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Effects of X-Radiation on Saccharine Consumption as a Function of Dosage and Interstimulus Interval

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EFFECTS OF X-RADIATION ON SACCHARINE CONSUMPTION AS A FUNCTION OF DOSAGE AND INTERSTIMULUS INTERVAL

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INTRODUCTION

In 1955 Garcia, Kimeldorf, and Koelling showed that ionizing radiation can serve as an aversive unconditional stimulus in the conditioning paradigm. The initial interest in this field has been shown to be justified by the wealth of studies that have been published and by some of the unique phenomena that have been discovered. One of these phenomena, that of backward conditioning, is of particular interest to the present study. The term "backward conditioning" is an unfortunate one in that it has been shown many times to be an unsuccessful conditioning paradigm (Kimble, 1961, p. 158). However, previous unsuccessful demonstrations have not usually used ionizing radiation as the unconditioned stimulus. The review of the literature that follows traces the history of behavioral research in the radiation field and pays particular attention to those studies which bear on the present study.

Since the study by Garcia et al (1955) is so basic to the evolution of radiation research, that experiment will be described. A group of rats were subject to an initial test of saccharine preference in a saccharine-water free choice situation. Exposure to gamma radiation in the amount of 0 roentgens (r), 30 r, or 57 r for six hours was made either in the presence of saccharine solution or water. In a post-irradiation test of saccharine preference, it was found that those animals that had been irradiated in the presence of saccharine showed a marked aversion to saccharine that varied directly with the amount of radiation. It was also found that the aversion was still present 30 days later. The animals that were irradiated in the presence of water did not show a similar aversion to saccharine.

Garcia and Kimeldorf (1957) performed a similar experiment in which the temporal interval between irradiation and saccharine presentation was varied. One group had access to saccharine for two hours immediately prior to a four hour exposure period of 37.6 r. Other groups received saccharine while being irradiated and a last group was given access to saccharine immediately after irradiation. It was found in a post-exposure presentation of saccharine that the groups that had received saccharine before or during the radiation exposure consumed significantly less saccharine than an associated non-irradiated control group. No such effect was found in the group that received saccharine after irradiation.

Smith and Morris (1963) attempted to discover the lowest threshold of x-irradiation exposure that could create the effect of conditioned aversion to a saccharine solution. For 500 day old rats, it was found that the threshold for the effect is less than 50 roentgens. It was also found that once the threshold was reached, further increases in the amount of irradiation up to 350 r at the rate of 30 r/min. produced no corresponding significant decrease in saccharine consumption. The amount of saccharine consumed prior to irradiation was shown not to be a factor in the strength of the aversion.

The preceding experiments have dealt with the effect of radiation on a drinking response; however, the effect of radiation as an aversive stimulus has been shown to affect other response measures. Arbit (1961) irradiated rats on four occasions at a dosage of .92 r/min. for 10 minutes in either a black or white box. In later tests of preference it was found that the subjects showed an aversion to the box in which they had been irradiated. Arbit analyzed the phenomenon by separating the subjects on the basis of emotionality. He found that highly "emotional" (reactive) animals, as measured by defecation and locomotion in an open-field test, showed a marked aversion to the box in which they had been irradiated while the non-reactive rats did not display the same aversion.

Kimeldorf, Garcia, and Rubadeau (1960) administered 119 r in 180 minutes to mice. They found that decreased saccharine consumption only occurred if saccharine was presented concurrently with the radiation exposure. When only water was presented during the exposure period the subjects drank as much saccharine in a post-test as a non-irradiated control group. In the same experiment, conditioned aversion was also demonstrated in cats, however, chocolate milk and not a saccharine solution was used as the CS.

Jarrard (1963) has investigated the effects of x-irradiation in operant behavior. He compared the performance of rats, one group of which were bar-pressing to avoid shock (RS=SS=10 sec.) and the other group of which were bar-pressing for food (VI=2 min.). It was found that performance of subjects in the avoidance situation did not change after irradiation of 100 r, 300 r, or 500 r, but performance of subjects working for food was affected. In a further extension of the experiment, Jarrard found that significant changes in food consumption in a non-bar press situation were obtained at lower radiation levels than those needed to cause significant changes in bar-pressing for food. It was also found that at higher levels of radiation exposure, changes in food consumption lasted longer than changes in operant behavior. Jarrard concluded from the above results that there is little support for the conclusion that the central nervous system is extremely sensitive to x-irradiation. Changes in behavior following x-irradiation, according to Jarrard, stem from the motivational effects of radiation sickness and not from the effects of radiation within the central nervous system.

Hunt and Kimeldorf (1962) suggest that x-irradiation does affect the central nervous system and they present evidence which they interpret as support for this claim. They found that if an x-ray tube above a sleeping rat is energized, the rat immediately awakens. They also found that the behavioral and heart rate changes were dependent on the rate of exposure and not the amount of exposure. Since x-rays are visible (Kimeldorf and Hunt, 1965, p. 131), it is possible that subjects are responding to the properties of x-ray induced apparent light. In order to test that hypothesis, a similar procedure was used on opthalmectomized animals. The same results were found, arousal occurred within 12 seconds at dosages varying from 1.9 r/sec. to .25 r/sec. Garcia and Kimeldorf (1958) also tested the effects of x-radiation on opthalmectomized rats. They irradiated a group of normal rats and a group of opthalmectomized rats in the presence of saccharine and found that both groups exhibited a decrement in saccharine consumption when tested at a later time. They used a dose rate of 5 r/hour or 1 r/hour for 6 hours.

Smith, Kimeldorf, and Hunt (1963) placed moths in a darkened x-ray exposure room. When the x-ray tube was energized, flight activity began immediately. The dosage for eliciting this behavior is .01 to 1.5 r/sec. and the latency is less than one second after exposure. The results of the preceding three experiments indicate that there is an effect of radiation independent of the symptoms of radiation sickness. These effects occur immediately upon the onset of exposure and the short latencies therefore suggest that an explanation based upon the effects of gross physiological damage is insufficient to explain the phenomena.

McLaurin and Scarborough (1963) extended the interstimulus interval (CS-UCS) to 25 minutes and 50 minutes. They found that all irradiated groups (81 r) avoided saccharine drinking equally irrespective of the interstimulus interval and that there was no suppression of saccharine consumption for the sham irradiated groups. Because of the long interstimulus intervals involved in radiation conditioning and because radiation causes no overt changes in behavior that would indicate that it is an aversive UCS (as electric shock) they concluded that ". . . radiation as a motivating stimulus has unique properties which make it relatively distinct from other nociceptive stimuli used in conditioning of avoidance behavior (p. 323)."

The results found with long interstimulus intervals bear an interesting relationship to the immediate effect studies previously cited. The nature of the effect associated with the irradiation differs in that in the immediate effect studies the response is one of awareness (waking up, flight activity) while the response of interest in long interstimulus studies is one that indicates no awareness of an overt aversive stimulus.

In a similar study (McLaurin, 1964), the interstimulus interval (ISI) was extended to 3, 60, 120, or 180 minutes after a CS presentation period of 15 minutes. The dose was 61.4 r for 10 minutes. Two types of controls were used in this study. One control was only sham irradiated while the other control was irradiated, however it had received no CS presentation (neither saccharine nor water). Immediately after irradiation all subjects were given a preference test between a saccharine solution and tap water for 24 consecutive days. It was found that saccharine consumption was suppressed for all groups that had had saccharine paired with radiation. Of the control groups, the group that had received radiation and no CS suppressed for only a few days but the sham-irradiated group did not suppress at all. The results indicate that there are two effects caused by irradiation. First, there is a general motivational effect that is reflected in awareness and activity. Secondly, there is a conditioned effect of irradiation which is probably due to its aversive nature and its ability to be temporally associated with other events.

McLaurin, Farley, Scarborough, and Rawlings (1964) found that there was no difference between groups of rats receiving saccharine, water, or no fluid prior to exposure in a test of saccharine aversion immediately after exposure to 66 r. They concluded that an association of a disturbed physiological state and the saccharine solution in the home cage immediately after exposure and not an association of x-irradiation with saccharine per se was responsible for the saccharine aversion. This experiment can also be considered an example of backward conditioning. In this case the UCS is the irradiation and the CS is the saccharine solution that was presented immediately after the exposure in the test of saccharine preference.

Morris and Smith (1964) tested the backward conditioning paradigm. Presentation of saccharine was made at varying intervals after a 100 r radiation exposure. It was found that with intervals as long as one hour a later aversion to saccharine was indicated. However, when the interval was six hours no effect was found.

Smith, Taylor, Morris, and Hendricks (1965) investigated three pre-irradiation conditions: saccharine, water, or no fluid; and two post-irradiation (100 r) preference test conditions: immediate or 24 hours later. It was found that all animals getting the immediate preference test avoided the saccharine while of those receiving the test 24 hours after irradiation only those that drank saccharine before irradiation demonstrated the saccharine aversion. Scarborough, Whaley, and Rogers (1964) presented a choice of tap water or saccharine solution at delays following irradiation (68 r) of 0 to 96 hours. After an additional six hours of fluid deprivation a post-irradiation test indicated a decrease in saccharine consumption in groups which had first received the saccharine from 0 to 12 hours after irradiation. No significant decrease in saccharine consumption was exhibited when the delay was 24 hours or more.

The preceding experiments indicate the unique nature of radiation as an aversive stimulus. It has been shown to be useful as a UCS in trace, simultaneous, and backward conditioning. Its use in backward conditioning stands as one of its most interesting characteristics since the literature of psychology is almost void of illustrations of this phenomena especially in cases in which it is manifested so clearly and predictably.

Radiation has also been shown to be an unsuccessful UCS under certain mitigating circumstances such as habituation to the saccharine solution in the period prior to radiation exposure. McLaurin, Farley, and Scarborough (1963) habituated rats to saccharine by presenting it as the only fluid for six days. After intervals of 3 or 6 days of only tap water, the animals were irradiated with 102 r in the presence of a saccharine solution. It was found that all groups that had been habituated were significantly different from the non-habituated groups in that a saccharine aversion was not shown. Farley, McLaurin, Scarborough, and Rawlings (1964) habituated groups of rats to saccharine for either 8, 4, 2, 1, or 0 days prior to an administration of 38.4 r. The groups habituated to saccharine did not display the usual aversion to saccharine. One group irradiated in the presence of saccharine with no prior habituation had recovered to 70% of the typical control saccharine consumption in a period of seven days after irradiation.

Garcia, Kimeldorf, and Hunt (1956) showed that the conditions present during an exposure session can act as a conditioned stimulus for the effects typical of the post-irradiation period. Animals deprived of food and water during exposure did not show a decrement in food and water consumption during sham irradiation. Animals that had food present or food and water present during exposure to 75 r over 8 hours displayed a lower consumption of food and water during a later sham exposure. It was found that as few as one pairing between radiation exposure and the conditions present during radiation exposure was sufficient to obtain the conditioning phenomenon.

The majority of the experiments that have dealt with ionizing radiation as an aversive stimulus have considered only one of the two major variables at a time. Experimenters have either varied radiation dosage or interstimulus interval. In the area of backward conditioning only the latter variable has been manipulated. The lack of information is particularly frustrating in that the effect of radiation level in trace and simultaneous conditioning is still not certain. One study (Garcia, et al, 1955) has found that as small a difference as that between 30 r and 57 r will result in increased aversion to the CS at the higher level of irradiation. On the contrary, another study (Smith and Morris, 1963) has found that once the threshold has been reached for the conditioned aversion effect, further increases in radiation level do not significantly increase the magnitude of the effect. The effects of interstimulus interval are more certain. The shorter the period of time separating the CS and the UCS, the greater the aversion effect. In the case where the UCS is presented prior to the CS the same relation seems to be true, however, no effect has been shown when the interstimulus interval has been greater than six hours.

More basic work with the major parameters of the paradigms is indicated. The purpose of the present study is to further pursue the effects of varying the interstimulus interval (ISI) and level of radiation in the backward conditioning paradigm. A two-factor design is employed; the two independent variables are level of radiation and ISI. The ISI is now defined as the interval between the end of the radiation period and the presentation of the CS. It is expected that there will be an inverse relation between the amount of saccharine consumed in a post-irradiation preference test and the magnitude of the radiation dosage. It is also expected that there will be a direct relation between the amount of saccharine consumed in the post-irradiation preference test and the length of the ISI.

METHOD

Subjects

The subjects (*Ss*) for the study were 72 male albino rats. Thirty-three *Ss* were obtained from Maxfield Animal Supply and the other thirty-nine *Ss* were obtained from the Western Michigan University colony. The WMU rats were either originally obtained at a prior date from Maxfield Animal Supply or were offspring of such rats. All the *Ss* weighed over 350 grams, but less than 520 grams, and were approximately four to five months old at the time of the study.

At all times during the experiment, except during irradiation, Wayne Lab-Blox were freely available to the *Ss*.

Apparatus

The X-ray unit utilized was a Mathison 140 PKV, 8 milliamper portable Therapy Unit. However, all irradiations were made at 120 KV and 8 milliampers. Attached to the gun area was an eight inch cone for directing the radiation. The total doses delivered by the apparatus was checked by a Bendix CDV 746 dosimeter capable of recording up to 600 roentgens.

The subjects were irradiated while in a standard wood animal shipping crate having a diameter of 15 inches and a height of 6 inches. The container was subdivided into 9 pie-shaped compartments each of which held one rat. The top of the shipping crate was also constructed of wood with a thickness of 3/8 inch.

The fluid containers used during fluid preference tests were clear plastic tubes with a separable bottom piece made of a hard yellow plastic. When the tube was filled, the bottom piece was attached and the tube inverted in such a way that there was no loss of fluid due to spilling. The fluid container was held to the cage through the use of a metal clip that had previously been affixed to the cage.

Procedure

The 12 groups were formed by randomly interspersing the Maxfield rats with the colony rats such that there were no more than 3 Maxfield rats in any 6 member group. Fluid preferences after 23 hours of fluid deprivation were tested for 4 days between a 0.1% saccharine solution (1 gm. sodium saccharine in 1 liter tap water) and tap water. Each preference test lasted for one hour and the position of the saccharine container and the water container were changed daily to prevent the development of a position preference.

On the fifth day the subjects were taken out of their home cages, placed in the radiation chamber and transported to the radiation room. They were placed under the x-ray unit for a period of 15 minutes. They were then brought back to their home cages. Twenty-three hours after the previous preference test and at a designated time after irradiation a single drinking tube containing a 0.1% saccharine solution was placed on each cage for one hour. On the sixth day, 23 hours after the tube containing saccharine had been removed the subjects were given another one hour test of saccharine-water preference. The preference test was repeated on the seventh day.

Table 1 illustrates the experimental design and the dose rate that each group received. The 0 r groups were control groups in that they were sham irradiated. During sham irradiation all conditions are the same as during a real radiation exposure except the _S_s are shielded by a layer of concrete blocks. The other dosages are 90 r, 170 r, and 340 r. The dose rates were computed on the basis of 15 minute radiation exposures. Different dose rates were obtained by placing the _S_s at varying distances from the x-ray source. The interval between the end of the exposure and the presentation of saccharine is termed the interstimulus interval; ISIs of five minutes, three hours, and nine hours were chosen on the basis of previous research.

TABLE 1

Summary of Experimental Design and Dose Rates for Each Group

Radiation Dosage	Interstimulus Interval		
	5 minutes	3 hours	9 hours
0 r	0	0	0
90 r	6.00 r/min.	6.00 r/min.	6.00 r/min.
170 r	11.33 r/min.	11.33 r/min.	11.33 r/min.
340 r	22.67 r/min.	22.67 r/min.	22.67 r/min.

Since it was desired that all irradiations be performed at the same time of day and since there was only room for a small number of animals under the x-ray tube at any one time, the experiment was performed on a staggered day schedule. The experiment first began for the sham groups, on the following day it began for the 90 r groups and then in order, for the 170 r groups and the 340 r groups.

RESULTS

The strength of the aversion to saccharine was measured by an Aversion Index score (AI). All calculations concerning pre-irradiation measures only consider the last two days of that four day period. The AI score was calculated as follows:

$$AI = \frac{\frac{\text{Post-Sach. Consump.}}{\text{Post-Total Consump.}} \times 100}{\frac{\text{Pre-Sach. Consump.}}{\text{Pre-Total Consump.}} + \frac{\text{Post-Sach. Consump.}}{\text{Post-Total Consump.}}} .$$

The AI score was used so that both pre-irradiation and post-irradiation behavior could be accounted for as well as the saccharine consumption and total consumption in one measure. This strategy was required because the groups were not matched for initial saccharine preference in the pre-irradiation phase of the experiment. The lower the AI score, the greater the aversion to saccharine in the post-irradiation test period.

Initial analyses of variance were computed to determine if there were any significant differences between the groups in terms of pre-irradiation saccharine preference or pre-irradiation total fluid consumption. In both cases ($F < 1$, df = 11,58; and $F = 1.21$, df = 11,58, respectively) no significant differences were found. In addition, tests of homogeneity of variance were performed and it was found that the pre-irradiation data was homogeneous ($F(\text{max.}) = 9.17$, df = 11,5; and $F(\text{max.}) = 12.1$, df = 11,5, respectively).

Table 2 contains the summary of the analysis of variance for the AI scores. As is indicated there were two significant factors, level of radiation and ISI; the interaction was not significant. As is shown in Figure 1, in general, the higher the radiation dosage, the lower the AI score which indicates a decrease in relative saccharine consumption. Table 3 contains the means for each group. An analysis of group scores was made using individual single tailed _t_-tests. Not all possible _t_-tests were carried out because some comparisons were irrelevant. An example of a relevant comparison is that of the group that received 0 r with an ISI of 5 minutes (5 m - 0 r) and the group that received 90 r with an ISI of 5 minutes (5 m - 90 r). The difference in means between these two groups indicates the effect of 90 r as compared to 0 r. An irrelevant comparison would be between 5 m - 0 r and 3 h - 90 r. The difference between these two groups is confounded since two factors are varying simultaneously.

The _t_-tests (Table 4) reveal a variety of interesting relations. In the 5 minute irradiation groups the minimum radiation level required to cause a significant aversion to saccharine was 170 r, and there was no significant increase in the strength of the aversion effect as the dosage of radiation was increased above 170 r.

TABLE 2

Summary of Analysis of Variance
of Aversion Index Scores

Source	SS	df	MS	F
R	707.59	3	235.86	6.27**
ISI	318.78	2	159.39	4.23*
R x ISI	475.02	6	79.17	2.10
Error	2182.23	58	37.62	

*$p < .05$ $F_{.95}(2,58) = 3.15$

**$p < .01$ $F_{.99}(3,58) = 4.13$

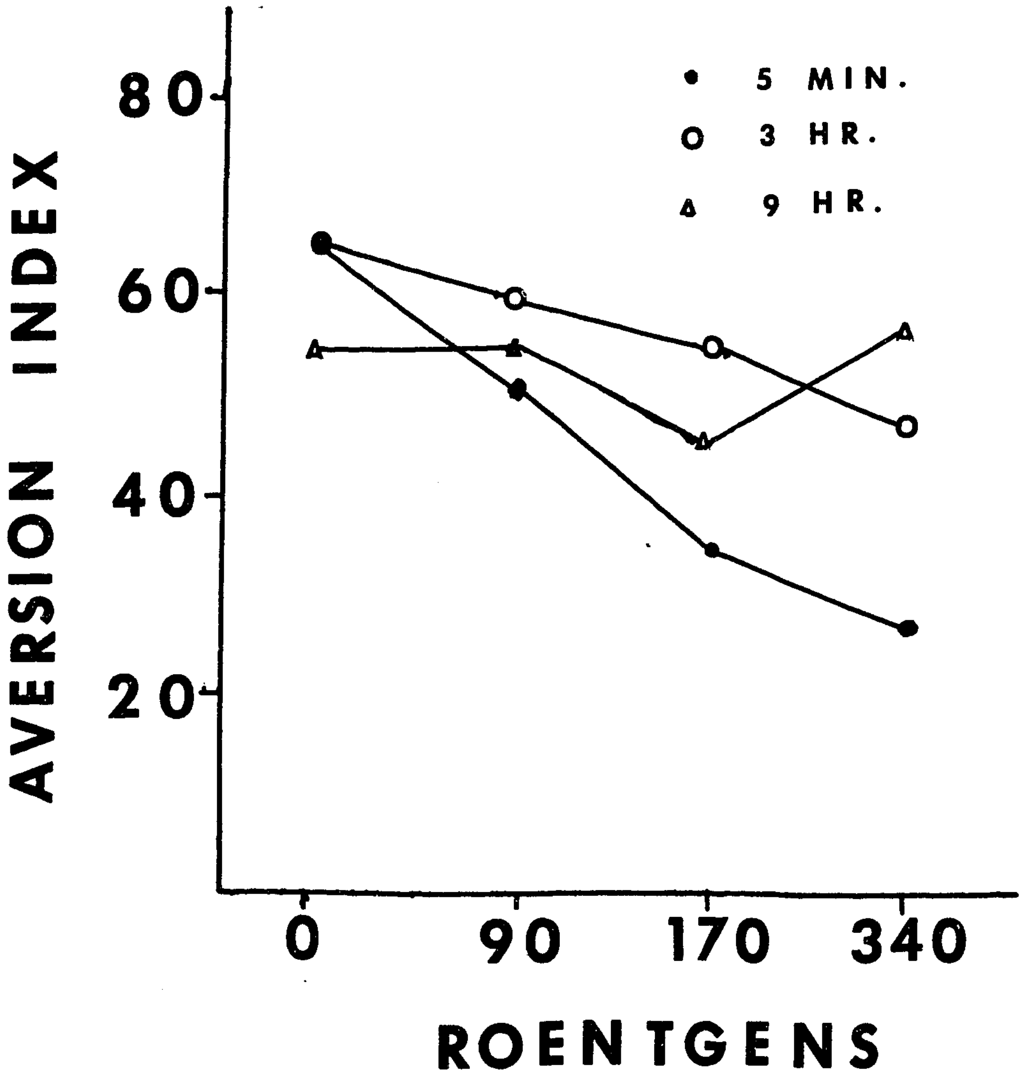

Figure 1. The aversion index as a function of dosage and interstimulus interval.

TABLE 3

Means of Aversion Index Scores

Roentgen	Interstimulus Interval		
	5 min.	3 hr.	9 hr.
0	65.5	65.6	54.6
90	51.7	60.0	54.8
170	34.3	55.2	44.7
340	26.7	47.2	56.3

TABLE 4

Summary of t-tests for Means of Aversion Index Scores

	5 m - 0 r	5 m - 90 r	5 m - 170 r	5 m - 340 r	3 h - 0 r	3 h - 90 r	3 h - 170 r	3 h - 340 r	9 h - 0 r	9 h - 90 r	9 h - 170 r	9 h - 340 r
5 m - 0 r		n.s.	.01	.01	n.s.				n.s.			
5 m - 90 r			.05	.01		n.s.				n.s.		
5 m - 170 r				n.s.			.01				n.s.	
5 m - 340 r								.01				.01
3 h - 0 r						n.s.	n.s.	.05	n.s.			
3 h - 90 r							n.s.	n.s.		n.s.		
3 h - 170 r								n.s.			n.s.	
3 h - 340 r												n.s.
9 h - 0 r										n.s.	n.s.	n.s.
9 h - 90 r											n.s.	n.s.
9 h - 170 r												n.s.
9 h - 340 r												

Note: The empty boxes above the diagonal line represent t-tests that were not performed.

For the groups that were irradiated 3 hours before being given saccharine, the only significant effect was observed between the 0 r group and the 340 r group. There were no significant differences in those groups with ISIs of 9 hours. There were no significant effects of ISI across the 0 r groups and the 90 r groups. However, the AI scores of the 5 minute groups irradiated with 170 r or 340 r were significantly lower than the corresponding 3 hour groups. In the case of 340 r exposure, the 5 minute group also had a significantly lower AI score than the 9 hour group.

In order to further investigate the source of the irradiation effect, an analysis was made of the changes in fluid consumption during the course of the experiment. Total Fluid Ratio (TFR) scores were calculated as follows:

$$TFR = \frac{\text{Post Consump.} \times 100}{\text{Pre-Consump.}}$$

The summary of the analysis of variance for TFR scores appears in Table 5. As is indicated both main effects were found to be significant, roentgens at the $p < .01$ level and ISI at the $.01 < p < .05$ level. The means of the TFR scores are listed in Table 6 and illustrated in Figure 2. It can be seen that the general direction of the effects are as follows:

1. Increases in roentgen dosage are associated with a decrease in TFR scores (less post consumption as compared to pre-consumption).

TABLE 5

Summary of Analysis of Variance
of Total Fluid Ratio Scores

Source	SS	df	MS	F
R	1328.56	3	442.85	4.69**
ISI	810.13	2	405.06	4.03*
R x ISI	457.00	6	79.17	< 1.00
Error	5479.53	58	94.47	

*$p < .05$ $F_{.95}(2,58) = 3.15$

**$p < .01$ $F_{.99}(3,58) = 4.13$

TABLE 6

Means of Total Fluid Ratio Scores

Roentgen	Interstimulus Interval		
	5 min.	3 hr.	9 hr.
0	113.2	106.6	115.6
90	93.3	117.0	112.5
170	85.8	118.7	104.0
340	68.5	94.2	90.2

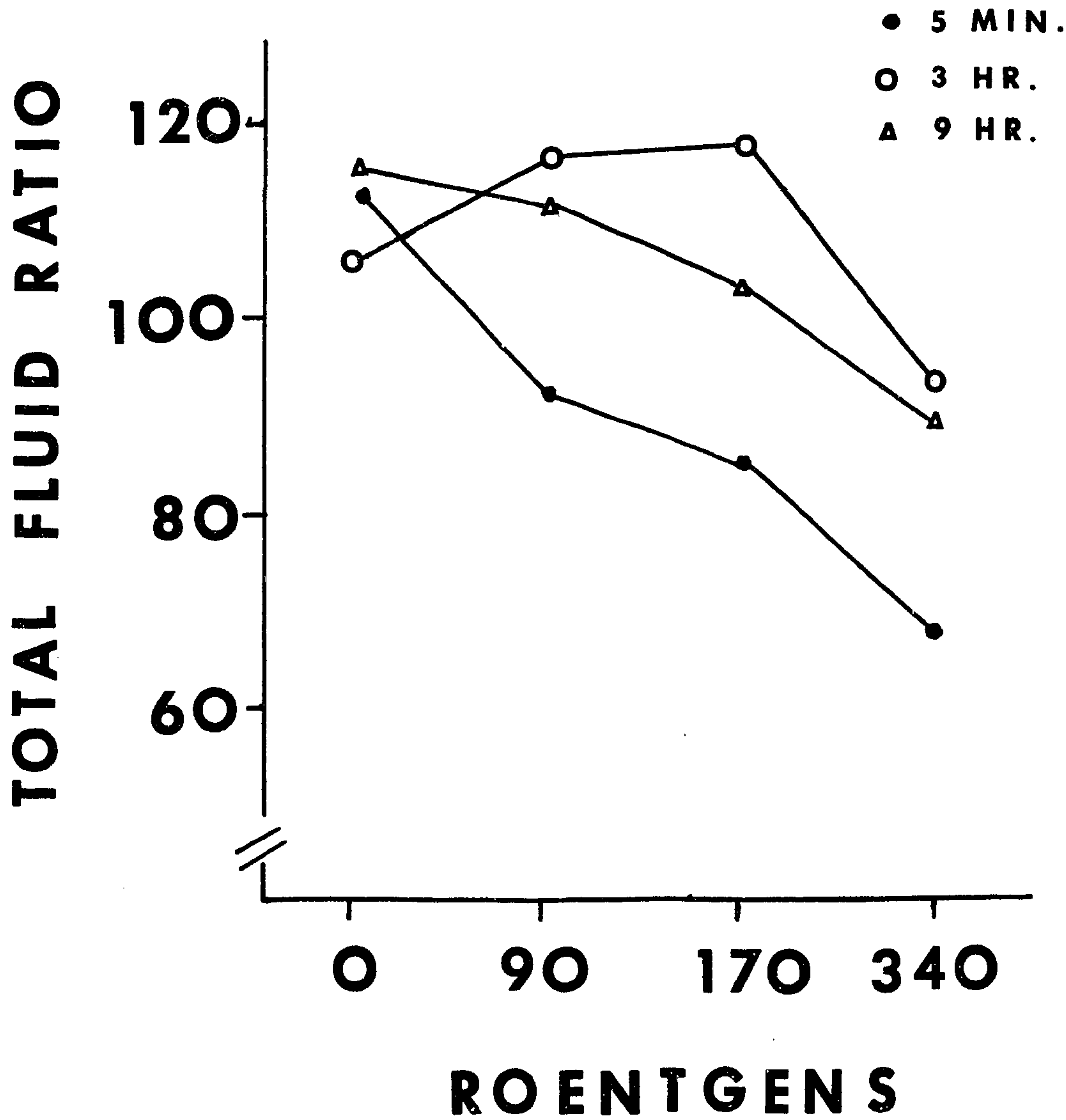

Figure 2. Total fluid ratio as a function of dosage and interstimulus interval.

2. Increases in ISI are associated with an increase in TFR scores (more post consumption as compared to pre-consumption).

Table 7 shows the post-irradiation saccharine consumption as a percentage of the pre-irradiation saccharine consumption. Table 8 contains the corresponding information for water consumption. The effect of roentgen dosage may be seen most clearly by comparing the 5 minute groups. As roentgen dosage increases, saccharine consumption decreases and water consumption increases. The effect of ISI may be seen most clearly in the 340 r groups. As the ISI is increased, saccharine consumption increases and water consumption decreases.

Table 9 contains the summary of the analysis of variance of saccharine consumption on the day of irradiation. Interstimulus interval is the only significant effect ($p < .05$). The means of saccharine consumption are reported in Table 10. Individual *t*-tests were performed and it was found that all significant differences involved the 3 hr. - 170 r group. The mean for this group was 30.7 ml. All the other groups had means between 19.8 ml and 24.2 ml.

TABLE 7

Post Irradiation Saccharine Consumption as a Percentage of Pre-Irradiation Saccharine Consumption

Roentgen	Interstimulus Interval		
	5 min.	3 hr.	9 hr.
0	184	156	137
90	99	145	129
170	64	140	92
340	40	92	105

TABLE 8

Post Irradiation Water Comsumption as
a Percentage of Pre-Irradiation
Water Consumption

Roentgen	Interstimulus Interval		
	5 min.	3 hr.	9 hr.
0	36	56	59
90	67	31	59
170	146	50	118
340	136	94	68

TABLE 9

Summary of Analysis of Variance of
Saccharine Consumption on Day of Irradiation

Source	SS	df	MS	F
R	21.02	3	7.01	1.66
ISI	30.28	2	15.14	3.59*
R x ISI	44.18	6	7.36	1.74
Error	244.49	58	4.22	

*$p < .05$ $F_{.95}(2,58) = 3.15$

TABLE 10

Means of Saccharine Consumption
on Day of Irradiation

Roentgen	Interstimulus Interval		
	5 min.	3 hr.	9 hr.
0	20.8	19.8	21.0
90	22.2	24.0	23.0
170	20.8	30.7	20.8
340	21.0	24.2	20.7

DISCUSSION

The purpose of this experiment was to investigate the relations between level of radiation, interstimulus intervals and suppression of saccharine solution consumption. It was hypothesized that there would be an inverse relation between the amount of saccharine consumed in the post irradiation preference test and the magnitude of the radiation dosage. It was also hypothesized that there would be a direct relation between the amount of saccharine consumed in the post irradiation preference test and the length of the interstimulus interval. Both hypotheses were supported as is indicated in Table 2 and in Figure 1.

The results (Table 4) indicate that for the 5-minute ISI groups, the threshold for the aversion effect is at least 170 r and that the threshold for the 3-hour ISI groups is 340 r. No reliable estimate of the threshold for the 9-hour ISI groups could be inferred. It was also found that for the groups irradiated at 170 r and 340 r the aversion effect was significantly greater for those groups having the shorter ISI. This is particularly evident in the groups irradiated with 340 r.

Some previous studies (Garcia, et al 1955; Garcia and Kimeldorf, 1957; Smith and Morris, 1963) indicate that a saccharine aversion effect was found with much lower doses of radiation (less than 50 r) than those used in the present study. However, these studies differ in some important aspects. Firstly, the three studies all investigated simultaneous or delayed conditions, while the present study involves backward conditioning, a form of trace conditioning. Secondly, the first two studies employ long exposure periods (four to six hours) whereas the present study employed a fifteen minute exposure period.

Other studies (Morris and Smith, 1964; Smith, et al, 1965; Scarborough, et al, 1964) are more similar to this investigation. They are all alike in that they used the UCS-CS presentation order and in that the ISI was of some finite length greater than zero. Two of these studies found a threshold for the aversion effect at 100 r and the third at 68 r. The significance of the length of the ISI in the present study supports results found by other investigators. One study (Morris and Smith, 1964) found no aversion effect at an ISI of six hours while another study (Scarborough, et al, 1964) found such an effect was present with as long an ISI as 3 hours but not 9 hours.

Also related to the issue of thresholds is the question of whether increases in roentgen dosage beyond the threshold will cause a stronger effect. The present study (Table 4) indicates that once the threshold has been reached further increases often result in a stronger effect, but that such effects are not significantly stronger ($p > .05$). However, inspection of Figure 1 suggests that further increases in roentgens above threshold may well cause significant effects if such increases were great enough.

An analysis of total consumption was made in order to find factors related to a lowered Aversion Index. It was found that there were systematic changes in consumption that paralleled changes in the Aversion Index (Figure 1 and Figure 2). Total fluid consumption was also analyzed into its components, saccharine and water consumption. This analysis revealed that the groups that had received 0 r typically increased their saccharine consumption in the post-exposure test while at the same time their water consumption decreased (Table 7 and Table 8). The opposite behavior was shown by those groups that had been given a high radiation dosage at the shorter ISIs (i.e.: groups 5 min. - 170 r, 5 min. - 340 r, and 3 hr. - 340 r). These groups decreased saccharine consumption and either increased water consumption relative to their own pre-irradiation consumption or decreased water consumption to a considerably smaller degree than did the 0 r groups.

The effect of the procedure can now be seen clearly: in those groups whose Aversion Index scores differed significantly from their respective 0 r control groups, the difference was caused by an aversion to saccharine solution and was not caused by an artifactual depression in total fluid consumption. This suggests that there was indeed an association between the saccharine solution and some aspect of the unconditioned stimulus. However, the nature of this association is still not clear. There are two ways in which the association may be made:

1. True conditioning occurred; the association is between the x-irradiation per se and the saccharine solution.

2. The nature of the event is that of the saccharine solution being associated with a disturbed physiological state induced by the x-irradiation.

The arguments against the first explanation are basic to the tenets of psychological science. First, no receptors for ionizing radiation have been found which have not either been shown to be unimportant in this process or are independent of the symptoms of radiation sickness (Kimeldorf and Hunt, 1965, pp. 260, 273). Second, in no previous experiment with any other unconditioned stimulus has conditioning taken place with interstimulus intervals as long as those used in radiation studies.

The argument against the second explanation is based on prior experimental findings. It has been demonstrated that there is a rapid behavioral response to low level x-irradiation to which the possibility of radiation sickness is very low (Kimeldorf and Hunt, 1965, p. 284).

In a further attempt to shed knowledge on this controversy, an analysis was made of saccharine solution consumption on the day of irradiation when saccharine was the only fluid presented. The result of this analysis (Table 9 and Table 10) indicated that there were no important differences in saccharine consumption on the day of irradiation. Therefore, it can be concluded that the Aversion Index is independent of the amount of saccharine ingested during presentation of the conditioned stimulus. This result poses a question to one of the explanations: If the x-radiation caused a disturbed physiological state, why did it not affect the amount of saccharine ingested in the period most immediate to the irradiation? The answer to this question is not clear, nor is it clear how the other problems previously posed can best be handled. Certainly, further research, directed towards the particular nature of the effects of ionizing radiation, will add to our understanding of the problems.

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APPENDIX

TABLE A

Pre-irradiation and Post-irradiation
Consumption of Water and Saccharine

	Consump. Day 3 & Day 4			Comsump. Day 6 & Day 7		
GROUP	Sacc. ml.	Water ml.	Avg. Total ml.	Sacc. ml.	Water ml.	Avg. Total ml.
5 m - 0 r	129	143	45.3	238	51	48.2
5 m - 90 r	164	95	43.2	163	64	37.8
5 m - 170 r	246	80	54.3	158	117	45.8
5 m - 340 r	259	97	59.3	103	132	39.2
3 h - 0 r	114	107	44.2	178	60	47.6
3 h - 90 r	166	93	43.2	240	29	44.8
3 h - 170 r	223	84	51.2	312	42	59.0
3 h - 340 r	214	96	51.7	197	90	47.8
9 h - 0 r	155	61	43.2	212	36	49.6
9 h - 90 r	190	71	43.5	246	42	48.0
9 h - 170 r	167	142	51.5	154	167	53.5
9 h - 340 r	169	109	46.3	177	74	41.8