Baseline	14.8	13.4	57	491.2	5.0	7.5
Baseline	13.6	13.9	57	148.2	4.5	7.9
Baseline	15.3	17.9	42	540.1	4.7	8.0
Baseline	9.8	8.5	63	359.0	4.5	8.8
Baseline	11.7	11.3	71	271.3	4.5	7.9
Radiation	single exposure of 10 R					
1	17.0	16.7	46	246.2	4.8	8.1
2	17.7	19.1	55	992.0	4.7	8.9
3	13.1	11.1	97	672.2	5.3	8.3
4	10.3	10.1	74	687.5	4.2	9.0
5	14.6	13.0	67	492.5	4.5	7.9
6	13.2	11.2	53	379.3	4.2	8.3
7	10.1	11.5	40	328.2	4.7	9.7
8	15.4	17.4	43	399.2	5.1	8.2
9	12.5	12.3	78	722.8	4.2	8.2
10	8.8	12.1	76	811.0	4.5	8.4
11	10.2	7.2	59	722.0	4.5	8.8
12	9.5	5.6	61	649.0	4.0	8.0
13	13.6	14.1	53	499.0	4.7	8.3
14	7.4	6.2	53	681.3	4.6	8.4

SUBJECT # 35   TILT CYCLE FREQUENCY .14cps (slow)   RADIATION DOSE 10 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	14.5	10.7	105	363.3	4.2	7.4
Baseline	13.4	16.9	95	176.4	4.3	7.8
Baseline	17.3	17.3	46	227.2	4.2	7.5
Baseline	11.1	8.8	66	269.5	4.0	7.7
Baseline	20.0	10.9	40	198.4	4.4	6.9
Radiation	single exposure of 10 R					
1	14.5	17.3	84	410.0	3.8	7.8
2	10.7	15.4	63	288.0	4.0	6.7
3	10.9	8.4	74	226.4	4.5	7.2
4	14.5	13.0	71	108.0	3.9	7.3
5	12.9	11.0	74	310.5	4.0	7.1
6	12.9	13.7	66	174.6	4.5	6.8
7	13.4	20.3	67	88.8	4.2	7.2
8	18.0	14.8	61	173.7	4.1	7.2
9	21.9	21.5	75	123.9	4.8	6.9
10	16.4	14.5	60	205.6	4.5	7.7
11	14.0	13.6	39	62.9	4.4	7.2
12	18.6	20.5	48	124.7	4.2	6.8
13	11.4	10.8	75	47.1	4.5	7.2
14	9.0	7.4	79	104.8	4.4	7.3

SUBJECT # 36 TILT CYCLE FREQUENCY .14cps (slow) RADIATION DOSE 2x450 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	33.2	39.2	56	325.8	4.6	8.0
Baseline	30.3	28.2	40	197.5	4.6	8.8
Baseline	23.5	14.5	69	421.4	4.9	8.6
Baseline	37.0	27.9	62	380.6	4.7	8.5
Baseline	30.6	39.3	46	116.0	5.1	9.4
Radiation	first exposure of 450 R					
1	20.9	16.3	43	188.1	5.4	10.1
2	25.2	30.2	39	121.8	5.7	8.6
3	30.2	28.9	32	148.4	5.3	8.9
4	37.3	48.2	38	129.8	5.2	9.0
5	25.1	24.5	32	89.9	5.1	8.6
6	28.8	23.3	37	147.6	5.0	9.2
7	31.5	27.5	34	112.5	5.1	8.1
8	second radiation exposure of 450 R					
9	79.1	86.4	35	39.9	4.2	8.7
10	62.4	49.7	25	101.7	5.0	8.8
11	41.3	46.3	35	292.7	5.5	9.0
12	51.9	40.8	25	214.5	5.3	9.0
13	95.3	74.7	34	271.8	4.9	8.8
14	55.3	65.0	34	139.2	4.9	9.6

SUBJECT # 37 TILT CYCLE FREQUENCY .14cps (slow) RADIATION DOSE 2x450 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	27.9	25.5	51	186.3	4.5	6.5
Baseline	41.1	63.5	70	323.6	4.5	6.9
Baseline	22.8	16.0	50	159.7	4.2	6.8
Baseline	31.9	26.2	40	162.8	4.1	6.4
Baseline	26.3	34.4	40	242.8	4.9	7.0
Radiation	first exposure of 450 R					
1	21.7	24.9	45	282.0	4.6	8.1
2	17.6	13.0	61	524.0	3.8	6.8
3	22.7	22.2	37	190.3	4.1	7.2
4	40.1	40.2	36	74.3	4.2	6.6
5	18.0	12.5	41	377.9	4.5	6.7
6	29.4	42.8	34	292.8	3.9	6.8
7	18.8	13.8	45	398.8	4.0	6.7
8	second radiation exposure of 450 R					
9	48.8	38.2	32	302.4	3.9	6.2
10	23.7	18.8	31	313.1	3.6	6.2
11	29.3	26.0	33	451.2	4.0	6.9
12	60.6	53.6	27	406.8	4.4	6.7
13	20.6	22.3	27	280.6	4.0	7.0
14	60.1	52.2	31	979.2	3.8	6.9

SUBJECT # 38 TILT CYCLE FREQUENCY .14cps (slow) RADIATION DOSE 2x450 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	13.2	12.6	51	62.4	4.8	7.5
Baseline	10.0	8.0	76	118.2	4.4	6.7
Baseline	9.2	9.9	57	80.1	3.9	8.2
Baseline	8.6	7.4	101	233.8	4.5	7.4
Baseline	6.0	4.1	90	146.0	4.1	7.6
Radiation	first exposure of 450 R					
1	11.1	11.8	91	140.7	4.0	7.5
2	13.3	11.1	85	180.4	4.6	9.2
3	15.8	11.0	50	205.6	3.9	8.2
4	12.7	11.3	74	202.4	4.3	7.7
5	15.5	11.9	48	55.6	3.3	7.7
6	10.6	9.4	45	80.3	5.0	7.8
7	15.7	20.5	67	96.5	4.3	7.6
8	second radiation exposure of 450 R					
9	12.5	12.3	27	49.1	4.2	8.1
10	13.9	9.8	34	34.6	3.9	7.6
11	10.6	12.3	35	151.1	3.6	8.1
12	8.6	7.3	68	347.1	3.8	7.4
13	13.5	8.0	58	118.2	3.3	7.5
14	14.2	18.6	31	260.0	3.6	7.9

SUBJECT # 39 TILT CYCLE FREQUENCY .14cps (slow) RADIATION DOSE 2x450 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	14.5	15.4	52	86.1	4.3	6.8
Baseline	10.0	8.1	30	120.6	5.0	6.5
Baseline	9.5	8.5	50	202.4	3.9	6.7
Baseline	15.5	13.0	43	87.2	4.5	6.2
Baseline	12.7	9.2	50	199.7	4.8	7.0
Radiation	first exposure of 450 R					
1	14.8	11.3	43	218.5	4.1	6.6
2	10.4	9.8	32	246.5	4.5	6.4
3	13.7	9.6	38	418.5	4.6	6.9
4	19.0	17.3	38	99.5	4.6	7.1
5	10.6	13.5	42	155.6	3.9	6.6
6	11.8	10.3	49	196.8	4.6	7.2
7	9.0	7.5	42	241.2	4.5	6.8
8	second radiation exposure of 450 R					
9	10.5	6.0	73	476.5	4.2	6.6
10	11.0	11.7	49	350.8	4.3	6.3
11	57.7	97.5	46	279.0	3.8	7.2
12	18.4	14.3	60	400.3	4.2	6.7
13	13.2	10.8	29	74.7	4.1	6.6
14	52.9	69.5	32	165.7	4.2	6.8

SUBJECT # 40   TILT CYCLE FREQUENCY .14cps (slow)   RADIATION DOSE 2x450 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	9.8	8.8	40	142.2	4.8	7.1
Baseline	7.5	5.7	66	90.7	4.3	6.5
Baseline	10.4	8.1	79	152.6	4.2	6.9
Baseline	15.0	9.8	32	64.3	4.5	6.6
Baseline	13.7	10.6	60	122.0	4.6	7.1
Radiation	first exposure of 450 R					
1	17.3	10.4	58	275.8	5.0	7.1
2	12.1	11.4	44	110.8	4.4	7.4
3	16.4	15.9	55	276.0	4.5	7.6
4	12.8	11.5	37	75.1	4.7	8.0
5	14.2	17.8	67	96.5	5.1	7.1
6	11.8	12.6	36	72.0	4.5	6.5
7	7.3	4.3	34	73.3	4.1	7.0
8	second radiation exposure 450 R					
9	6.5	4.8	33	62.5	4.8	7.0
10	8.6	8.4	37	162.7	5.2	7.3
11	7.8	7.4	40	138.5	5.3	7.9
12	7.2	5.7	48	137.5	4.8	6.3
13	9.5	6.3	45	103.6	4.8	7.5
14	7.2	6.1	34	76.0	4.7	8.1

SUBJECT # 41 TILT CYCLE FREQUENCY .14cps (slow) RADIATION DOSE 900 R

DAY	LATENCY(sec.) MEAN	LATENCY(sec.) S.D.	TOTAL RESPONSES	DURATION(sec.) of LEVER HOLDING	NYSTAGMUS 30rpm	NYSTAGMUS 60rpm
Baseline	59.9	70.5	35	152.0	5.3	6.9
Baseline	34.8	22.4	49	190.5	5.0	6.7
Baseline	61.0	52.4	58	149.5	5.6	6.3
Baseline	46.2	37.4	41	102.7	4.3	6.7
Baseline	39.8	27.2	48	262.0	5.0	6.2
Radiation	single exposure of 900 R					
1	54.7	43.0	36	192.3	4.8	6.5
2	58.7	65.9	29	583.5	5.5	8.0
3	53.9	48.3	44	980.7	4.7	8.3
4	120.4	178.6	27	509.4	4.6	7.7
5	195.1	308.9	48	1339.1	4.1	6.9
6	86.5	68.7	62	1155.3	4.5	7.6
7	120.9	173.5	52	477.1	4.1	7.3
8	155.4	183.3	51	843.0	4.9	7.0
9	145.3	132.5	38	405.2	4.6	6.9
10	144.2	178.5	32	328.5	4.4	6.9
11	137.2	180.2	60	819.0	4.3	7.0
12	189.8	263.7	62	583.4	4.6	7.1
13	201.6	391.8	46	920.5	4.9	6.8
14	143.6	170.3	56	281.4	4.6	6.9

SUBJECT # 42 **TILT CYCLE FREQUENCY** .14cps (slow) **RADIATION DOSE** 900 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	24.4	19.1	49	96.7	4.5	7.1
Baseline	21.9	26.7	55	169.0	4.4	7.6
Baseline	20.2	20.3	58	101.3	4.7	7.0
Baseline	23.2	19.7	64	100.5	4.2	6.7
Baseline	24.2	25.9	42	185.2	4.4	7.2
Radiation	single exposure of 900 R					
1	16.8	17.2	71	570.9	4.2	6.8
2	17.0	28.9	72	642.9	4.8	7.0
3	22.7	23.8	53	417.4	4.3	7.3
4	21.3	21.2	40	319.3	4.1	6.8
5	53.3	81.1	42	312.3	4.1	7.7
6	50.6	70.7	59	292.3	4.8	7.2
7	55.6	85.7	43	373.8	4.0	7.3
8	83.3	113.2	34	267.1	4.2	7.5
9	50.2	88.1	48	364.0	3.9	6.8
10	45.5	118.5	45	157.8	3.9	6.8
11						
12						
13			Died			
14						

SUBJECT # 43 TILT CYCLE FREQUENCY .14cps (slow) RADIATION DOSE 900 R

DAY	LATENCY(sec.) MEAN	LATENCY(sec.) S.D.	TOTAL RESPONSES	DURATION(sec.) of LEVER HOLDING	NYSTAGMUS 30rpm	NYSTAGMUS 60rpm
Baseline	22.3	24.8	41	52.1	4.1	7.8
Baseline	14.5	14.0	43	115.5	5.2	7.5
Baseline	17.2	18.9	64	80.4	4.5	7.0
Baseline	16.1	18.7	59	60.8	4.8	7.8
Baseline	17.5	21.3	43	35.5	5.1	8.1
Radiation	single exposure of 900 R					
1	26.8	29.4	65	122.4	4.3	7.5
2	28.7	31.4	34	154.8	4.3	7.2
3	22.7	36.1	26	89.5	4.5	6.9
4	57.5	54.2	35	155.6	5.1	7.8
5	30.8	45.9	38	206.1	4.7	7.3
6	46.2	47.0	35	253.5	4.8	7.2
7	41.5	55.3	33	34.7	3.7	7.7
8	39.8	55.6	32	117.0	4.6	8.5
9	31.6	37.6	29	84.7	4.9	7.6
10	47.3	88.6	38	349.1	4.6	7.9
11	36.2	42.2	24	105.0	4.8	7.2
12						
13			Died			
14						

SUBJECT # 44   TILT CYCLE FREQUENCY .14cps (slow)   RADIATION DOSE 900 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	8.5	9.6	35	86.1	4.3	8.1
Baseline	10.2	11.5	42	145.6	4.2	7.2
Baseline	8.3	8.6	40	111.2	4.3	6.8
Baseline	9.0	7.2	38	79.3	4.7	7.3
Baseline	9.8	7.4	78	102.5	4.8	6.8
Radiation	single exposure of 900 R					
1	14.3	9.2	70	228.0	4.3	7.0
2	11.1	8.6	32	153.7	4.6	7.3
3	16.3	15.9	35	363.9	4.2	7.4
4	44.2	38.3	33	129.5	3.7	6.0
5	15.1	11.0	33	71.6	4.1	7.8
6	22.5	31.7	64	299.8	4.3	7.3
7	12.2	16.5	47	127.8	4.2	7.3
8	26.5	21.7	33	112.5	4.1	7.8
9	16.9	12.6	33	146.8	4.6	7.1
10	16.5	10.9	25	272.3	4.5	7.6
11	65.7	90.6	21	105.3	4.6	8.1
12	------------	------------	------------	------------	------------	------------
13			Died			
14						

SUBJECT # 45   TILT CYCLE FREQUENCY .14cps (slow)   RADIATION DOSE 900 R

DAY	LATENCY(sec.)		TOTAL	DURATION(sec.) of	NYSTAGMUS	
	MEAN	S.D.	RESPONSES	LEVER HOLDING	30rpm	60rpm
Baseline	6.2	4.5	25	119.6	4.0	7.1
Baseline	6.6	4.2	29	86.1	4.9	7.1
Baseline	5.7	3.8	39	154.7	4.4	6.4
Baseline	5.2	4.3	58	199.7	4.7	6.2
Baseline	6.1	4.0	32	174.1	4.3	5.8
Radiation	single exposure of 900 R					
1	13.1	13.6	31	275.2	4.3	6.7
2	11.9	11.6	35	272.2	4.8	7.1
3	11.7	11.1	37	182.7	4.6	6.5
4	7.3	5.0	26	199.5	4.5	6.3
5	17.0	21.3	28	155.3	4.6	7.1
6	13.8	13.0	23	118.2	4.5	6.6
7	16.1	20.6	27	136.8	4.5	6.4
8	38.2	39.9	23	468.9	4.5	7.8
9	46.3	56.9	35	438.9	4.5	6.6
10	73.0	80.1	30	203.2	6.1	10.7
11	-------	-------	-------	-------	-------	-------
12			Died			
13						
14						