

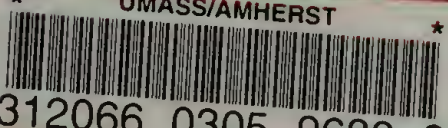


University of  
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## Emergence of stimulus bound drinking with a reinforcement contingency,

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EMERGENCE OF STIMULUS BOUND DRINKING  
WITH A REINFORCEMENT CONTINGENCY

A Master's Thesis

by

Herman Lewis

Submitted to:

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of the  
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EMERGENCE OF STIMULUS BOUND DRINKING  
WITH A REINFORCEMENT CONTINGENCY

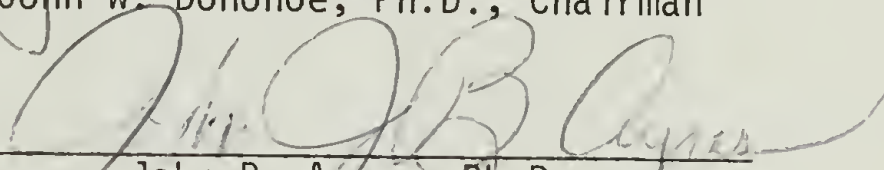
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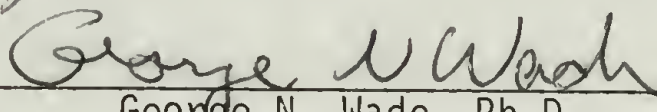
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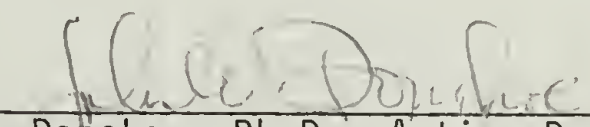
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## ABSTRACT

The experiment tested the hypothesis that contingent offset of electrical stimulation of the lateral hypothalamus serves as adventitious reinforcement in the formation of stimulus bound behaviors. Animals were paired in a yoked control design. Electrical stimulation of the brain (ESB) was delivered for 60 seconds. Stimulation was turned off contingent on the lead animals licking a drinking tube. Yoked animals received ESB contingent on the lead animals behavior. Lead animals exhibited more drinking behavior than control animals as measured by pre-treatment and post-treatment drinking rates during ESB. Results support a reinforcement interpretation of stimulus bound behaviors.

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## INTRODUCTION

Stimulus bound behavior is defined as behavior beginning soon after the onset of stimulation and terminating with the offset of stimulation. Stimulus bound behaviors were first observed by Hess (1943) who reported that ESB induced eating in cats. Since then, other investigators have found many behaviors induced by brain stimulation in several species. These include: eating in cats (Coons, 1963), drinking in goats (Andersson and McCann, 1955), aggression in cats (Flynn, 1967), hoarding in rats (Herberg and Blundell, 1967), gnawing in rats (Roberts and Carey, 1965), male copulatory behavior in rats (Caggiula and Hoebel, 1966), and aggression in rats (Panksepp and Trowill, 1969).

The present research was designed to test the reinforcement hypothesis suggested by Trowill (unpublished). Trowill notes that three possible sources of reinforcement exist in the elicitation and maintenance of stimulus bound behaviors. They are: 1) the goal object and its parameters, 2) the particular response independent of the goal object, and 3) the electrical stimulation, which apparently controls the occurrence of the response. The proposed experiment was designed to test the hypothesis that the formation of stimulus bound drinking could be at least partially explained by sources of adventitious reinforcement associated with the electrical stimulation in the normal stimulus bound situation. In this experiment the role of stimulation offset occurring contingently with the behavior (drinking) was investigated.

The hypothesis that contingent offset of ESB serves as adventitious

reinforcement in the formation of stimulus bound behaviors was suggested by Trowill (unpublished). The offset of stimulation as the important shaping factor of the behavior implies a negative state associated with the stimulation which occurs sometime before the offset of stimulation. This aversive state sets the stage for the occurrence of stimulation offset to be reinforcing. The ambivalent (positive, negative) nature of the stimulation has been investigated by a number of workers: Bower and Miller (1958), Steiner, Beer, and Schaffer (1969), and Mendelson and Freed (1973). These investigators have shown that: 1) animals will perform to escape long durations of positive self-stimulation when the stimulation is longer than 1 to 2 seconds; 2) animals prefer signaled over unsignaled positive reinforcement; and 3) animals will learn to escape self-produced rates of stimulation when these rates are "played back" to them. These studies indicate the involvement of an aversive state associated with the long durations of stimulation associated with ESB in the stimulus bound situation.

A number of observations argue against this escape interpretation. Chisolm and Trowill (1972) suggest that animals will learn to activate relatively long durations of stimulation (up to 30 seconds) with or without control of the offset of stimulation. The effect of increasing the electrical intensity seems to be to increase the preferred duration of stimulation. Chisolm and Trowill (1972). A second argument against the aversive stimulation interpretation is apparent from observations of animals. There is no indication of "aversive like" rodent behavior such as crouching, squealing, jumping, or defecating during stimulation, Trowill (unpublished). Valenstein's (1970) non-specific motivational interpretation (prepotency) suggests that the behavior induced by ESB is

tied to the execution of the behavior as a reinforcement event rather than to the consequences for the animal. Valenstein proposes that the stimulation does not possess an immutable relationship with the emerging (elicited) behavior pattern. The prepotency hypothesis suggests that the particular behavior elicited had a high probability of occurrence at the time of ESB. Thus, Valenstein proposes that the response emerges from the coincidence of an elevated drive state for the particular response and the occurrence of electrical stimulation. Valenstein (1970) proposes that the elevated motivational state is imposed by the stimulation and acts upon a specific response hierarchy from which the emerging behavior is elicited. Chisolm (1971) in an attempt to manipulate pre-potency, found that a response (drinking) paired with stimulation was not sufficient to influence the formation of a particular response. Valenstein's prepotency hypothesis (1969) also suggests that onset of stimulation might be a controlling factor in the formation of response patterns. Chisolm and Trowill (1972) in a study in which the onset of stimulation occurred during a particular response, failed to support the onset hypothesis.

The role of reinforcement in the formation of stimulus bound behaviors may account for the formation of multiple independent behaviors such as feeding, drinking, and gnawing, as well as for the multiple response contingencies such as the nature of the goal object, the particular response elicited and the nature of stimulation. Pilot data collected by the author gave some indication that the nature of the electrically elicited act may be determined by the response occurring at the time of offset of stimulation. That is, animals could be shaped to drink with the offset of ESB contingent on drinking. Six of ten subjects which exhibited vigorous locomotor-exploratory behavior were shaped to engage in a particular

stimulus bound behavior, (eating, drinking, or gnawing).

The proposed experiment was designed to test the hypothesis that formation of stimulus bound drinking and other stimulation induced behaviors can be at least partially explained by the adventitious control of electrical stimulation of the brain provided by the occurrence of stimulation offset.

## METHOD

Subjects. The subjects were 20 Charles River, male, albino rats, approximately 90 to 120 days old, weighing 300 to 400 grams at surgery. They were housed with free access to Purina Lab Chow and water available in their home cages. Each animal was food deprived 17 hours prior to surgery.

Apparatus. For pre-treatment, treatment, and post-treatment I phases, subjects were tested in a 14 x 18 x 18 inch high fiber board box with a plexiglass front. Light, ventilation, and white noise were provided in the chamber. On one side of the box was mounted a regular drinking spout 1½ inches above the grid floor. A drinkometer panel (Grason Stadler) was used to record discrete licks on the drinking tube. The presentation of trials during screening, treatment, and reward tests were initiated by the experimenter via a hand-held switch which activated conventional programming and recording equipment. Pre-treatment and post-treatment phases were initiated by fully automated equipment.

The post-treatment II phase was conducted in a different rectangular plexiglass chamber with a grid floor. The drinking tube placement was 1½ inches above the grid floor. All presentations were activated and recorded by a Nova computer, which was programmed to give the same presentations as in post-treatment I.

The electrical brain stimulation for the experiment was given with a flexible cable attached to the electrode by means of a small connector. Sixty cycle sine wave stimulation was delivered to the animal from a 110 volt A.C. line via a step-down transformer. Relatively constant

current was obtained by placing a one megohm resistor in series with the animal. The current was regulated with a micropotentiometer.

### Procedure

Surgery. Each animal was anesthetized with Nembutal anesthesia (40 mg./kg.) and positioned in a stereotaxic instrument. Each animal was implanted bilaterally with stainless steel monopolar electrodes. The electrodes were insulated with Insul-X, except for .5 mm at the tip. Electrodes were implanted 1.5 mm posterior to bregma, 1.6 mm lateral to the midline, and 9.1 mm below skull top (Pellegrino and Cushman, 1967). Three stainless steel screws were attached to the skull to form a triangle around the electrodes. One screw served as a common for the electrodes. The screws and electrodes were cemented to the skull with cranio-plastic cement. Subjects were given one week of post-operative recovery in their home cages with ad lib chow.

Screening. Subjects were given 30 seconds of stimulation in the test chamber without the drinking tube for twenty trials to arrive at a current intensity and the most positive electrode site for each animal. Current was turned up until subjects exhibited vigorous locomotor-exploratory behavior. A current intensity was established for both electrodes. Current intensities were adjusted to the minimum value which would elicit forward searching locomotor-exploratory behavior.

Pre-treatment Test and Yoking Procedure. During pre-treatment, ESB was given for 60 seconds on a total of 40 trials with the drinkometer tube available. Subjects were stimulated for 60 seconds at the current level established in the screening session. Each trial was followed by a 60 second inter-trial interval (I.T.I.). In order to equate the lead

and yoked groups, animals were rank ordered according to the amount of drinking during pre-treatment. Animals were paired from highest to lowest by using a coin flip to determine yoked and lead animals. Lead animals determined the offset of stimulation by their drinking behavior or approach to the tube. The yoked animal paired with the lead animal was tested using the current intensity determined during screening. The offset of stimulation was contingent on the performance of the lead animal of the pair.

Treatment. Paired subjects received ESB every 60 seconds in the test chamber. During stimulation, the experimenter shaped lead animals to drink from the tube by contingently turning off the ESB immediately after the appropriate behavioral response. Animals exhibited intense locomotor-exploratory behavior during the initial shaping session and the experimenter began by successive approximation to turn off the stimulation as the animal approached the tube and touched it. Shaping progressed easily from approaches to the tube to licking the tube. The experimenter initially required two seconds of licking and then progressive increases of two seconds to terminate ESB. The criterion for the lead animal was raised until the response reached 10 or more seconds of licking on two consecutive trials, or until total trials during shaping reached 40.

Post-treatment Tests I and II. Upon reaching the criterion, subjects were unpaired and placed in the chamber for 40 trials of stimulation as in the pre-treatment test situation. Two sessions of 20 trials were given in the initial apparatus with the drinkometer tube available. Subjects were automatically stimulated for 60 seconds at the established current level. Each trial was followed by a 60 second I.T.I.

Post-treatment II was conducted in the second test chamber with the same conditions as post-treatment test I. Two sessions of 20 trials of 60 seconds of stimulation were given in the second test chamber. The number of licks during stimulation and the number of seconds licking during stimulation were recorded for each animal.

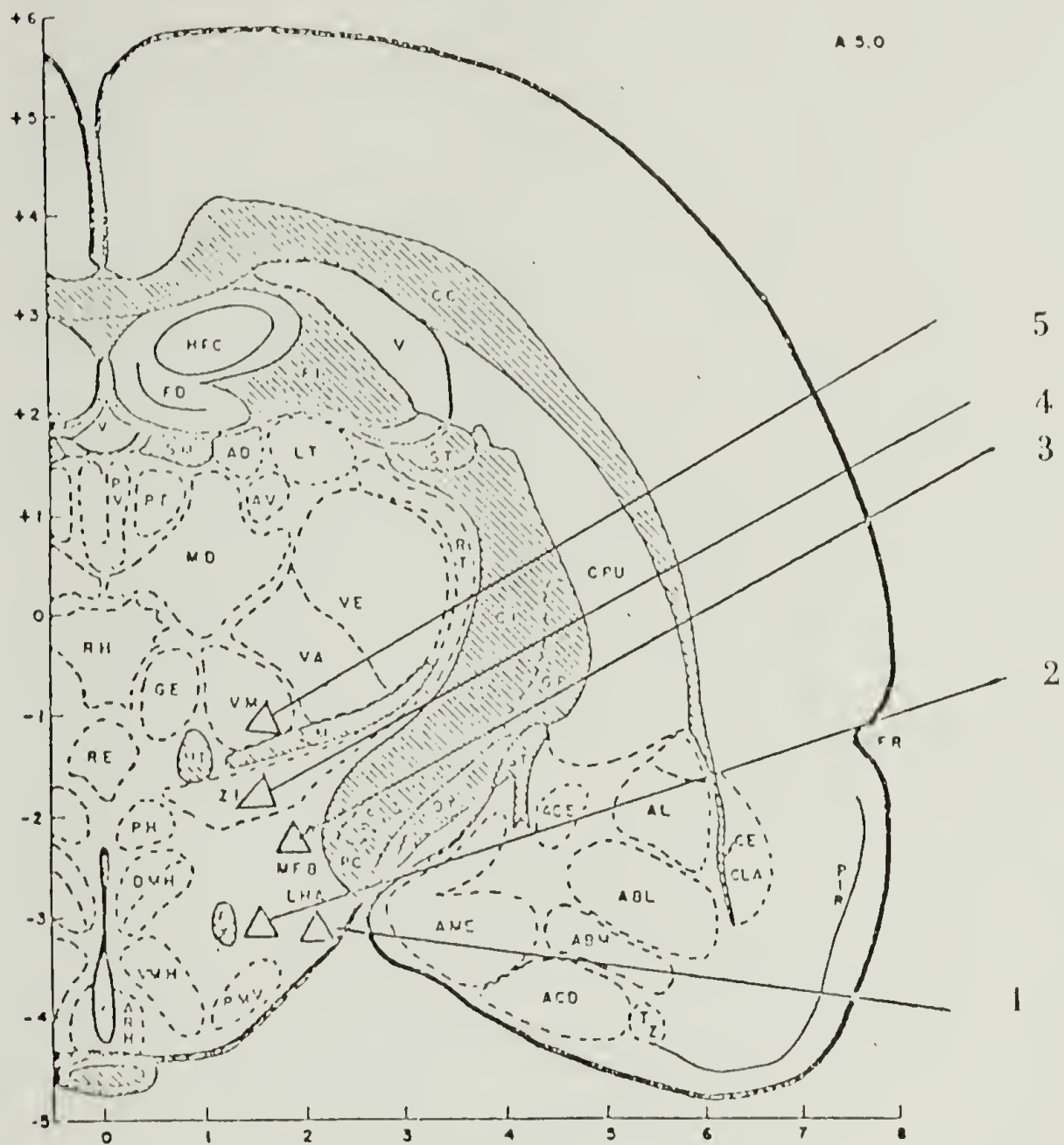
Self-Stimulation. Following post-treatment II, animals were tested to determine if the electrode site would support self-stimulation. This was done in the same apparatus described in post-treatment test II. Animals were shaped to bar press for the onset of .5 second pulses of ESB with the current being maintained at the level used in the other procedures. Upon acquisition of the response, the animals were allowed to bar press for 10 trials of .5 seconds of ESB at the established intensity.

## RESULTS

Histology. Figure 1 shows the areas of the brain which were stimulated. Table 1 shows the location in the brain of electrodes for each pair of animals. This comparison of anatomical locations shows that all electrodes were in areas of the brain which are regarded as positive reward sites. All placements were in the lateral hypothalamus (LHA) (Areas 1 and 2), median forebrain bundle (MFB) area 3, or areas more dorsal; Zona Incerta (ZI) area 4, and ventral thalamus (VTN) area 5. For lead animals, four electrodes were located in the lateral hypothalamus, five in the zona incerta and one in the ventral thalamus. For yoked animals, four electrodes were located in the lateral area, three in (ZI) and one in the ventral thalamus (Table 1). These locations overlap with areas from which stimulus bound behaviors have been elicited. Area 3 (MFB) is the site which could be expected to provide the most rewarding self-stimulation, with area 4 (ZI) and areas 1 and 2 (LHA) also being highly positive sites. The relation between these anatomical locations and the elicitation and maintenance of stimulus bound drinking is not discernable from the positive sites used in this experiment.

Screening. The screening procedure was used to determine current levels which would maintain locomotor-exploratory behavior during ESB. All animals exhibited consistent patterns of locomotor-exploratory behavior at the current levels (microamps) used (see Table II).

The current intensities which supported vigorous locomotor-exploratory behaviors also supported some other behaviors, such as grooming, gnawing, and tail carrying (Table II). These current levels aroused the animal



### Histology Summary

Fig. 1. Localization of Electrode Sites Used for Stimulation

- Area 1 Lateral Hypothalamus (LHA)
- Area 2 Lateral Hypothalamus (LHA)
- Area 3 Median Forebrain Bundle (MFB)
- Area 4 Zona Incerta (ZI)
- Area 5 Ventral Thalamus (V)

Table I. Localization of Electrode Sites for Pairs of Animals.

Area I. Lateral Hypothalamus (LHA)  
 Area II. Lateral Hypothalamus (LHA)  
 Area III. Median Forebrain Bundle (MFB)  
 Area IV. Zona Incerta (ZI)  
 Area V. Ventral Thalamus (VM)

LEAD	ELECTRODE LOCATION (AREA)	YOKED	ELECTRODE LOCATION (AREA)
M-11	2 (LHA)	M-02	3 (MFB)
M-12	3 (MFB)	M-01	3 (MFB)
M-13N	4 (ZI)	M03N	4 (ZI)
M-05	4 (ZI)	M04	3 (MFB)
M-09N	4 (ZI)	M06N	3 (MFB)
M-07	4 (ZI)	RM-2	4 (ZI)
M-08	1 (LHA)	M-10	4 (ZI)
M-15	3 (MFB)	M-19	2 (LHA)
M-18	4 (ZI)	RM-1	5 (VM)
M-17N	5 (VM)	M-14	3 (MFB)

TABLE II. SCREENING Stimulation Locus:  
Test for Preferred Side of ESB

Table shows the electrode location, current level number of screening trials and associated behaviors for individual animals

animal number	right side mA	left side mA	no. of trials		Comments	Final Disposition	
			rt	lft		Locus	Intensity
M-11	26		22	14		right	26
M-12	30		22	14		right	30
M-15		80	8	8		left	80
M-13n		28			motor effect (50mA)	left	28
M-18	30		18	23		right	30
M-07		80	16	17		left	80
M-08	10		12	12		right	10
M-05	18		20	13	grooming	right	18
M-17n	40				intense I-E behavior	right	40
M-09n	60					right	60
M-02	56		23	8	grooming, gnawing	right	56
M-01	26		30	8	grooming, gnawing	right	26
M-19	40		6	20	grooming	right	40
M-03n		56				left	56
M-2		50				left	50
M-10		40	6	6	grooming, gnawing	left	40
M-04		22	18	20		left	22
M-14		40	12	16		left	40
M-06n		30				left	30
M-1		50				left	50

and supported the forward searching, sniffing behaviors usually associated with positive reward and stimulus bound behaviors. The level of arousal was judged by the experimenter to be sufficient to maintain the behavior without causing animals to display the stereotyped motor activities sometimes associated with high current intensities.

Pre-Treatment. In order to establish that subjects were not pre-potent drinkers and to pair animals in terms of baseline drinking data, the pre-treatment test was given. During pre-treatment, baseline rates of drinking were established for each animal. The current levels established in screening were used for stimulation. None of the subjects exhibited consistent patterns of drinking during forty trials of stimulation. Drinking in total licks and seconds of drinking during pre-treatment are shown in Tables III and IV. These measures indicated that none of the animals fit the definition of stimulus bound drinkers.

None of the animals drank at consistent rates during stimulation, nor did they drink on most trials. They appeared to be drinking only as a part of the pattern of exploring the box. By observation, a considerable amount of similar drinking occurred while stimulation was off during the intertrial intervals.

The relative absence of drinking during the pre-treatment test provided a low baseline measure for pairing and for experimental manipulation. Pairing of the animals on the basis of drinking rates during the pre-treatment test was done according to the data in Table V.

The mean licks and mean seconds (Tables VI and VII) of licking were compared for the two groups during pre-treatment. The low level of licking during pre-treatment for both groups reflects the absence of pre-potent stimulus bound drinking. The mean latency for the lead animals

Total number of ticks for each animal during each phase of testing and treatment.

	EMALD										ZOKELD									
	N-11	N-12	N13n	N-05	W09n	N-07	N-08	N-15	N-18	L17n	N-02	M-01	N03n	N-04	N06n	N12	N-10	N-19	N-1	N-14
pre treatment	137	122	2	57	11	3	4	3	3	41	105	53	11	47	18	0	62	0	5	15
treatment	628	959	108	635	452	906	175	636	1199	294	283	1	1	56	11	1	28	127	0	3
post treatment (1)	132	776	55	11850	404	1320	824	808	108	237	112	0	0	7	1	0	1	25	1	40
post treatment (2)	755	287	41	2350	67	5235	21	40	52	262	1566	0	43	1	17	17	15	129	66	59

TABLE IV  
Total number of seconds locking for each animal during each phase of testing and treatment.

	LEAD												YOKED											
	W-11	W-12	W-13	W-05	W-09	W-07	W-08	W-15	W-18	W-17	W-02	W-01	W-03	W-04	W-06	W-2	W-10	W-19	W-1	W-1				
Pre treatment test	39	30	2	31	12	3	4	7	2	9	81	13	7	32	12	0	7	0	5	8				
treatment	162	176	24	122	103	155	34	112	130	121	50	1	1	23	4	0	13	29	2	3				
post treatment (1)	275	160	21	888	104	258	148	161	38	89	21	0	0	3	0	0	1	7	1	42				
post treatment (2)	170	66	31	171	91	879	13	26	18	124	279	0	9	1	8	15	12	13	27	23				

TABLE V Pairing of animals prior to treatment.

Pairing was done on the basis of number of seconds licking.

Pair Lead vs Yoked	Current in Microamps (MA)	Total licks during stimula- tion	Seconds licking during stimula- tion
<u>M-11</u>	26	137	39
M-02	56	405	81
<u>M-12</u>	30	122	30
M-01	26	53	13
<u>M-13N</u>	28	2	2
M-03N	56	11	7
<u>M-05</u>	18	57	31
M-04	22	47	32
<u>M-09N</u>	60	11	12
M-06N	30	18	12
<u>M-07</u>	80	3	3
RM-2	50	0	0
<u>M-08</u>	10	4	4
M-10	40	62	7
<u>M-15</u>	80	8	7
M-19	40	0	0
M-18	30	3	2
RM-1	50	5	5
<u>M-17N</u>	40	41	9
M-14	46	15	8

\* Lead animals underlined

Mean Number of Licks  
During Each Phase  
of Testing and Treatment

	LEAD	YOKED
Pre Treatment	38.8	61.6
Treatment	599.2	51.3
Post Treatment (1)	982.0	18.7
Post Treatment (2)	911.0	191.3

Mean Number of Seconds  
Licking During each Phase  
of Testing and Treatment

	LEAD	YOKED
Pre Treatment	13.9	16.5
Treatment	113.9	12.6
Post Treatment (1)	214.2	7.5
Post Treatment (2)	188.9	38.7

during pre-treatment was 31.2 seconds. Latencies for yoked animals were not recorded. The mean licks during stimulation for lead animals was 38.8 and for yoked animals 61.6 (Table VII). A t-test for the difference between means shows that the two groups did not differ significantly during the pre-treatment test ( $t = .54, df = 18, p < .25$ ).

Electrode locations were not related to drinking rates during pre-treatment.

Treatment. During the initial trials of shaping all animals exhibited forward searching, sniffing behavior. ESB was terminated when the lead animals approached the drinking tube. Lead animals began to orient themselves toward the drinking tube and to lick the drinking tube. Nine of the ten lead animals reached the criterion of 10 seconds of drinking on two consecutive trials. Table VI shows that mean number of licks for lead animals increased during treatment as compared with pre-treatment. A much higher level of licking by the lead animals during treatment as compared to yoked animals is apparent from the data. The latency for the lead group decreased to 22.4 seconds during treatment. No latency data were recorded for the yoked group. Mean seconds of licking (Table VII) increased for the lead group, showing that the drinking behavior for lead animals became more consistent than for yoked animals during treatment. The mean seconds drinking for leads during treatment was 599.2 seconds. To demonstrate the difference in drinking behavior during treatment a percentage drinking score was computed to reflect the amount of drinking during treatment relative to the total amount of drinking during both pre-treatment and treatment. For example, if an animal licked 10 times during pre-treatment and 20 times during treatment, his percent drinking score for treatment would be 66%.  $100\left(\frac{\text{Treatment}}{\text{Pre-treatment} + \text{Treatment}}\right) = 20/10 + 20 = 66\%$

A score of 50% during treatment would mean animals were drinking equally during pre-treatment and treatment. The percent drinking score for the lead group was 94% during treatment and for the yoked group 39%.

The lead animals significantly increased their licking during treatment. A t-test for the difference between the percent drinking score and the expected drinking score (50%) for the lead animals was significant, ( $t = 26.6$ ,  $q$  df,  $p < .001$ ). The yoked animals decreased their drinking during treatment relative to pre-treatment, although not reliably. A t-test was not significant, ( $t = .94$ ,  $df = 9$ ,  $p < .4$ ). The lead animals drinking rates were increased significantly above the yoked group by the treatment. A t-test between the lead and yoked group was significant ( $t = 4.78$ ,  $df = 18$ ,  $p < .001$ ). Two of the lead animals (M18, M09N) reached the criterion of 10 seconds on two consecutive trials in less than 20 trials (see appendix). These pairs of animals were terminated with one session (20 trials) of treatment. One animal (M-13N) failed to reach the criterion. The results of the treatment phase showed that the termination of ESB could be used in shaping a specific response (drinking).

Drinking rates were not related to the anatomical location of electrodes during treatment.

Post-Treatment I. Post-treatment test I was given to test the persistence of the drinking established in the treatment phase and to compare post-treatment drinking with pre-treatment.

Table VII shows that lead animals continued to drink at elevated rates. The drinking rates for seven of ten lead animals continued to increase, while the rates of three declined slightly during the two sessions (40 trials) of post-treatment I. The mean number of seconds licking (Table VII) and the total licks (Table VI) both show increases in drinking rates

above pre-treatment and treatment rates for the lead group. Lead animals made an average of 982 licks during post-treatment test I as compared to 19 for yoked controls. The latency for the lead group was 21.6 seconds during post-treatment I. Relative drinking rates between the group were computed so comparisons could be made with pre-treatment. A percent drinking score of post-treatment I drinking relative to pre-treatment was computed. For lead animals, 93% of licking was done during post-treatment I and 22% for yoked animals as compared to pre-treatment. A t-test between the percentages of the lead and yoked groups was significant ( $t = 6.19$ ,  $18df$ ,  $p < .001$ ). A comparison of the percent drinking score, 93%, with the expected score, 50%, shows the difference which the treatment effect had on the lead group which persisted during post-treatment I ( $t = 17.1$ ,  $df = 9$ ,  $p < .001$ ). In comparison, the yoked group shows a significant decrease in post-treatment I below the expected drinking score of 50% to 22%. A t-test was significant ( $t = 2.4$ ,  $df = 9$ ,  $p < .025$ ). These results indicate that the treatment procedure was successful in significantly increasing and maintaining drinking rates for lead animals above pre-treatment.

Drinking rates during post-treatment I could not be correlated to specific electrode sites.

Post-Treatment II. Post-treatment II was given in a different test chamber to test the effects of a different environment and to determine the durability of the ongoing drinking behavior established in treatment which continued during post-treatment test I.

Mean licks for lead animals decreased slightly from 982 on the 40 trials of post-treatment I to 911 for the 40 trials of post-treatment II. Means seconds drinking decreased from 214.2 seconds on 40 trials of post-

treatment I to 188.9 seconds on 40 trials of post-treatment II (Tables VI and VII). Mean drinking levels decreased for seven of the ten lead animals (Tables VI and VII).

Although drinking rates decreased somewhat for lead animals, six of the ten animals were still drinking at consistently high rates. The four lead animals whose drinking rates declined most appeared to sit for the full 60 seconds of ESB, exhibiting little or no locomotor-exploratory behavior. The average latency for lead animals during post-treatment II was 22.8 seconds.

One control animal (M-02) began drinking reliably during the 40 trials of post-treatment II (see Appendix). This animal exhibited high rates of licking for the first session of post-treatment II, but returned to low levels during the second session of 40 trials. Eight of ten yoked animals drank at higher levels in the new test chamber than in the post-treatment I test chamber. Six of these animals drank at their highest rates during the 40 trials of post-treatment II (Table V).

Lead animals had a mean of 89% drinking on post-treatment II relative to total drinking on pre-treatment and post-treatment test I. Yoked animals exhibited a relative percentage of 60% on post-treatment test II. The lead animals continued to maintain the difference in drinking rates from the baseline rates of pre-treatment. The percent drinking score during post-treatment II was 89% for lead animals, compared to the expected value of 50% if drinking remained at pre-treatment levels. This difference was significantly above pre-treatment levels ( $t = 13.50$ ,  $df = 9$ ,  $p < .001$ ). Yoked animals drank somewhat more during post-treatment II as compared to pre-treatment and their percent drinking scores returned above pre-treatment levels to 60%. A t-test for the difference from pre-treatment percent drinking was not significant, however ( $t = .79$ ,  $df = 9$ ,  $p < .2$ ). When

TABLE VIII

## TEST FOR SELF-STIMULATION

24

Total Bar Presses Per Minute During Bar Press  
Acquisition and for Ten Trials of Half Second  
Pulses of ESLH

	ACQ	TRIALS										mean
		1	2	3	4	5	6	7	8	9	10	
M-11	127	15	22	29	35	37	17	40	47	39	49	33.0
M-12	588											
M-13N	150	8	5	7	12	14	14	11	18	18	21	12.8
M-05	244	24	36	21	40	34	37	43	42	38	41	35.6
M-09N	446	11	8	18	13	12	0	0	10	30	22	12.4
M-07	554	16	8	13	15	35	46	12	39	42	38	26.4
M-15	1259											
M-18	957											
M-17N	223	7	0	23	6	23	24	2	32	17	14	14.8
RM-2	230	48	30	46	47	45	46	42	36	45	47	43.2
RM-1	248	15	28	33	49	45	34	38	21	36	37	36.6
M-04	400	25	39	26	22	35	27	38	27	2	38	27.9
M-14	169	25	17	0	31	19	0	0	11	48	49	20.0
M-03N	1797	23	10	11	8	11	2	0	6	4	9	16.8
M-10	375	21	15	0	6	4	12	30	23	13	19	14.3
M-06N	200											

\* Animals excluded due to lost skull caps -(M-01, M-02, M-08, M-19)

One lead animal and three yoked animals were not tested due to lost skull caps. The acquisition of the bar press response indicates that the current levels can be regarded as positively reinforcing for both lead and yoked animals. Performance on the self-stimulation test shows no direct correlation with electrode locations. This result indicates that the nature of the stimulation initially had a positive rather than negative reinforcement value for both groups.

Scores for both groups show a significant correlation on the self-stimulation test and the drinking rates during post-treatment tests I and II. The mean bar presses during self-stimulation were rank ordered with the mean number of licks during post-treatment tests I and II to demonstrate the relationship. A Spearman rank correlation coefficient was significant ( $r = .60, p < .05$ ).

## DISCUSSION

Stimulus bound behaviors have been defined as behaviors beginning soon after the onset and terminating soon after the offset of electrical stimulation of specific brain sites (Valenstein, et al., 1969). The specific behavior patterns of most animals begins one to two seconds after the onset of stimulation and stops abruptly after its termination. However, Valenstein has noted that in a few instances, the response latency on a 30 second stimulation test may be as long as 15 seconds and the duration of response patterns may be variable. Some animals respond for almost the entire period of stimulation but a few are observed to respond for only about a 5 second period.

The hypothesis tested in this experiment was that the offset of electrical stimulation serves as a source of adventitious reinforcement in the formation of stimulus bound behaviors. The hypothesis was tested by making the offset of ESB contingent on a pre-selected response, drinking, and noting if that response increased above a baseline level. The offset hypothesis suggests that a negative state is associated with stimulation offset and animals will perform to escape this negative state. The acquisition, growth and maintenance of drinking by the lead animals for whom the contingency was in effect during the experiment supports the offset hypothesis. The drinking behavior observed fits the description of the behavior of stimulus bound animals as described in the literature and the results of each phase of the experiment, including screening, pre-treatment test, treatment, post-treatment tests I and II and self-stimulation were as described below, consistent with the predictions of the offset hypothesis.

During screening, the behavior of all animals during ESB showed patterns similar to those observed by other investigators. The typical forward searching, sniffing behaviors usually associated with stimulus bound positive self-stimulation animals were obtained from all animals during the screening sessions prior to pre-treatment. The drinking patterns during the pre-treatment test showed that animals that did drink could not be considered stimulus bound at that point. Animals were not drinking consistently and drinking was not confined to the periods of stimulation. However, the behavior patterns that emerged during treatment, when the contingency between drinking and the offset of stimulation was first established, looked much like classic stimulus bound behavior. There was a gradual growth of the behavior from a baseline rate to a highly consistent pattern of drinking and this drinking was confined to the periods of ESB. The latencies for lead animals for whom ESB offset was contingent decreased during treatment, even with the potentially long (60 seconds) period of stimulation used in this research. The amount of licking was also high enough to fit the stimulus bound definitions typically employed. In contrast, the drinking bouts of yoked animals who received the same number and temporal distribution of stimulation periods but with no contingency between drinking and offset of ESB, did not increase during treatment and did not fit the descriptions of stimulus bound behaviors.

The post-treatment tests in which there was no necessary relationship between stimulation offset and drinking, showed that the behavior continued to grow and that it persisted for a relatively long period of 80 trials and at high rates of speed for all animals. The post-treatment results indicated that the behavior of the lead animals acquired when offset of ESB and drinking were contingent continued to fit the defining conditions

the percent drinking scores of lead and yoked groups were compared during post-treatment II, the difference was reliable. A t-test was significant for the difference between the two means ( $t = 2.29$ , 18 df,  $p < .05$ ).

To evaluate the change in drinking during post-treatment II, the percent drinking scores for lead and yoked groups relative to total drinking on both post- and pre-treatment tests were compared by taking the difference scores (percentages) between lead and yoked animals for post-treatment tests I and II. A t-test was significant ( $t = 2.81$ , 18 df,  $p < .001$ ). To evaluate this significant difference in drinking rates, a t-test was done to compare the change for both groups from post-treatment I to post-treatment II. For the lead group, a t-test was not significant ( $t = .42$ ,  $df = 9$ ,  $p < .5$ ). To evaluate the difference in drinking rates for yoked animals during post-treatment II as compared to post-treatment I, a t-test was significant ( $t = 2.94$ ,  $df = 9$ ,  $p < .01$ ). These results indicated that the treatment effect continued to maintain the differences between the lead and yoked group during the (80 trials) of post-treatment I and II, even with the increase in drinking by the yoked animals during post-treatment II. The differences were still highly significant, although lead animals began to respond at lower rates and control animals began to exhibit higher rates of drinking in the new environment of post-treatment test II.

#### Test For Self-Stimulation

Table VIII shows data for lead and yoked animals during the test for self-stimulation. Six of ten yoked animals and six of ten lead animals acquired the bar press for half second pulses at the current intensity used during treatment and post-treatment phases. Three lead animals and one yoked animal failed to acquire the bar press response.

of stimulus bound behaviors. The stimulation came on, the behavior began shortly after, continued during stimulation and terminated shortly after the offset of stimulation.

According to the hypothesis tested here, the behavior persisted during the post-treatment tests because it happened to occur just prior to ESB offset and was reinforced adventitiously by the same reinforcement which was responsible for its acquisition. Under the conditions of the normal stimulus bound screening sessions, the stimulation comes on and goes off in the presence of the goal object independently of the animals behavior. The fact that the behavior of lead animals was maintained under the reinforcement conditions of the normal stimulus bound situation suggests that once a behavior has been adopted, sufficient adventitious reinforcement exists, without the necessity of the offset contingency, to maintain the behavior. In other words, the manipulation of the offset of stimulation during treatment was sufficient to elevate the level of drinking to a point where it could be maintained by the adventitious reinforcement conditions that prevail in the normal stimulus bound situation.

The fact that yoked animals began to drink in the new environment of post-treatment also appears consistent with the patterns of behavior which appear under similar procedures in the literature. The drinking exhibited by yoked animals shows that the environmental conditions of the stimulus bound situation can affect the occurrence of a response (drinking) without changing the particular goal object or response. In the typical stimulus bound situation the availability, attractiveness, accessibility of goal objects and the size, shape and other conditions of the environment have an effect on the occurrence of a particular

response. Long exposure to ESB in the presence of consistent goal objects and a consistent environment also seems to increase the probability of animals eventually becoming stimulus bound. Valenstein (1973) has reported instances in which some animals took as many as 700 to 800 trials before any stimulus bound behaviors emerged. The large number of trials (120) leading up to post-treatment II may have set the stage for emergence of drinking by the yoked animals in the new environment. The new environment thus sets the stage for increased locomotor-exploratory behavior and increased interaction with an already familiar goal object, thus increasing the probability of the yoked animals engaging in stimulus bound drinking. This again indicates consistency between the typical stimulus bound screening procedure and the conditions of the post-treatment test in this experiment.

The fact that all animals appeared to be positive self-stimulators meets with similar observations about stimulus bound animals in general. The self-stimulation test showed that the onset of stimulation had a positive reinforcement value (animals would bar press for .5 second pulses). The typical stimulus bound animal is thought to be responding to the effects of positive brain stimulation and this experiment is shown to be the same by the self-stimulation test.

The behavior patterns which emerged during this experiment look like stimulus bound behaviors. The behavior patterns can be explained by the sources of reinforcement which exist in the typical stimulus bound situation. The stimulation and its parameters is the source of reinforcement which controls the occurrence of the behaviors in this experiment. The goal object and the response pattern are also thought of as sources which affect the emergence and maintenance of the particular

response (drinking). The contingent offset of ESB as a shaping factor implies a negative state associated with the long periods of stimulation. This aversive state sets the stage for the offset of stimulation to be reinforcing. The occurrence of the behavior during the stimulation accounts for the ability of this reinforcement mechanism to increase the duration and amount of drinking. The fact that these conditions can exist (although they do not necessarily exist) in the post-treatment test, and in the normal stimulus bound screening situation, would account for their ability to maintain the behavior at a consistently high level of responding under those conditions.

All of these results point to reinforcement provided by ESB offset as the controlling variable in the acquisition of stimulus bound behaviors. The comprehensive explanation of such behavior that a reinforcement hypothesis provides has been previously noted by Trowill (unpublished). The offset of stimulation as the important shaping factor of the behavior implies an aversive condition which the animal will attempt to escape. The occurrence of stimulus bound drinking with the offset of ESB contingent on the drinking behavior reflects the aversive condition which the animals attempts to escape and sets the stage for offset to be reinforcing. In this experiment, the fact that the latency of the drinking decreased as the drinking behavior was being shaped indicates a transformation of the stimulation from positive to negative. The decreased latency points to the conditions under which the drinking response is performed and indicates that the animals will learn to escape sooner and sooner in the stimulation period until the animal begins to respond as soon as the stimulation becomes aversive.

## The Offset Hypothesis

The occurrence of the offset, contingent on the drinking behavior, in the shaping procedure, sets the stage for the animals to gain and maintain adventitious control over the negative reinforcement associated with the stimulation by learning a response to escape these conditions. The stimulus offset interpretation of stimulus bound behavior would predict that the probability of occurrence or nonoccurrence of stimulus bound behavior should be a function of the probability of response occurrence during the stimulation and especially prior to the offset of stimulation (Trowill, unpublished). The probability of any response should depend on its strength relative to other stimulus bound responses. The occurrence of the response in the presence of stimulation is the necessary condition for the reinforcement associated with the offset of stimulation to become a reinforcing event, thus increasing the probability of the response occurring during the next stimulation period. For a response to be reinforced, it must occur prior to the conditions of reinforcement surrounding the offset of stimulation according to the offset hypothesis. In contrast, Valenstein's prepotency hypothesis suggests that a particular behavior is elicited from a hierarchy of prepotent responses and that the emerging behavior had the highest probability of occurrence at the time of ESB onset. Chisholm and Trowill (1972) discounted the involvement of reinforcement in the formation of stimulus bound behaviors as far as the onset of stimulation is concerned. By turning on ESB during the interaction of animals with a particular goal object, they found that this contingency did not increase the probability of that behavior becoming stimulus bound. The prepotency hypothesis, in contrast to the offset hypothesis, suggests that the stimulation does not possess

an immutable relationship with the emerging behavior pattern. The offset hypothesis which depends on the conditions surrounding the stimulation offset to provide reinforcement suggests an intricate involvement between stimulation and the emerging stimulus bound behavior. The importance of the prepotency notion to the offset hypothesis is noted by the fact that any behavior occurring during the negative conditions prior to offset can be reinforced. A prepotent behavior which has the highest operant level in the response hierarchy established by the conditions of stimulation is the most probable behavior to be reinforced by the offset of stimulation. That is, the high operant level of a behavior sets the stage for that behavior to be adventitiously reinforced.

In this experiment the occurrence of the offset of stimulation in an environment with a limited choice of goal objects (drinking tube) resulted in the acquisition of the particular response when the contingency between drinking and stimulation was made. This demonstrates that the experimental situation contains the prerequisites for natural behavior patterns to be influenced by chance association of ESB with a particular behavior in the acquisition of stimulus bound behaviors. As Trowill points out, the potency of reinforcement as a phenomenon is in its ability to account for the operation of multiple response contingencies (Trowill, unpublished). In this case, the response is determined by the animals' predisposition to drink (prepotency), the limited choice of goal objects, and the occurrence of electrical stimulation (ESB) (Trowill, unpublished). The fact that yoked animals began to drink in the new environment also appears consistent with the patterns of behavior which appear under similar procedures in the literature, such as the object switching test used by Valenstein. This further indicates that environ-

mental factors interact with the behavior in providing reinforcement contingencies.

The Valenstein prepotency hypothesis (1969) suggests that the onset of stimulation might be a controlling factor in the elicitation and formation of response patterns. Chisolm and Trowill (1972), in their study failed to support the onset hypothesis with regard to reinforcement. The occurrence of the onset of stimulation without the negative state of affairs associated with the stimulation would indicate the inability of onset to control the formation of stimulus bound behavior.

### Other Views

Chisholm and Trowill (1972), in a study of incentive shifts, have demonstrated that the nature and intensity of stimulation affected the rates of stimulus bound behaviors. They found positive and negative contrast effects with different concentrations of sucrose and different intensities of stimulation. Trowill (1971, unpublished) suggests that the goal object, the response and the electrical stimulation, all apparently play a reinforcement role in the formation and maintenance of stimulus bound behavior.

The apparent positive to negative change in the nature of stimulus bound current may provide incentive value for behaviors occurring contingently with the offset of stimulation. Trowill (unpublished) suggests that this need not imply an aversive state at the neural substrate level. It is possible that the animal receiving on-going stimulation during a stimulus bound screening session adopts a behavior that coincidentally occurs with the offset of stimulation because that behavior superstitiously appears to provide control over stimulation through its

chance association with the offset. This assumes that control itself is reinforcing in this situation. The behavior might be thought to acquire incentive value from the information it provides about the duration of stimulation.

An alternative explanation would involve a coping response interpretation. The animal would adopt a behavior which is associated with the stimulation in order to endure the relatively long periods of stimulation and the aversive nature of stimulation in the stimulus bound situation. Schiff, Rusak, and Block (1970) support this hypothesis. They found that the average duration of ESB accepted by rats in a shuttle box increased when rats were tested in the presence of another rat (male or female) or in a larger testing area, thus demonstrating an increased tolerance for the aversive stimulation. This suggests that environmental contingencies can influence the conditions under which animals will learn to interact with an available goal object to reduce the effect of the aversive stimulation.

Valenstein (1970) has speculated that the stimulation is tied to (or elicits) the behavior and that reinforcement may be sufficient to maintain the behavior. The confirmation of the offset hypothesis supports this view but fails to support the other prepotency notions of Valenstein et al. Steiner, Beer and Schaeffer (1969) and Bower and Miller (1958) found that rats would learn to escape self-produced rates of stimulation when their self-generated, pre-recorded patterns of ESB were "played back". Mendelson and Freed (1973) concluded that rats terminate ESB because it changes from rewarding to punishing when left on. These results suggest the aversive conditions under which the offset of stimulation becomes a reinforcing event according to the notions of the

offset hypothesis. The offset hypothesis is supported by both the findings of the Beer et al., and Mendelson and Freed studies.

A small percentage of animals have been described which immediately respond to stimulation with a specific behavior on the first trial and respond continuously at high rates during stimulation. The behavior shaped by the treatment procedure in this experiment closely resembles the behavior of another group of stimulus bound animals which appear to adopt a behavior in a learned fashion. The results of the present experiment indicate that the behavior which results from the manipulation of contingent offset to produce drinking is an example of animals learning to respond to the reinforcement contingencies in the normal stimulus bound paradigm.

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APPENDIX A

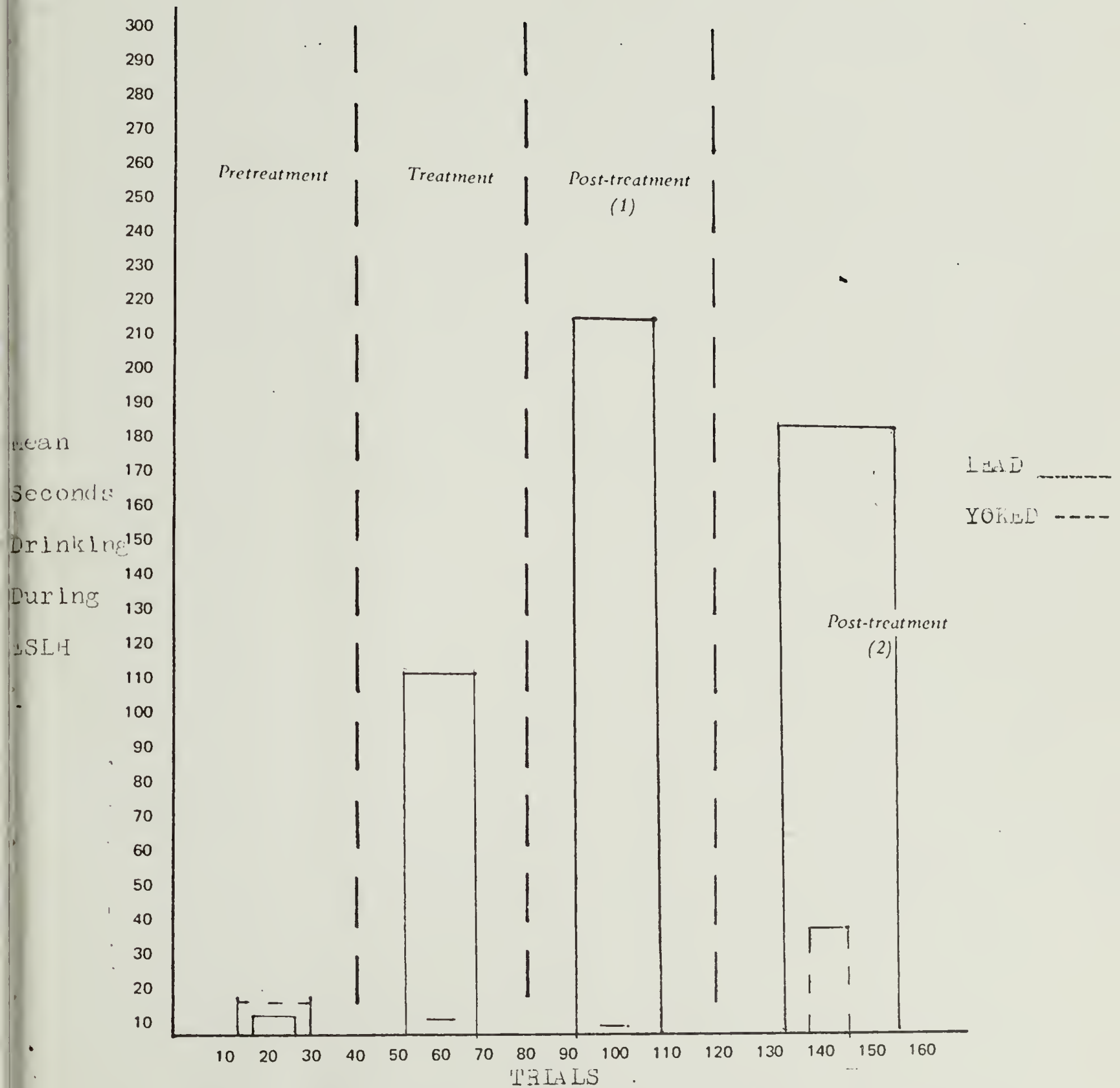


Fig. II Mean number of seconds drinking during stimulation for lead and yoked groups.

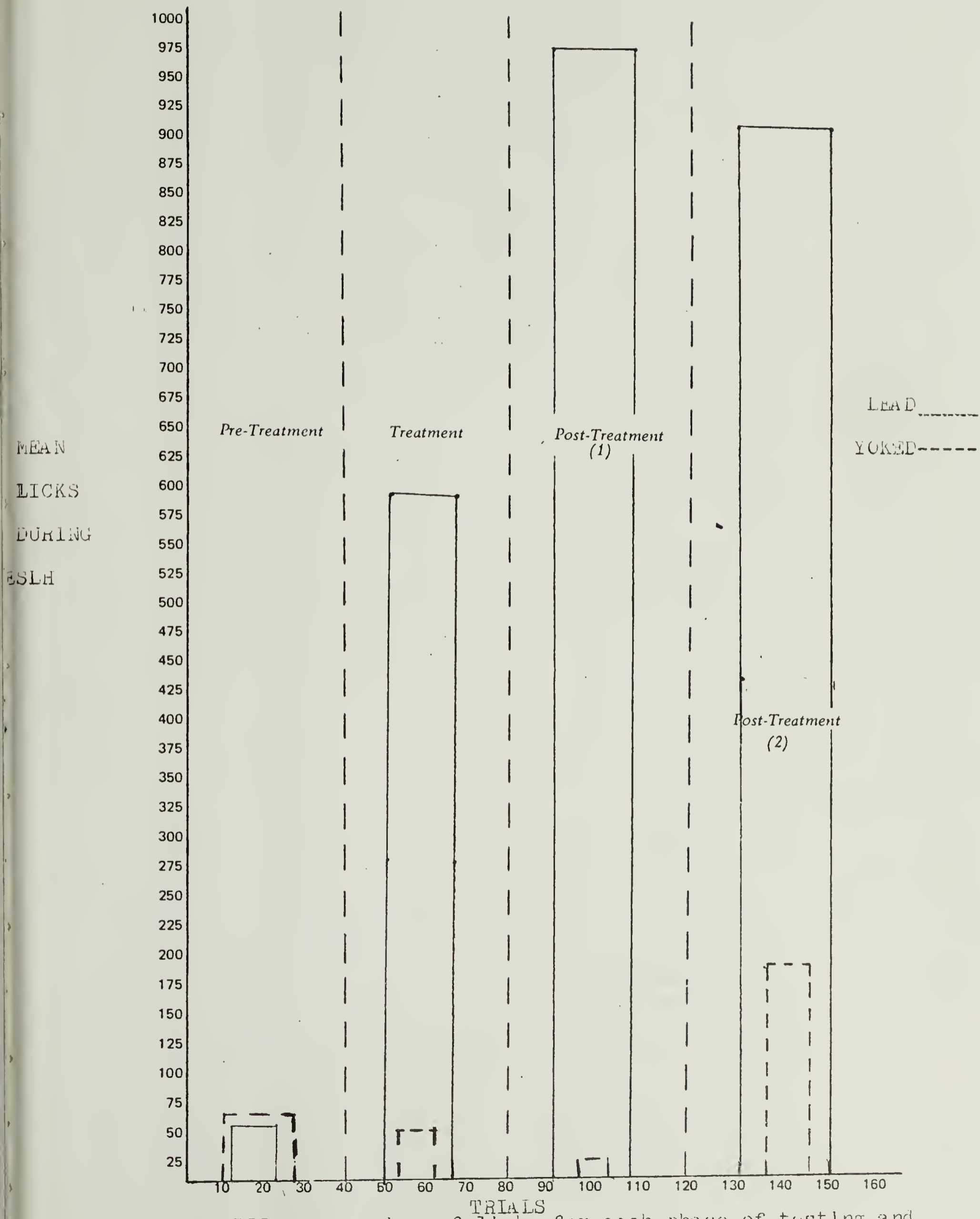


Fig. III mean number of licks for each phase of testing and treatment for lead and yoked groups.

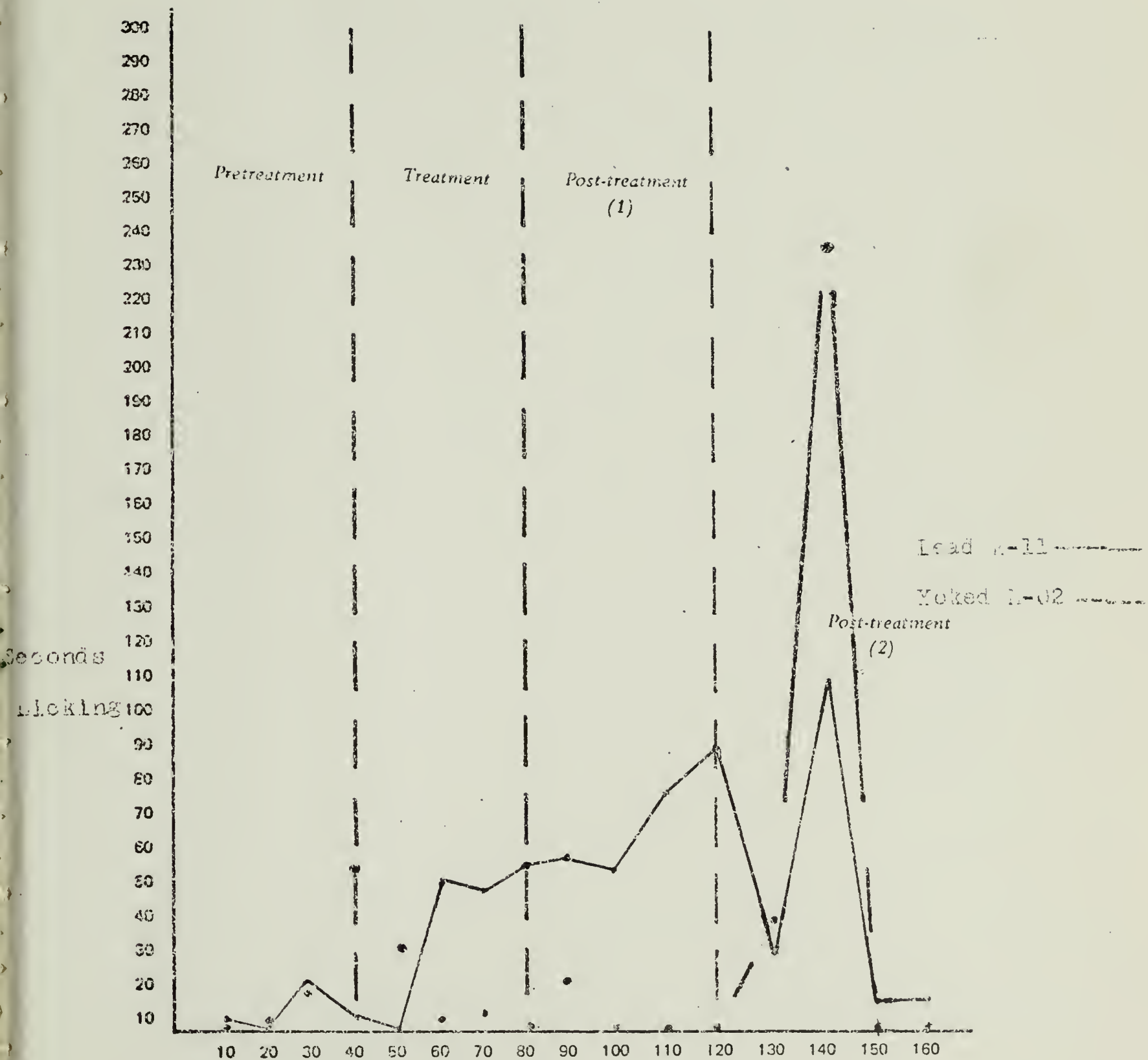


Fig. IV Number Of Seconds Licking during stimulation.

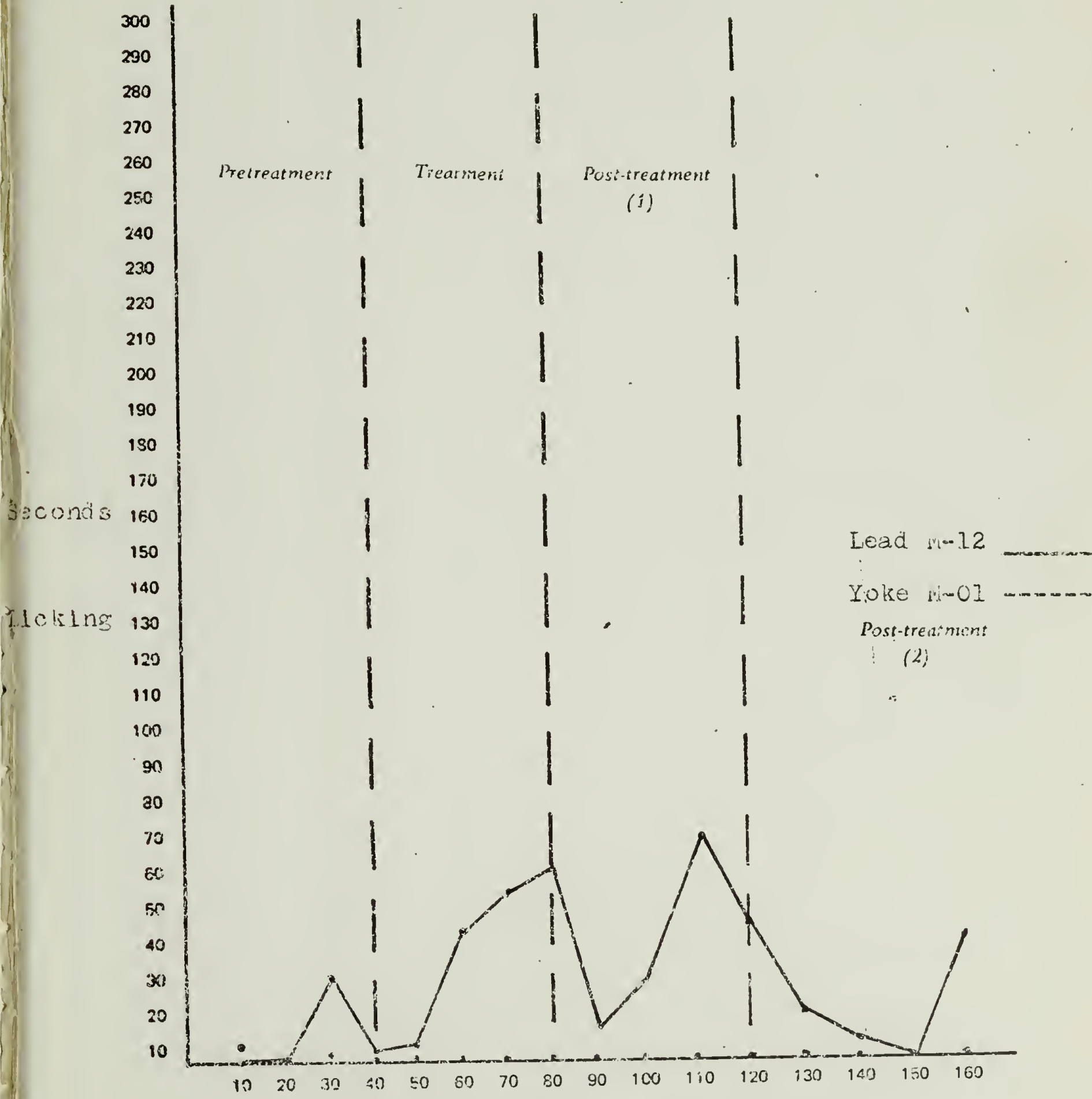


Fig. V Number of seconds licking

during stimulation.

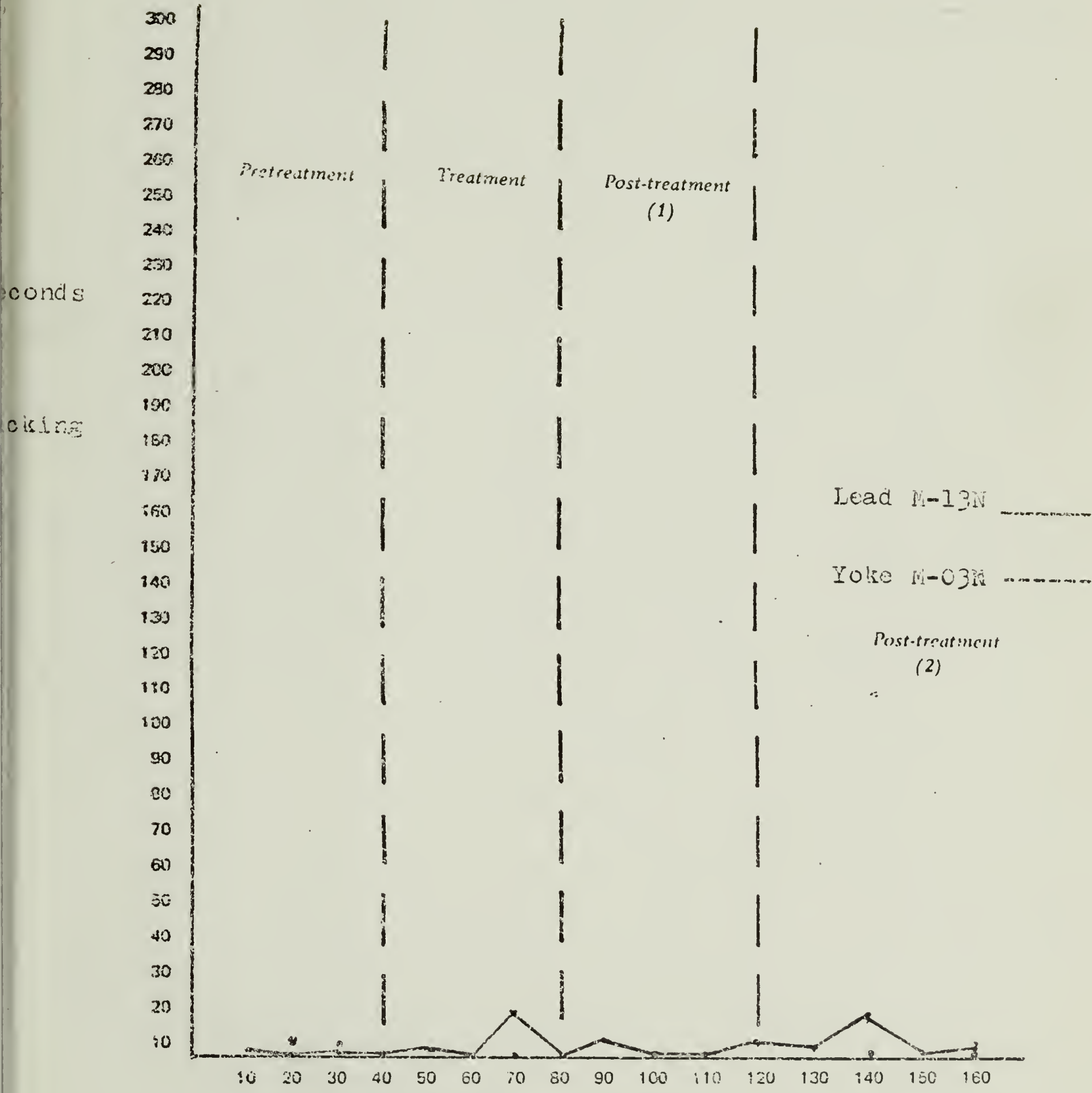


Fig. VI Number of seconds licking

during stimulation.

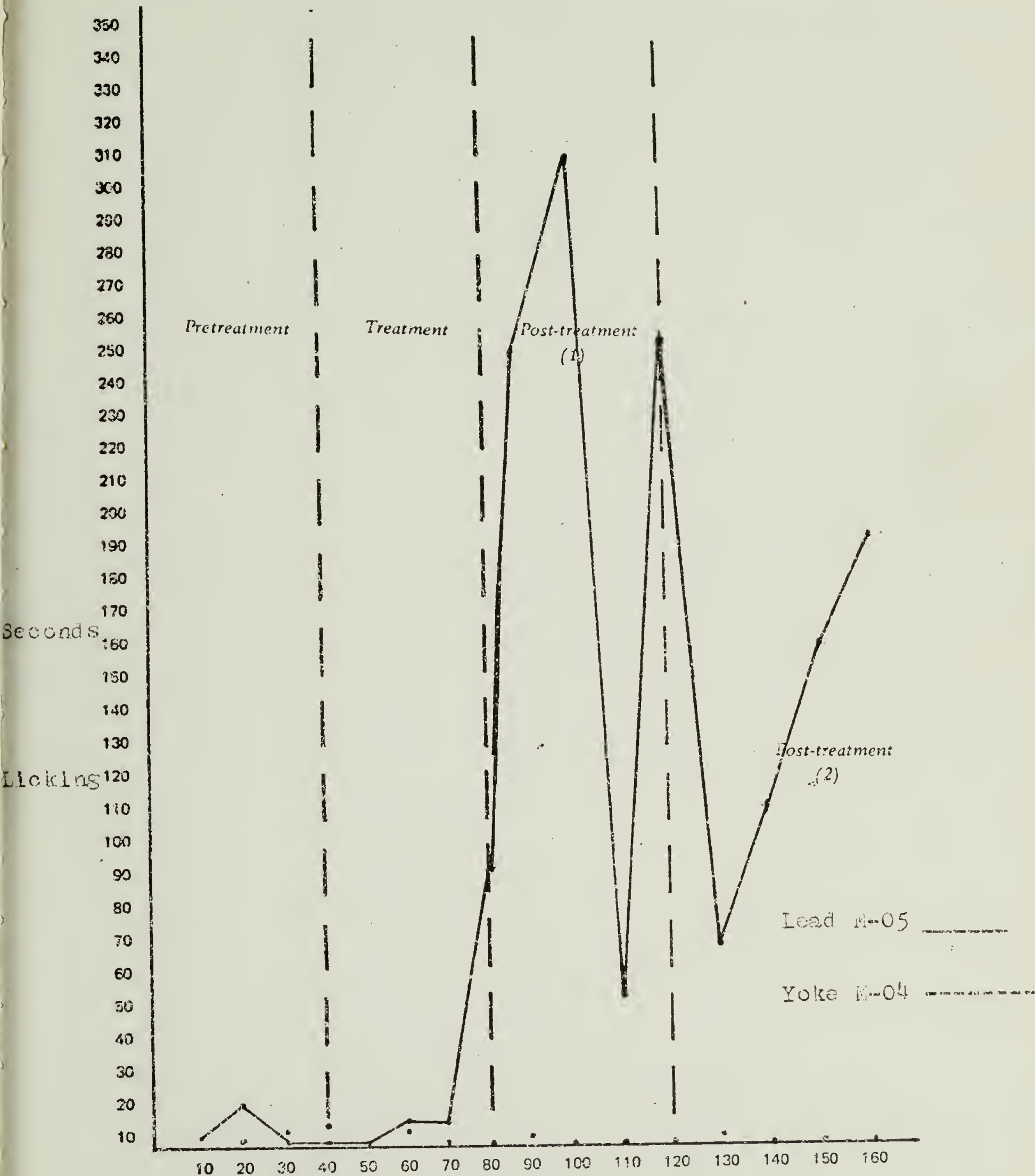


Fig. VII Number of seconds licking

during stimulation.

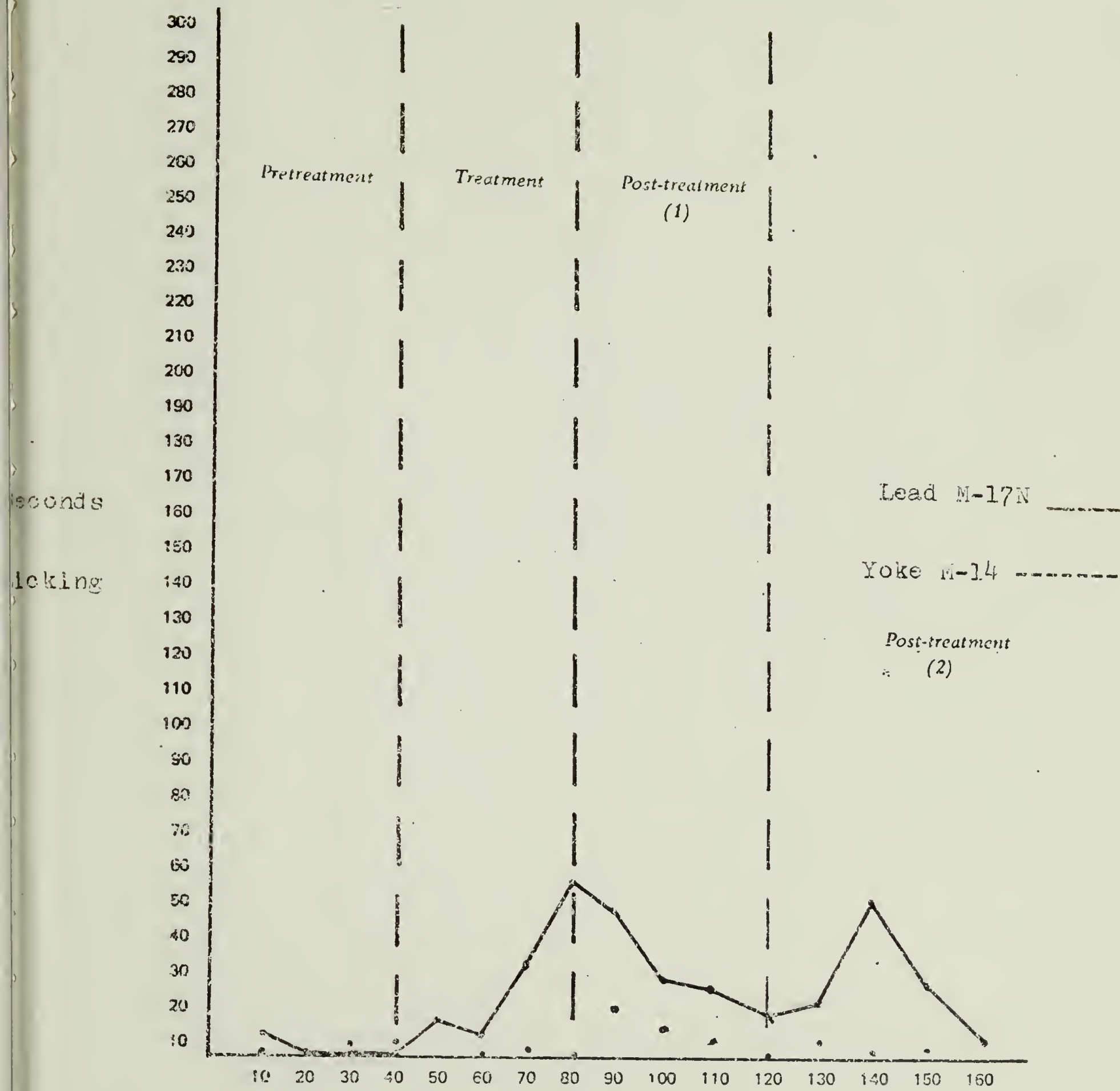


Fig. VIII Number of seconds licking

during stimulation

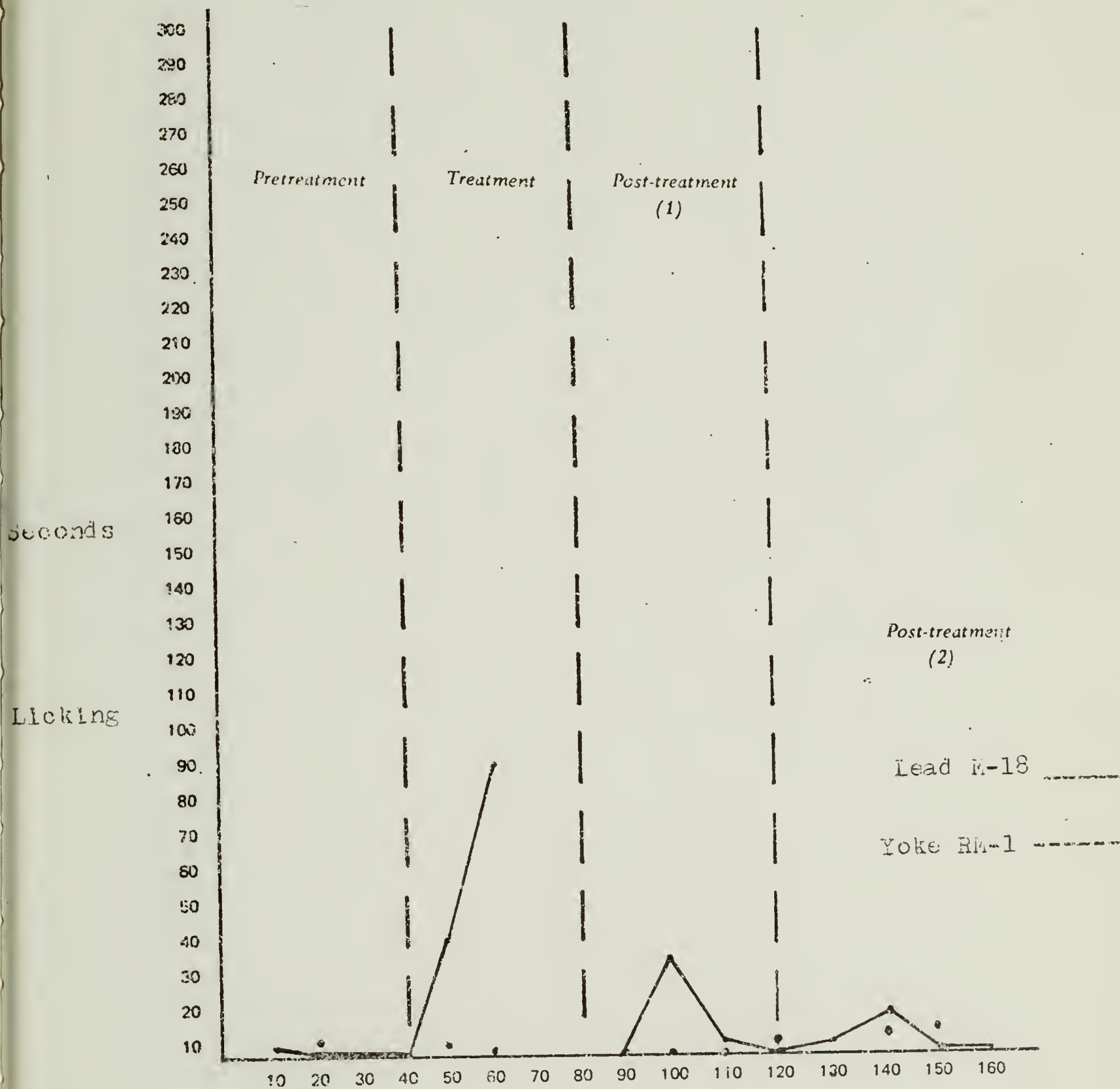


Fig. IX Number of seconds licking during stimulation.

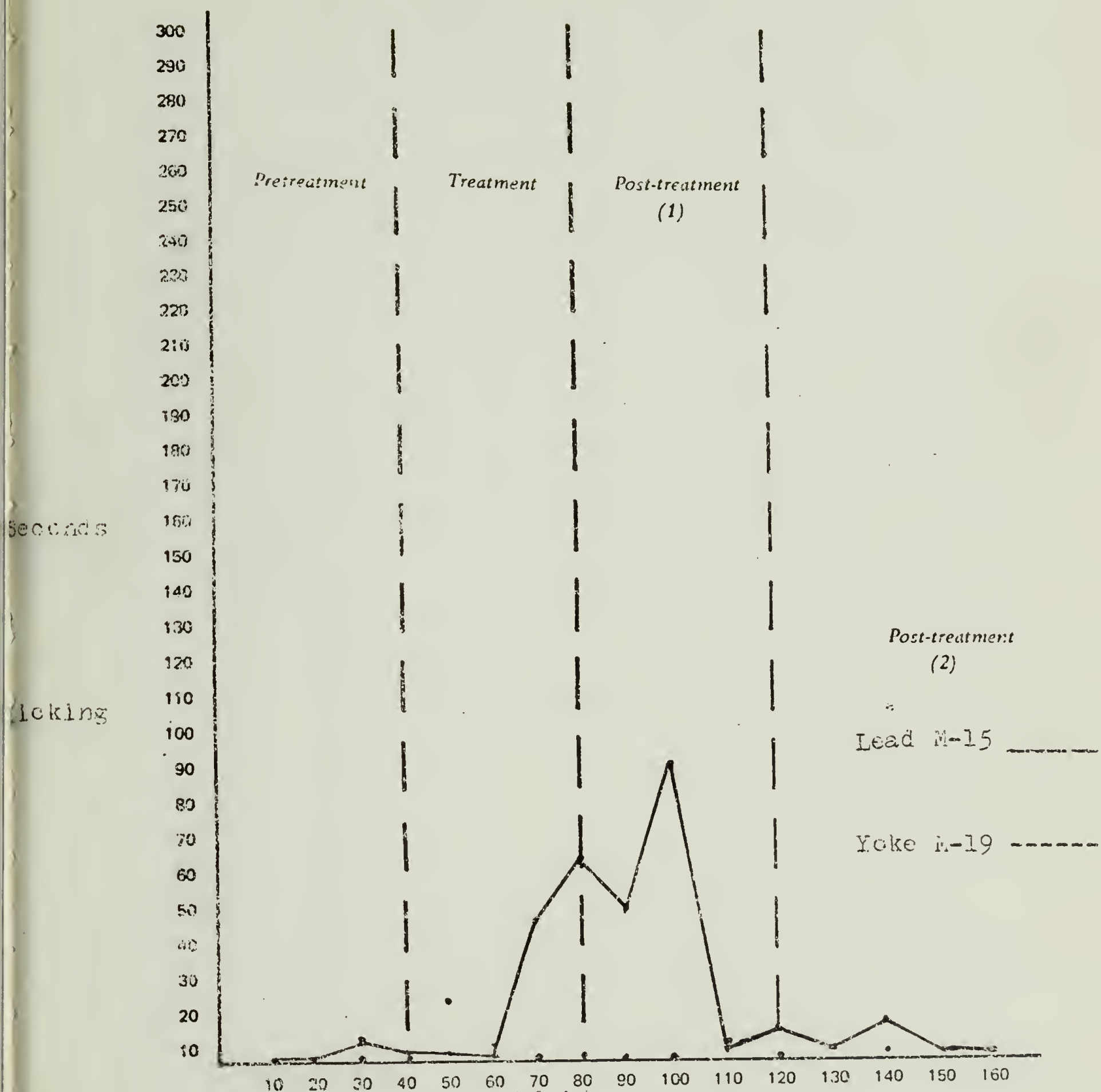


Fig. X Number of seconds licking

during stimulation.

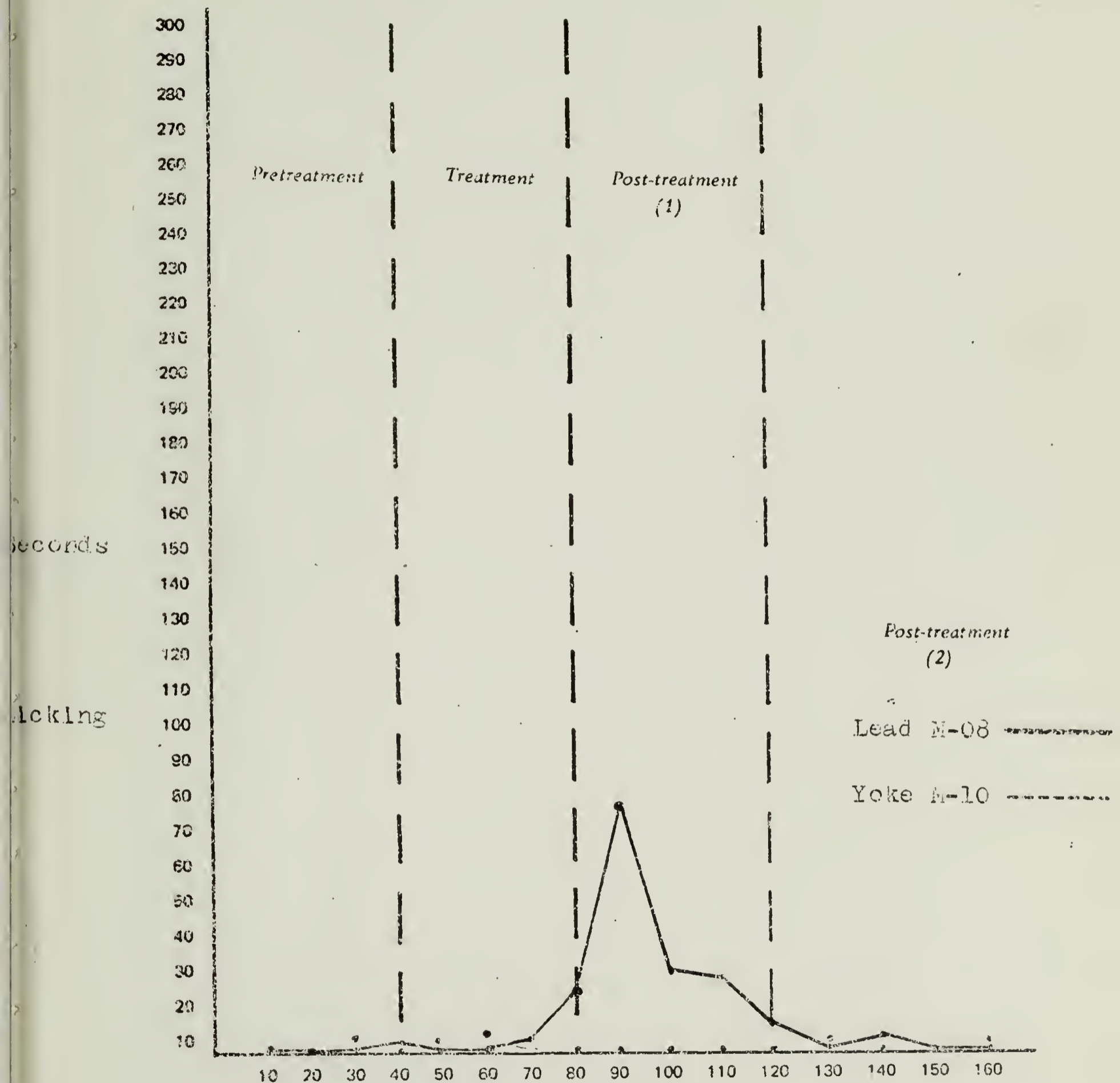


Fig. XI Number of seconds licking

during stimulation.

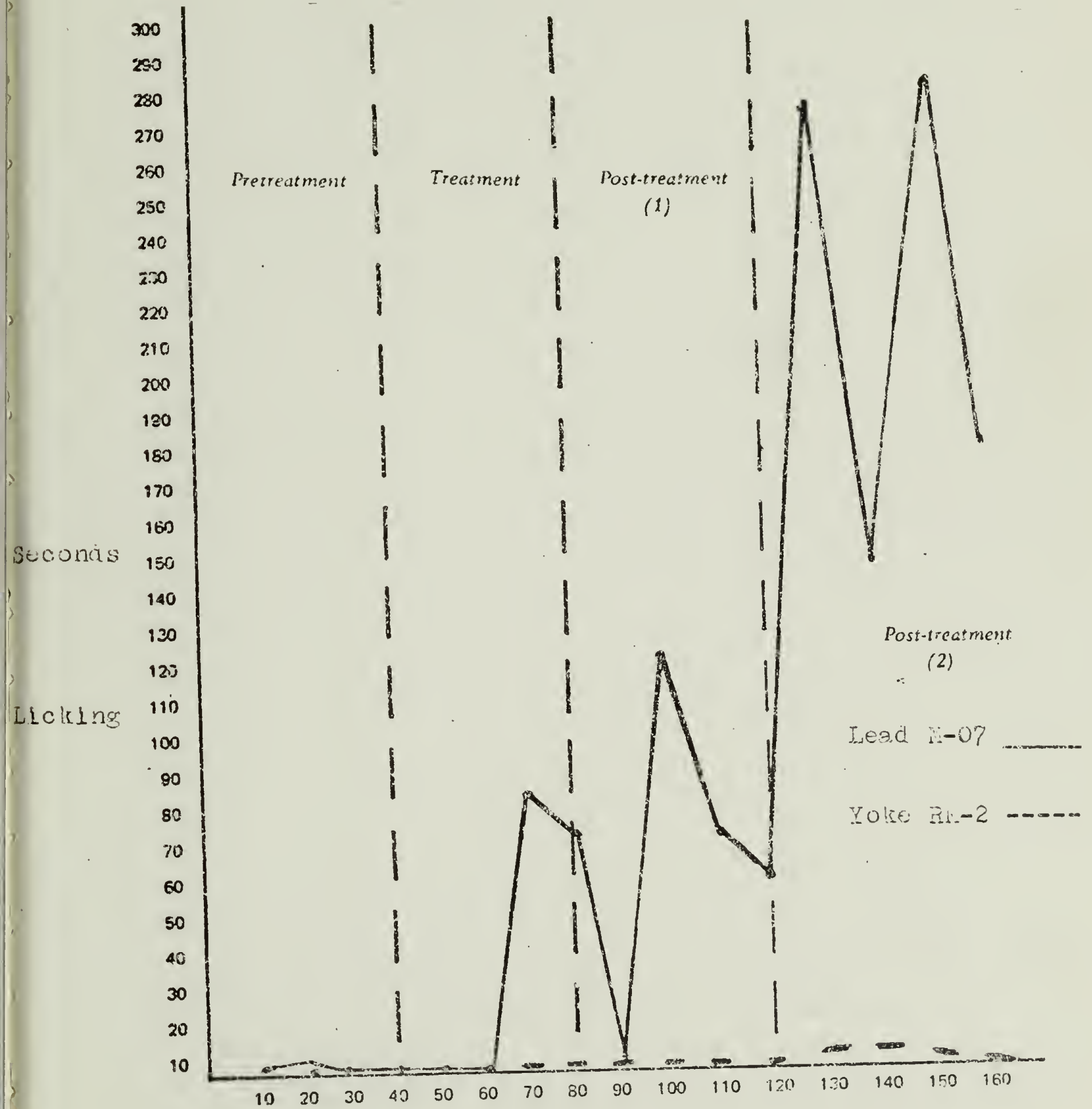


Fig XII Number of seconds licking  
during stimulation.

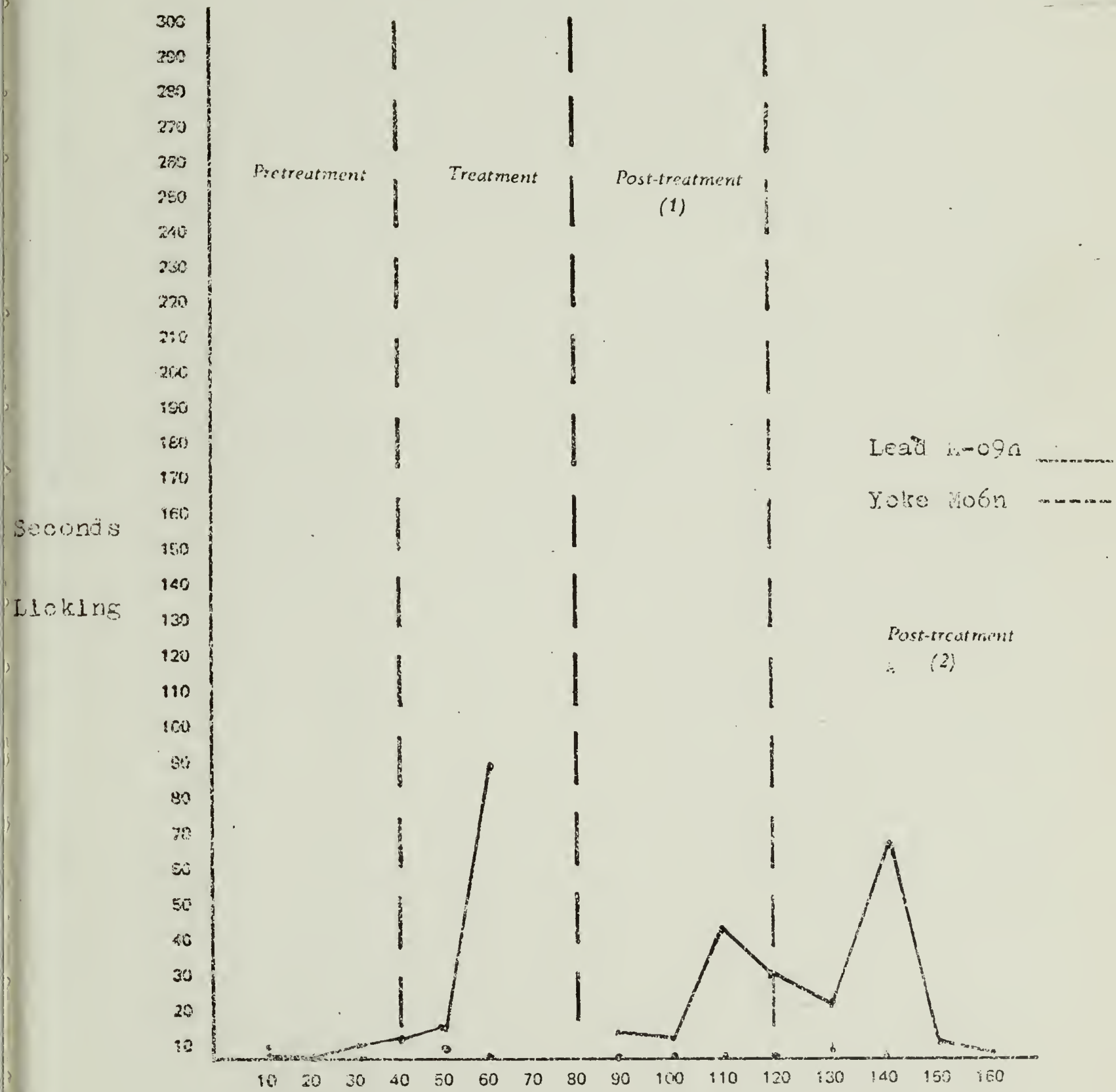


Fig. XIII Number Of seconds licking

during stimulation



