SOME EFFECTS OF DRIVE CHANGES ON LOCAL AND OVERALL RESPONDING REINFORCED BY DIFFERENT SUCROSE SOLUTIONS

BY

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PART I

SURVEY OF STUDIES ON MAGNITUDE OF REINFORCEMENT AND DRIVE

Magnitude of reinforcement

Interest in the effects of variations in reinforcement magnitude on learning and performance in animals has increased markedly during the last decade, and there are now numerous experimental papers dealing with various aspects of this topic. These papers have been concerned, for the most part, with the following problems:

1. What is the effect of reinforcement magnitude on rate of learning and asymptotic performance%
2. What is the effect of reinforcement magnitude on resistance to experimental extinction%
3. What is the nature of the dimension of reinforcement, whose quantitative variation produces behavioral changes?
4. Are there any differences in performance in terms of whether a given subject experiences only one reinforcement magnitude in a given situation, or more than one allowing possible comparisons?
5. What is the effect of reinforcement magnitude on acquired reward value?

The discussion on magnitude of reinforcement will follow an outline suggested by each of these questions, and in each case an attempt will be made to draw conclusions as definite as the available evidence allows.

1. Rate of learning and asymptotic performance. The evidence to be reported here is based on situations in which animals are given a series of rewarded training trials under one of several quantities of reinforcement, and measurements are made of terminal performance level and rate of approach to this level.

Relevant manipulations have included variations in reinforcement amount by three classes of operations. These are (a) variation in weight, volume, or size of a single reinforcing unit or in number of equal-weight reinforcement units; (b) variation in duration of exposure to the reinforcement; (c) variation in concentration of sucrose and saccharin solutions.

(a) Variation in weight and number of reinforcement units. Apparently the first study of quantitative variation was Grindley's[1], reported in 1929. He trained five groups of chicks to run down a runway to either 0, 1, 2, 4, or 6 grains of boiled rice. When running

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[1] Grindley, G. C. Experiments on the influence of the amount of reward on learning in young chickens. Brit. J. Psychol., 1929, 20, 173-180.

times on the last five of seven trials were plotted against the number of grains of rice, an increasing, negatively accelerated curve was obtained. In other words, he found that the animals ran the runway in shorter time when the reinforcement was large than when it was small.

Wolfe and Kaplon[2] also used chicks as subjects and ran three groups of them successively on each of three problems, a runway, a detour problem, and a T-maze. Running times throughout the 25 or 35 trials given on each problem fell in the following order, shortest to longest, for the three reinforcement amounts used: four quarter grains of popcorn, one full grain, and one quarter grain. Critical ratios on the final training days indicated no significant differences between groups, but several differences approached significance in comparisons involving the one quarter grain group. Observation of the curves in this study indicates a similar rate of approach to the asymptotes among all groups on all problems.

Crespi[3] gave runway training to various groups of rats, with the number of reinforcement units given as reward varied in logarithmic steps. Each reinforcement unit weighed .02 grams and the numbers of units used were 1, 4, 16, 64, and 256. He found that the amount of

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[2] Wolfe, J. B., and Kaplon, M. D. Effect of amount of reward and consummative activity on learning in chickens. J. comp. physiol. Psychol., 1941, 31, 353-361.

[3] Crespi, L. P. Quantitative variation of incentive and performance in the white rat. Amer. J. Psychol., 1942, 55, 467-517.

reinforcement affects performance at asymptote but not rate of approach to the asymptote. Asymptotic running speeds were an approximately logarithmic function of the number of incentive units, but rate of approach to these asymptotes was approximately constant for the various reinforcement values.

Zeaman[4], in another runway study, varied the weight of single reinforcement units as follows: .05, .20, .40, .80, 1.60, and 2.40 grams. His conclusions supported those of Crespi's: quantitative variation affects terminal level of performance but not rate of approach to this level.

In another study by Armus[5] in which rats were given runway training under 20-21 hr. food deprivation, it was found that the groups reinforced with ten 45-mg. food pellets showed faster acquisition in terms of both starting and running times than the group reinforced with only one such pellet. These acquisition results support previous findings of Crespi and Zeaman. Additional runway studies have corroborated these findings. Among these are the

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[4] Zeaman, D. Response latency as a function of the amount of reinforcement. J. exp. Psychol., 1949, 39, 466-483.

[5] Armus, H. L. Effect of magnitude of reinforcement on acquisition and extinction of a running response. J. exp. Psychol., 1959, 58, 61-63.

studies of Lawrence and Miller[6], Metzger, Cotton, and Lewis[7], and Spence[8].

Two other runway studies should be commented on here. Pereboom and Crawford[9] measured both forward running time and competing response time over 40 trials, and found that reinforcement magnitude affects both variables, the latter more so. These results suggest that a good deal of the learning that is shown by decrease in running time may actually reflect the elimination of competing response tendencies, such as exploration and the like, rather than a marked decrease in forward running time. Pereboom's data essentially paralleled Cotton's[10] drive-variation results, demonstrating that certain forms of competing or irrelevant behavior contribute more to the differences in total runway time as a function of hours of food deprivation than do changes in the vigor (speed) of the instrumental response itself.

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[6] Lawrence, D. H., and Miller, N. E. A positive relationship between reinforcement and resistance to extinction produced by removing a source of confusion from a technique that had produced opposite results. J. exp. Psychol., 1947, 37, 494-509.

[7] Metzer, R., Cotton, J. W., and Lewis, D. J. Effect of reinforcement magnitude and order of presentation of different magnitudes on runway behavior. J. comp. physiol. Psychol., 1957, 50, 184-188.

[8] Spence, K. W. Behavior theory and conditioning. New Haven: Yale Univer. Press, 1956, p. 260.

[9] Pereboom, A. C., and Crawford, B. M. Instrumental and competing behavior as a function of trials and reward magnitude. J. exp. Psychol., 1958, 56, 82-85.

[10] Cotton, J. W. Running time as a function of amount of food deprivation. J. exp. Psychol., 1953, 46, 188-198.

Gagne[11] found an increase in rate of acquisition and a decrease in terminal latency for eight training trials, as a function of reinforcement amount. However, in this study, reinforcement amount was related to intertrial interval such that the longer rest intervals were associated with larger amounts. The faster learning rate for larger amounts may be due to the distribution of practice effect, and not to the amount of reinforcement received.

A study by Hutt[12] utilizing the bar-pressing response confirms the runway finding that asymptotic performance is positively related to reinforcement magnitude. Hutt varied both quantity and quality of reinforcement factorially and assessed their effects on rate of responding under periodic reinforcement. The three quantities were 3, 12, and 50-mgm., manipulated by varying the size of the food dipper, and the three qualities were a basic diet plus saccharin (most preferred), basic diet alone and basic diet plus citric acid (least preferred). His results showed that rate of responding during periodic reinforcement is a function of both the taste and the amount of food reward, although differences in amount are a more potent determinant of response rate than are differences in taste. Rate of

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[11] Gagne, R. M. The effect of spacing of trials on the acquisition and extinction of a conditioned operant response. J. exp. Psychol., 1941, 29, 201-216.

[12] Hutt, P. J. Rate of bar pressing as a function of quality and quantity of food reward. J. comp. physiol. Psychol., 1954, 47, 235-239.

performance was found to be an increasing function of the amount of reinforcement.

Several studies have used more complex tasks, such as visual discriminations and T-maze problems. Reynolds[13] trained two groups of rats on a black-white discrimination with a single reinforcement unit weighing either 30 or 160 mgm. and found that, although mean response times for the two groups differed significantly, differences in trials to criterion were negligible. Other investigators such as Hopkins[14] and Schrier[15] have obtained discrimination learning results in substantial agreement with Reynolds.

In another study, Reynolds[16] compared acquisition of a simple T-maze habit over a constant number of trials with the reinforcement unit weighing either 30 or 160 mgm. He found a greater percentage of correct responses and faster running times for the larger amount group.

A final set of three papers are related in that, in each, one

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[13] Reynolds, B. The acquisition of a black-white discrimination habit under two levels of reinforcement. J. exp. Psychol., 1949, 39, 760-769.

[14] Hopkins, C. O. Effectiveness of secondary reinforcing stimuli as a function of the quantity and quality of food reinforcement. J. exp. Psychol., 1955, 50, 339-342.

[15] Schrier, A. M. Amount of incentive and performance on a black-white discrimination problem. J. comp. physiol. Psychol., 1956, 49, 123-125.

[16] Reynolds, B. Aquisition of a simple spatial discrimination as a function of the amount of reinforcement. J. exp. Psychol., 1950, 40, 152-160.

of the magnitudes employed was a zero magnitude. Furchtgott and Rubin[17] used a two-unit, linear T-maze and assigned different groups of rats to a single reinforcement unit weighing either 0, 20, 75, 250, or 2500 mgm. No differences in terms of three measures of rate of learning were found except that all groups receiving any positive amount did better than the group receiving zero amount. However, they found that the positive amount groups did differentiate in running speeds, the two larger reward groups running faster than the two smaller reward groups.

Seward, Shea, and Elkind[18] found a significant interaction between reinforcement amount and trials, but there was no improvement at all when the goal box was empty. Smith and Kinney[19] found faster bar-pressing for a reward of 20% sucrose solution than for plain water, during a single 26 min. session. These studies support Furchtgott and Rubin's study that a positive amount leads to faster learning than zero amount.

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[17] Furchtgott, E., and Rubin, R. D. The effect of magnitude of reward on maze learning in the white rat. J. comp. physiol. Psychol., 1953, 46, 9-12.

[18] Seward, J. P., Shea, R. A., and Elkind, D. Evidence for the interaction of drive and reward. Amer. J. Psychol., 1958, 71, 404-407.

[19] Smith, M., and Kinney, G. C. Sugar as a reward for hungry and nonhungry rats. J. exp. Psychol., 1956, 51, 348-352.

(b) Variation in duration of reinforcement exposure. Kling[20] used a runway, the thirst drive, and water as reinforcement. Amount of water reinforcement was manipulated factorially with two levels each of duration of exposure to the drinking tube, and drinking tube diameter. Running speeds over the last three of thirteen daily trials were found to be unsystematically related to the volume of water consumed per trial, time per trial actually spent drinking, and proportion of goal box time spent drinking. They were, however, positively related to ingestion rate.

Fehrer[21] carried out two experiments, one with a U maze, the other with a runway, using the thirst drive and varying both time in the goal box and amount of reinforcement. Running speeds were found not to vary systematically with either amount of reinforcement (40 sec. drinking vs. 10 sec. drinking followed by an additional 30 sec. in the now empty goal box) or time in the goal box (10 sec. drinking vs. 10 sec. drinking followed by 30 sec. delay in the goal box). The absence of running speed differences between high and low reward groups was explained on the basis of the particular reinforcement procedure used.

Spence[22] has pointed out that in the majority of the studies of the type in which weight or number of reinforcement units are manipulated, duration of time spent in the goal box has been

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[20] Kling, J. W. Speed of running as a function of goal-box behavior. J. comp. physiol. Psychol., 1956, 49, 474-476.

[21] Fehrer, Elizabeth. Effects of amount of reinforcement and of pre- and postreinforcement delays on learning and extinction. J. exp. Psychol., 1956, 52, 167-176.

[22] Spence, op. cit., p. 301.

confounded with magnitude, subjects typically being allowed to remain in the goal box until the reinforcement has been consumed (the Fehrer study being an exception). Two of Spence's students, Swisher and Czeh, varied magnitude and duration independently by allowing rats with larger amounts time in the goal box equivalent to that of animals with smaller amounts, but then allowed them to finish eating elsewhere. These two studies[23] both produced evidence that performance varies as a function of duration in the goal box and not amount consumed. Thus they agree with Kling and Fehrer in the finding that performance does not vary with the actual amount consumed, but disagree with Fehrer's finding that performance did not vary with duration either.

Kraeling[24], in investigating the effect upon instrumental response strength of three factors commonly confounded in investigations of amount of food reward, found that time of exposure to sucrose solution did not have a significant effect upon the strength of the instrumental response, but that it was an important determinant of the strength of the consummatory response. As this experiment contradicts Spence's findings, further investigation is needed to establish consistent findings.

(c) Variation in concentration of sugar and saccharin solutions. Studies in which variation in reinforcement magnitude is achieved by

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[23] Ibid., p. 138.

[24] Kraeling, Doris. Analysis of amount of reward as a variable in learning. J. comp. physiol. Psychol., 1961, 54, 560-565.

manipulating the concentration of sugar or saccharin solutions provide some apparent exceptions to the generalizations that rate of learning is independent of quantity of reinforcing agent, and asymptotic performance is a monotonic function of quantity.

In the investigation of the magnitude of reinforcing agent, the technique of manipulating the concentration of a soluble nutrient, such as sucrose, has distinct advantages. It controls stimulation prior to ingestion and reduces variation in required ingestive activity. If the stimulational aspects of the reinforcing agent are of importance, the use of a concentration scale provides a more rational metric for the scaling of gustatory stimuli than is permitted by such units as weight, volume or number of solid food particles. Since concentration is a significant dimension of stimuli in sensory research, analysis of the mechanisms involved in reinforcement may be facilitated by being brought into relation with extant knowledge of receptor processes. Such analyses may be promoted by the additional device of using simple substances of known chemical composition, such as sucrose, about which much relevant information is already available from studies of various aspects of taste, as well as from research in food acceptance and nutrition[25].

The first investigator to vary concentration of sugar solutions was Guttman[26]. Four concentrations of sucrose, 4%, 8%, 16%, and 32%,

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[25] Guttman, N. Operant conditioning, extinction, and periodic reinforcement in relation to concentration of sucrose used as reinforcing agent. J. exp. Psychol., 1953, 46, 213-224.

[26] Ibid.

were used as reinforcing agent with four groups of rats (N = 80) in a study of bar-pressing behavior. Each group received a single concentration during magazine training and conditioning under continuous reinforcement. Following extinction and reconditioning, performance was observed under periodic reinforcement for five days. Then twenty subjects from the various groups were tested under periodic reinforcement an additional twelve times with each of the four concentrations previously used. The findings obtained during original conditioning are of immediate concern. These findings were: (1) the time required to condition and to execute 500 responses decreased as concentration increased; (2) the averaged acquisition curves indicated a positive relation between concentration and the rate of approach to the asymptotic rate of responding under continuous reinforcement; and (3) the relationship between concentration and rate of responding under continuous reinforcement at various stages beyond 100 reinforcements was nonmonotonic, increasing to 16% and then decreasing. Guttman's acquisition curves do not confirm Zeaman's finding that the number of reinforcements required to reach the performance asymptote is constant for various amounts of reinforcing agent. The 32% group achieved a relatively constant rate with a smaller number of reinforcements than did the other groups.

Guttman's general findings were confirmed in a second study[27],

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[27] Guttman, N. Equal-reinforcement values for sucrose and glucose solutions compared with equal sweetness values. J. comp. physiol. Psychol., 1954, 47, 358-363.

in which he was further interested in determining if the reinforcing values of sucrose and glucose solutions for rats in a bar-pressing situation were consistent with the relative sweetness of various concentrations of sucrose and glucose found by human observers. Results indicated that rate of bar-pressing was an increasing function of concentration of both substances, with sucrose always producing higher rates of responses than similar concentrations of glucose.

Young and Shuford, in two studies [28] [29], investigated the effect of sucrose concentration on a running response. In the first study latency and running time were measured where concentrations were 2%, 6%, 18%, and 54%. By the end of eighteen daily trials the groups had ordered themselves in terms of latencies in the order indicated, greatest to least. But asymptotic running speeds were the same for all groups. Finally the higher the concentration, the sooner these speeds were achieved, a finding paralleling Guttman's, but contradicting the findings of Crespi and Zeaman, mentioned earlier. In the second study they used well-nourished rats, without any deprivation. They found that these rats approached the sucrose solution, after several daily 1-second contacts with it, at a speed of locomotion that varied

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[28] Young, P. T., and Shuford, E. H. Intensity, duration, and repetition of hedonic processes as related to acquisition of motives. J. comp. physiol. Psychol., 1954, 47, 298-305.

[29] Young, P. T., and Shuford, E. H. Quantitative control of motivation through sucrose solutions of different concentrations. J. comp. physiol. Psychol., 1955, 48, 114-118.

directly with the concentration of solution. The speed of locomotion, however, was not found to be as consistent an appraisal of relative value among the test solutions as were preference tests. They also found that the rate of running to a sucrose solution was dependent upon the number of previous contacts with it as well as upon the concentration of solution used as a reward.

Hughes[30] varied both the concentration and volume of saccharin solution, and assessed their effect on latency, running time, and percentage of correct responses in a T-maze. For trials 2-40, the percentage of correct responses increased significantly with both variables. Latency and running time decreased significantly with volume but not concentration. There was also a significant interaction between volume and concentration, such that for the smaller of two volumes the effect of concentration was monotonic, but for the larger volume the effect of concentration was nonmonotonic.

Smith and Duffy[31] reported faster learning of a T-maze habit when the reward was 4 cc. 20% sucrose than when only .1 cc., in terms of increase in percentage correct turns and decreases in running time. Here there seems to be another exception to the generalization that reinforcement magnitude does not affect rate of learning.

Kraeling[32] in using sucrose as the reward for the instrumental

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[30] Hughes, L. H. Saccharine reinforcement in a T-maze. J. comp. physiol. Psychol., 1957, 50, 431-435.

[31] Smith, M., and Duffy, M. Evidence for a dual reinforcing effect of sugar. J. comp. physiol. Psychol., 1957, 50, 242-247.

[32] Kraeling op. cit.

response of running in a straight alley, found that concentration of sucrose solution was a major determinant of the strength of the instrumental response throughout training and that concentration of sucrose solution was an important determinant of the strength of the consummatory response, this effect being greater early in training than late in training.

2. Resistance to extinction. Studies of the effect of reinforcement magnitude on resistance to extinction may be grouped in terms of the extinction measures employed. Some investigators have used as their measures trials to an extinction criterion, while others have assessed performance over a constant number of extinction trials.

(a) Trials to an extinction criterion. Three studies which used a measure of trials to a specified extinction criterion failed to find systematic effects of prior reinforcement magnitude. Lawrence and Miller[33] found an insignificant difference in trials to running response extinction criteria of either 3 or 5 min. latency as a function of prior amount. Reynolds[34] gave rewards to three groups of rats for 25 consecutive bar-pressing responses. The three groups

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[33] Lawrence and Miller, op. cit.

[34] Reynolds, B. Resistance to extinction as a function of the amount of reinforcement present during acquisition. J. exp. Psychol., 1950, 40, 46-52.

received one 60 mgm. pellet, 2 of these pellets, or one 160 mgm. pellet for each response. No significant differences were found between any of the groups in terms of responses to an extinction criterion of 5 min. In another study, Reynolds, Marx, and Henderson[35] found no significant differences in trials to extinction of a bar-pressing response following 120 against 30 mgm. reward.

One study using a measure of trials to a specified extinction criterion found a systematic effect. Young and Shuford[36], extinguishing their subjects with distilled water, found that the slope of their extinction curves of running speeds varied directly with prior concentration.

(b) Performance over a constant number of extinction trials. Zeaman[37] subjected his subjects to extinction of the running response after they had completed their rewarded training, either with or without test phases intervening between training and extinction. He found that the effect of previous magnitude was to alter the rate of approach to a final common performance level.

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[35] Reynolds, B., Marx, M. H. and Henderson, R. L. Resistance to extinction as a function of drive-reward interaction. J. comp. physiol. Psychol., 1952, 45, 36-42.

[36] Young and Shuford, op. cit.

[37] Zeaman, op. cit.

Gagne[38] reported a higher terminal extinction level for greater reward amounts with longer intertrial intervals.

Following periodic reinforcement (PR) under three levels each of quantity and quality, Hutt's[39] rats were given two ½-hr. extinction sessions. A high positive correlation existed between PR rate and number of responses during extinction with both variables, more responses being emitted following periodic reinforcement with larger amounts and preferred qualities. Guttman[40] found that resistance to extinction in terms of rate of responding in the initial 15 min. of extinction is an increasing monotonic function of the concentration used in conditioning.

Fehrer[41] found greater resistance to extinction (in terms of both running speeds over a constant number of trials and trials to various criteria) following the condition of 10 sec. drinking followed by 30 sec. postreinforcement delay in the goal box, than following either 10 sec. or 40 sec. drinking time in the goal box.

If the assumption is taken here that learning effects are relatively permanent while performance effects are momentary, it would seem that, on the basis of extinction performance differences found for a constant number of trials, magnitude of reward does affect

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[38] Gagne, op. cit.

[39] Hutt, op. cit.

[40] Guttman, op. cit.

[41] Fehrer, op. cit.

learning when the absolute method is used. This method, employed in the studies previously mentioned, is characterized by the use of only one reinforcement value for each subject in each phase of an experiment. However, it might be that the higher performance level during extinction following larger amounts is due to the fact that terminal acquisition level is higher the greater the amounts of reinforcement. Metzer, Cotton, and Lewis[42] found this to be so. They reported results of an analysis of covariance upon extinction scores where performance levels at the beginning of extinction were equated in terms of running times during the last five reinforced trials. Under these circumstances, the effect of test-phase amount on extinction disappeared. They conclude, " . . . reward affects performance on extinction through differential levels of performance just prior to extinction rather than affecting performance on extinction directly."[43] If this interpretation is applied to the other studies in which performance was measured over a constant number of extinction trials, the conclusion that reinforcement magnitude does affect amount of learning is maintained.

3. Mechanisms of reinforcement. Five possible mechanisms of magnitude variation are: (a) amount of nutrient material for assimilation, (b) preconsummatory stimulation, (c) consummatory

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[42] Metzer, Cotton, and Lewis, op. cit.

[43] Ibid., p. 188.

activity, (d) consummatory stimulation and (e) postingestive concentration[44].

Since the concern here is with the conditions of reinforcement, a distinction must be made between <u>necessary</u> and <u>sufficient</u> conditions. If quantitative variation is shown to affect behavior when one of the mechanisms, let us say <u>A</u>, is held constant, this would indicate that variation in that mechanism is not necessary for reinforcement magnitude effects. On the other hand, lack of behavioral variation would not indicate that the mechanism is necessary, for it may be irrelevant. If a single mechanism, let us say <u>B</u>, is varied and this produced behavioral variations, it may be concluded that variation in that mechanism is sufficient. But if there is no behavioral variation, it must be that that mechanism, <u>B</u>, is not sufficient, for some other mechanism is also needed to produce the behavioral change.

(a) <u>Amount of nutrient material</u>. A number of studies indicate that the amount of nutrient material available for assimilation is not a necessary condition for variation in reinforcement magnitude. The first study with saccharin reinforcements is that of Sheffield and Roby[45]. In one experiment food-deprived subjects were given 42 trials

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[44] Pubols, B. H. Jr. Incentive magnitude, learning, and performance. <u>Psychol. Bull.</u>, 1960, <u>57</u>, 89-115.

[45] Sheffield, F. D., and Roby, T. B. Reward value of a non-nutritive sweet taste. <u>J. comp. physiol. Psychol.</u>, 1950, <u>43</u>, 471-481.

with saccharin solution in one arm of a T-maze and tap water in the other. There developed a significant increase in choices of the saccharin side, as well as an increase in rate of ingestion and decrease in running time.

Hughes[46] showed that not only can rats learn in the absence of reinforcement by nutrient material, but that performance is differentially affected by saccharin concentration.

A study by Sheffield, Wulff, and Backer[47] and one by Kagan[48], using sexually motivated male rats as subjects with receptive females indicate that behavior may be modified in the absence of alterations in the effects of deprivation. Sheffield _et al_. compared running speeds when the reinforcement was either a female rat in heat or another male. Even though ejaculation was not permitted, the subjects ran faster to the receptive female than to the male reinforcement.

Several studies, already mentioned, such as Kling[49], Fehrer[50],

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[46] Hughes, _op. cit._

[47] Sheffield, F. D., Wulff, J. J., and Backer, R. Reward value of copulation without sex drive reduction. _J. comp. physiol. Psychol_., 1951, _44_, 3-8.

[48] Kagan, J. Differential reward value of incomplete and complete sexual behavior. _J. comp. physiol. Psychol_., 1955, _48_, 59-64.

[49] Kling, _op. cit_.

[50] Fehrer, _op. cit_.

and those of Swisher and Czeh[51] indicate that, when reinforcements are administered peripherally, variation in amount of nutrient material is not a sufficient mechanism of reinforcement magnitude.

(b) Preconsummatory stimulation. The results of studies in which either duration of reinforcement exposure or concentration of sugar or saccharin are manipulated have shown that variations in preconsummatory stimulation are not necessary for variations in behavior to be found. Studies such as McKelvey's[52] in which preconsummatory visual stimulation was independently manipulated indicate that variation in this mechanism is neither necessary nor sufficient for behavioral change. McKelvey varied the duration of reinforcement exposure and visual size of the reinforcement during acquisition of a black-white discrimination and found that duration of reward affected the performance measure, but not the acquisition measure. However, preconsummatory stimulation was shown to have no systematic effect on behavior by either measure.

(c) Amount of consummatory activity. When reinforcement magnitude is varied by manipulating volume found, as for example by manipulating the concentration of sucrose solutions, the amount of

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[51] Swisher and Czeh, op. cit., p. 138.

[52] McKelvey, R. K. The relationship between training methods and reward variables in brightness discrimination learning. J. comp. physiol. Psychol., 1956, 49, 485-491.

consummatory activity does seem to be, by considering a number of studies in which ingestion rate was measured, a sufficient condition to produce behavioral variations. For example, Sheffield, Roby, and Campbell[53] found a high positive correlation between running speed and ingestion rate (reinforcements were water, saccharin, dextrose, or dextrose plus saccharin solutions). Kling[54] also found that the important consummatory activity variable is ingestion rate. Further evidence comes from the study of Sheffield, Wulff, and Backer[55] of a positive relationship between running speed and percentage of opportunities to attempt copulation.

However, contrary evidence was produced by Davis and Keehn[56] who studied magnitude of reinforcement and consummatory behavior in the Skinner box situation. They measured the rates at which rats licked saline, sucrose, and saccharin solutions, and found that the local rate of licking was constant for all solutions. They explain their amplification of Sheffield's results on the basis of Gilbert's[57] operant dimensions. Gilbert described seven dimensions of an operant

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[53] Sheffield, F. D., Roby, T. B., and Campbell, B.A. Drive reduction versus consummatory behavior as determinants of reinforcement. <u>J. comp. physiol. Psychol.</u>, 1954, <u>47</u>, 349-354.

[54] Kling, <u>op. cit.</u>

[55] Sheffield, Wulff, and Backer, <u>op. cit.</u>

[56] Davis, J. D., and Keehn, J. D. Magnitude of reinforcement and consummatory behavior. <u>Science</u>, 1959, <u>130</u>, 269-271.

[57] Gilbert, T. F. Fundamental dimensional properties of the operant. <u>Psychol. Rev.</u>, 1958, <u>65</u>, 272-282.

as fundamental in the sense that other operations of behavior measurement are reducible to these seven and the seven are not further reducible within the realm of behavioral discourse. The seven dimensions are (a) latency, defined as the time between opportunity for an operant and its initial occurrence; (b) tempo, defined as the rate of emission of a continuously ongoing operant, or the period of a single operant; (c) perseveration, defined as the proportion of the time from the occurrence of the first operant to the completion of the last in which operants are usually occurring; (d) duration, the total time from the initiation of the first operant to the completion of the last; (e) intension, the amount of movement that takes place in an operant involving some specified part of the organism's topography; (f) extension, the degree of the topography involved in an operant, and (g) direction, i.e., of the organism's movement with respect to some fixed reference point.

Davis and Keehn maintain that while Sheffield's study showed that different reward conditions lead to different operant and consumption rates, he did not indicate whether these differences are due to the tempo, perseveration, or latency of the consummatory behavior. On the other hand, Davis and Keehn are inclined to consider perseveration as accounting for the differences in instrumental performance with different reinforcing stimuli. However they stress that an investigation of the effects of the quantity or quality of a reinforcing substance on instrumental behavior in terms of Gilbert's dimensions is necessary before these effects can be adequately explained.

(d) Amount of consummatory stimulation. Studies by Kling[58] and Spence[59] have found performance variations suggesting that variations in amount of consummatory stimulation are not necessary for reinforcement magnitude effects.

Cockrell[60], however, manipulating concentrations of saccharin, found that variations in amount of consummatory stimulation are sufficient to produce behavioral variations.

(e) Postingestive concentration. Collier and Siskel[61] examined rate of bar-pressing as a joint function of sucrose concentration, interreinforcement interval and portion of session. The interactions as well as the main effects of these variables were significant. Results showed that amount of reinforcement is an increasing function of stimulation and a decreasing function of the postingestive concentration of the reinforcing substance. Therefore, they conclude, that postingestive concentration is sufficient to produce behavioral variations.

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[58] Kling, op. cit.

[59] Spence, op. cit., p. 301.

[60] Cockrell, J. T. Operant behavior of white rats in relation to the concentration of a non-nutritive sweet substance used as reinforcement. Unpublished doctoral dissertation, Univ. of Indiana, 1952. From Pubols, B. H. Jr. Incentive magnitude, learning, and performance. Psychol. Bull., 1960, 57, 89-115.

[61] Collier, George, and Siskel, M., Jr. Performance as a joint function of amount of reinforcement and interreinforcement interval. J. exp. Psychol., 1959, 57, 115-120.

Therefore, it seems that none of these mechanisms of reinforcement is necessary for bringing out performance differences as a function of reinforcement magnitude, but that variations in either amount of consummatory activity or stimulation associated with that activity or postingestive concentration are sufficient conditions.

4. Comparison of absolute and differential methods of varying reinforcement magnitude. Lawson[62] calls the method whereby each subject experiences only one value the "absolute" method, and the method whereby each subject experiences more than one value the "differential " method. Several studies afford a rather direct comparison of the two methods in that they are compared within a single experimental design.

Logan, Beier, and Ellis[63] compared runway speeds during acquisition when the reinforcement was nine 45 mgm. pellets for one group of rats, five such pellets for a second group, and, for a third group, nine pellets on a random half of the trials and one on the other half. Thus, the first two groups were trained according to the absolute method, the third according to the differential. Overall

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[62] Lawson, R. Brightness discrimination performance and secondary reward strength as a function of primary award amount. J. comp. physiol. Psychol., 1957, 50, 35-39.

[63] Logan, F. A., Beier, Eileen M., and Ellis, R. A. Effect of varied reinforcement on speed of locomotion. J. exp. Psychol., 1955, 49, 260-266.

running speed was greater for the first group than for either of the other two. Observation of their Figure 2[64] indicates similar rates of approach to terminal speeds in all cases.

In a follow-up study, Logan, Beier, and Kincaid[65] reported the extinction results of this experiment and a related one. For the first experiment none of the three groups differed in their relative rates of extinction. In the related experiment, extinction followed 60 acquisition trials with nine pellets on each trial, nine vs. zero each on a random half, or nine vs. one. In this case the two varied-amount (differential method) groups were superior to the constant amount group. Therefore it seems that relative rate of extinction is retarded by previous comparison of reinforcement values.

Lawson[66] determined the effects of reinforcement magnitude on discrimination learning by having rats learn two problems concurrently, a black-grey discrimination and a white-grey discrimination, grey being negative in both cases. For some subjects the reward was the same for correct responses on both problems, either five pellets or one pellet (absolute method). For other subjects the reward was five pellets on one problem and one on the other (differential method). The two

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[64] Ibid., p. 264.

[65] Logan, F. A., Beier, Eileen M., and Kincaid, W. D. Extinction following partial and varied reinforcement. J. exp. Psychol., 1956, 52, 65-70.

[66] Lawson, op. cit.

absolute groups did not differ significantly from each other in terms of errors over a constant number of trials. However, the differential groups showed significantly fewer errors on the large reward discrimination than on the small reward one.

In two studies Schrier[67] [68] divided monkeys into a differential and several absolute groups. In various phases of each experiment differential subjects received experience with 1, 2, 4, or 8 food pellets. Subjects of each of four absolute groups received experience with only one of the four magnitudes. In the 1958 study effects on errors during a series of discrimination problems were assessed. The two groups did not differ in over-all performance; however, the slope of the reinforcement function was significantly greater for the differential method than for the absolute method.

5. Acquired reward value as a function of reinforcement magnitude. Experimental studies of secondary reinforcement were recently reviewed by Myers[69]. On the basis of the evidence he

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[67] Schrier, A. M. Effect of the method of presenting varied amounts of food incentive on performance by monkeys. Unpublished doctoral dissertation, Univer. of Wisconsin, 1956. From Schrier, A. M. Comparison of two methods of investigating the effect of amount of reward on performance. J. comp. physiol. Psychol., 1958, 51, 725-731.

[68] Schrier, A. M. Comparison of two methods of investigating the effect of amount of reward on performance. J. comp. physiol. Psychol., 1958, 51, 725-731.

[69] Myers, J. L. Secondary reinforcement: A review of recent experimentation. Psychol. Bull., 1958, 55, 284-301.

discussed (D'Amato[70], Hopkins[71], Lawson[72]), he concluded that, " . . . the effect of amount of reward is so slight, that it can only be detected when the subject is forced to choose between secondary reinforcers previously associated with different sized rewards"[73]. The finding was that an effect appeared only when training was by the differential method, but not the absolute.

Two additional studies since Myers's review are those of Lawson[74] and Butter and Thomas[75]. Lawson compared the absolute and differential methods within a single design, in their effects on secondary reward strength. No differential effect of primary reward amount on secondary reward strength was shown by either method. Butter and Thomas, using the absolute method, show results at variance with those reviewed by Myers. Two independent groups of rats were trained to approach a Skinner box dipper upon presentation of a magazine click and received 8% and 24% sucrose solutions, respectively. In testing,

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[70] D'Amato, M. R. Secondary reinforcement and magnitude of primary reinforcement. J. comp. physiol. Psychol., 1955, 48, 378-380.

[71] Hopkins, op. cit.

[72] Lawson, R. Amount of primary reward and strength of secondary reward. J. exp. Psychol., 1953, 46, 183-187.

[73] Myers, op. cit., p. 294.

[74] Lawson, op. cit.

[75] Butter, C. M., and Thomas, D. R. Secondary reinforcement as a function of the amount of primary reinforcement. J. comp. physiol. Psychol., 1958, 51, 346-348.

subjects bar-pressed for the click alone. The 24% group exceeded the 8% group in speed of magazine approach in training, and bar-pressed significantly more often. Both experimental groups bar-pressed significantly more often than a control group which had never received sucrose solution in the Skinner boxes. It was concluded that an opportunity for comparison of different reward amounts is not essential for the establishment of differential secondary reinforcement. Butter and Thomas suggest that the earlier failures with the absolute method might be due to the possibility that the primary amounts were too large toward the asymptote of the primary reward amount function.

No clear-cut conclusions concerning acquired reward value as a function of reinforcement magnitude can be reached until more research has been completed. It can only be said, tentatively, that amount of primary reward does affect strength of secondary reward, and that this effect is more likely to be evidenced if the differential method of reinforcement presentation is used.

Returning now to the problems stated at the beginning of the discussion on magnitude of reinforcement, certain tentative generalizations may be made.

1. With the absolute method, quantitative variation in reinforcements has no apparent effect on rate of learning. One exception may be the manipulation of concentration of sucrose solutions. Also learning is quicker with any positive reinforcement amount than with zero amount.

2. Asymptotic performance is an increasing function of reinforcement magnitude.

3. Magnitude of reinforcement affects resistance to extinction indirectly through differences in terminal level of rewarded performance.

4. None of the mechanisms whereby behavioral results of quantitative variation are effected are necessary.

5. Sufficient mechanisms seem to be amount of consummatory activity and stimulation from the reinforcement associated with consummatory activity.

6. The slope of the reinforcement function is greater when training is by the differential method than by the absolute method.

7. Acquired reward value is an increasing function of magnitude of primary reward.

Interaction of reinforcement magnitude with other variables

(a) Quality of reward. Hutt[76] found that the effects of quantity and quality of reward on rate of bar-pressing during both periodic reinforcement and extinction were independent of each other.

(b) Partial reinforcement. Hulse[77], investigating the role of percentage of reinforcement (100% or 46%), amount of reinforcement

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[76] Hutt, op. cit.

[77] Hulse, S. H. Amount and percentage of reinforcement and duration of goal confinement in conditioning and extinction. J. exp. Psychol., 1958, 56, 48-57.

(1.0 gm. or .08 gm), and duration of goal-box confinement on nonreinforcement training trials (10 sec. or 60 sec.) as parameters of running response found that continuous reinforcement produced faster running than partial reinforcement and that large reward produced faster running than small rewards. He also measured running speeds over a constant number of extinction trials and found a significant interaction between the effects of prior percentage of reinforcement and amount of reinforcement such that, with partial reinforcement, resistance to extinction was greater following a larger amount, but with continuous reinforcement, the reverse effect resulted.

Goodrich[78] in demonstrating that the relative performance of 50% and 100% reinforced groups varies during the course of acquisition, and that these effects vary with the point in the response chain measured, found that for the starting and running speed measures the 50% group was inferior in the early trials but superior at the performance asymptote. He discussed his results in relation to Amsel's[79] frustration theory which says that the occurrence of nonreinforcements after some minimal number of reinforcement trials produces a motivational state of "frustration"

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[78] Goodrich, K. P. Performance in different segments of an instrumental response chain as a function of reinforcement schedule. J. exp. Psychol., 1959, 57, 57-63.

[79] Amsel, Abram. The role of frustrative nonreward in noncontinuous reward situations. Psychol. Bull., 1958, 55, 102-117.

which may act to facilitate subsequent performance. According to this theory a conditioned (antedating) form of frustration, called $r_f - s_f$, will occur back in the alley itself. The occurrence of this will produce a motivational increase in the 50% subjects' performance and will lead to eventual superiority of this group over the 100% subjects.

Interaction between reinforcement magnitude and drive

Seward, Shea, and Elkind[80] factorially varied reinforcement magnitude and length of food deprivation, and assessed their effect on running speed. Both main effects were significant, as was the interaction between them. However this interaction is based on comparisons involving zero reward amount and zero hours deprivation. No learning took place under satiation or when the goal box was empty. Therefore the interaction might represent a special case found only when values of either reinforcement magnitude or length of deprivation are zero. This is attested by a study by Reynolds and Pavlik[81]. They varied reinforcement magnitude (.1, 1.0, and 2.0 gm) and deprivation time (3, 22, and 44 hours) factorially with 9 groups of animals over 72 runway trials and reported

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[80] Seward, Shea, and Elkind, op. cit.

[81] Reynolds, W. F., and Pavlik, W. B. Running speed as a function of deprivation period and reward magnitude. J. comp. physiol. Psychol., 1960, 53, 615-618.

reciprocal latencies over the last 20 of these trials. Differences as a function of both reinforcement amount and deprivation were significant. However, the interaction between these two variables was not significant, and this result was interpreted as being consistent with Spence's suggestion that reinforcement amount and deprivation (K and D) interact in an additive fashion, instead of in a multiplicative fashion as Hull's theory states.

In contrast, Reynolds, Marx, and Henderson[82], in a study utilizing bar-pressing behavior, reported a significant interaction between amount of reinforcement and drive level on trials to an extinction criterion of 5 min. with no bar-pressing, such that high drive-high reward and low drive-low reward animals extinguished more rapidly than high drive-low reward or low drive-high reward animals. Reynolds and Pavlik suggest that this difference might be a function of the different response measures used in the two studies. Another possibility lies in the definition of drive. For Reynolds and Pavlik drive was defined in terms of the length of food deprivation. In contrast, Reynolds, Marx, and Henderson manipulated both amount fed and deprivation time simultaneously.

Another study on the effects of deprivation time and reinforcement magnitude on speed of running a straight alley was made by Weiss[83]. Deprivation time and reinforcement magnitude

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[82] Reynolds, Marx, and Henderson, op. cit.

[83] Weiss, R. F. Deprivation and reward magnitude effects on speed throughout the goal gradient. J. exp. Psychol., 1960, 60, 384-390.

appeared to combine additively, as in Reynolds and Pavlik's study (significant main effects, nonsignificant interaction), as is implied by Spence's assumption of an additive relationship between drive (D) and reinforcement motivation (K). Reinforcement effects on asymptotic running speed fell short of significance, though an analysis of earlier trials did tend to suggest that deprivation and reinforcement magnitude also combine additively to determine running speed. Reinforcement effects on running speed (trials 1-20) appeared to increase as deprivation increased, but this interaction did not approach statistical significance. The goal gradient was found to increase in steepness during the course of acquisition, and the effects of deprivation and reward were both greater in the middle portions of the alley than at the start or end.

The contrasts found between Weiss's and Reynolds's 1960 study with that of Reynolds, Marx, and Henderson, imply that more research is needed to specify the conditions of both drive and reinforcement under which an interaction between them would be expected. The experiment presented in this paper is an attempt to add to this research.

PART II

SOME EFFECTS OF DRIVE CHANGES ON LOCAL AND OVERALL RESPONDING REINFORCED BY DIFFERENT SUCROSE SOLUTIONS

CHAPTER II

INTRODUCTION

Investigators in the area of animal learning have shown a continuing interest in the parameters of reinforcement magnitude, or quantity, and drive. This may be seen by the number of studies reviewed in Part I. One may determine from these studies that magnitude or quantity of reinforcement plays an important role in the organism's rate of responding.

The course of this role in changing performance is a question of major interest. Both overshooting of the expected asymptote of performance when the magnitude is increased and undershooting when the magnitude is decreased have been reported (Crespi[84], [85], Spence[86], Zeaman[87]). Both gradual and abrupt changes in performance following a change in magnitude of reinforcement have been observed (Crespi[88], [89], Dufort and Kimble[90], Pereboom[91],

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[84] Crespi, <u>op. cit.</u>

[85] Crespi, L. P. Amount of reinforcement and level of performance. <u>Psychol. Rev.</u>, 1944, <u>51</u>, 341-357.

[86] Spence, <u>op. cit.</u> p. 301.

[87] Zeaman, <u>op. cit.</u>

[88] Crespi, <u>op. cit.</u>

[89] Crespi, <u>op. cit.</u>

[90] Dufort, R. H., and Kimble, G. A. Changes in response strength with changes in the amount of reinforcement. <u>J. exp. Psychol.</u>, 1956, <u>51</u>, 185-191.

[91] Pereboom, <u>op. cit.</u>

Spence[92]). In these experiments on shifts in reinforcement the subject's experience with the first magnitude of reinforcement was gained concurrently with the acquisition of the instrumental response. The shift in reinforcement occurred at some point after asymptote had presumably been reached. In such a procedure the acquisition of the instrumental response and the experience with the reinforcement value are confounded. Collier and Marx[93] examined the effect of shifts in magnitude of reinforcement when the experience of the first magnitude of reinforcement and the acquisition of the instrumental response occur independently. Three groups of rats were magazine-trained on either 4%, 11.3%, or 32% concentrations of sucrose solutions. All groups were then bar-press trained on 11.3% sucrose on a 1-min. periodic reinforcement schedule for 10 days. The mean number of bar presses for the 4% group was greater than that for the 11.3% group, while the mean number of bar presses of the 11.3% group was greater than that for the 32% group for the 10 days of rewarded bar-pressing and the 4 days of extinction. The investigators point out that the results of their experiment offer difficulties for motivational and habit interpretations of reward. They suggest, instead, that the effects which

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[92] Spence, op. cit. p. 308.

[93] Collier, George, and Marx, M. H. Changes in performance as a function of shifts in the magnitude of reinforcement. J. exp. Psychol., 1959, 57, 305-309.

had led to these interpretations can be subsumed under the phenomena observed in determinations of psychological scales (Collier and Siskel[94]). Collier and Myers[95], on the basis of variations of concentration, volume, and interval between sucrose reinforcements in a bar-pressing situation with rats as subjects, showed that initial rate of responding is an increasing function of concentration and volume, and a decreasing function of interval, while the terminal rate is a decreasing function of concentration and volume and an increasing function of interval. They concluded, on analyzing their results, that two independent processes govern rate of responding in this situation, taste and momentary satiation. The former reflects sensory intensity and quality, the latter the momentary postingestive concentration.

The course of the role of magnitude of reinforcement in elimination of competing responses is another question to be considered. Quite interesting, and as Cotton[96] found out with deprivation states, the influence of the reinforcement is primarily one of eliminating competing responses (retracing, sitting, etc.) rather than increasing the rate of the instrumental response itself (Pereboom and Crawford[97]). In his experiment, Cotton analyzed the

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[94] Collier and Siskel, op. cit.

[95] Collier, George and Myers, Leonhard. The loci of reinforcement. J. exp. Psychol., 1961, 61, 57-66.

[96] Cotton, op. cit.

[97] Pereboom and Crawford, op. cit.

animal's actual running responses as well as competing responses which were made on the runway. Results indicated that the influence of varying hours of deprivation (0, 6, 16, and 22 hours) on running time was virtually non-existent when trials in which competing responses were present were eliminated from the analysis. Pereboom and Crawford, in a study of instrumental and noninstrumental acts in a straight runway, used training and reinforcement magnitude as independent variables. Two groups of 10 rats each were given systematic adaptation on one day and 40 acquisition trials on the next. The subjects were required to shuttle in a free-responding fashion between two food cups placed at opposite ends of a 16-ft. homogeneous runway, with one group receiving a 50-mg. pellet for each traversal and the other a 10-mg. pellet. Instrumental (cumulative forward progression) and competing (retracing, sitting, etc.) times were recorded for each reinforcement traversal. Results showed that reinforcement magnitude affects both forward running time and competing response time, the latter more so. These results, paralleling Cotton's, suggest that a good deal of the learning that is shown by decrease in running time may actually reflect the elimination of competing response tendencies, such as exploration and the like, rather than a marked decrease in forward running time.

As Cotton's and Pereboom's studies have employed the runway in showing how drive and reinforcement magnitude may affect behavior, the present study was designed to provide information as to the manner in which magnitude of reinforcement and drive are related in the bar-pressing situation. Precise evidence on continuous measurement of rate of responding is hard to obtain with the runway technique, but free operant behaviour reinforced on fixed ratio schedules shows local rates that are independent of reinforcement magnitude (Ferster & Skinner[98]).

The two methods of investigation employed in the present study are called the absolute and differential methods. Reinforcement magnitude effects may be investigated by (a) the absolute method of comparing groups or subjects one of which always receives a higher amount of reinforcement for making the given response than the other, or (b) by the differential method of comparing the strengths of S-R connections learned by the same subjects when these connections are followed by different reinforcement amounts. Under the differential method some quantitative differences in response followed by different reinforcement amounts are apparently always found (Greene[99]) (Saltzman[100]) (Meyer[101]); under the absolute method differences

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[98] Ferster, C. B., and Skinner, B. F. Schedules of reinforcement, New York: Appleton - Century - Crofts, 1957.

[99] Greene, J. E. Magnitude of reward and acquisition of a black-white discrimination habit. J. exp. Psychol., 1953, 46, 113-119.

[100] Saltzman, I. J. Maze learning in the absence of primary reinforcement: a study of secondary reinforcement. J. comp. physiol. Psychol., 1949, 42, 161-173.

[101] Meyer, D. R. The effect of differential rewards on discrimination reversal learning by monkeys. J. exp. Psychol., 1951, 41, 268-274.

between groups are not found for all measures (Furchtgott[102]) (Maher[103]) (Reynolds [104] [105]).

A recent experiment (Barakat [106]) employed the differential method in a study similar to the present one. With this method each subject experienced more than one value in each phase of the experiment. Using water and sucrose as reinforcing agents, the investigator examined overall and local rates of responding of seven rats reinforced on conjunctive and tandem schedules as functions of reinforcement magnitude and drive. (*Conjunctive* schedules require the satisfaction of an interval and a ratio concurrently. Responses are not reinforced until the passage of an interval of time *and* the performance of a number of responses. In *tandem* schedules reinforcements are delivered after both an interval and a ratio are satisfied consecutively.) She found that local rates of responding (bursts of responses before each reinforcement) did not vary with reinforcement magnitude, but that

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[102] Furchtgott, *op. cit.*

[103] Maher, W. B. and Wickens, D. D. Effect of differential quantity of reward on acquisition and performance of a maze habit. *J. comp. physiol. Psychol.*, 1954, *47*, 44-46.

[104] Reynolds, B. The acquisition of a black-white discrimination habit under two levels of reinforcement. *J. exp. Psychol.*, 1949, *39*, 760-769.

[105] Reynolds, B. Acquisition of a simple spatial discrimination as a function of the amount of reinforcement. *J. exp. Psychol.*, 1954, *40*, 152-160.

[106] Barakat, Hind. The effects of schedules and magnitudes of reinforcement on behavior. Unpublished M. A. thesis. American University of Beirut, Beirut, Lebanon, 1962, p. 14.

they could be increased by increasing deprivation conditions. The results also showed that overall rates (total number of responses within each experimental session divided by total time of the session) did not follow reinforcement magnitudes when thirsty rats were reinforced with sucrose solutions; however, hungry and thirsty rats responded more for greater than for lesser magnitudes of reinforcement.

This experiment investigates local and overall response rates of 9 rats reinforced on a fixed ratio (FR) schedule as functions of reinforcement magnitude and drive. (An FR or fixed ratio schedule means that a response is reinforced upon completion of a fixed number of responses counted from the preceding reinforcement.) Water and various concentrations of sucrose solution were used as reinforcing agents in the bar-pressing situation, with shifts being made in drive conditions from a thirst-deprivation schedule to one of hunger-thirst deprivation. The absolute method of experimentation was used in the stabilization phase of the experiment and the differential method in the phases of reinforcement and drive level changes. By employing the absolute method, the stabilization phase of this experiment offers a comparison of results obtained with those of preliminary studies using the differential method.

CHAPTER III

Method

Subjects

Nine male white rats of local stock were used in this experiment. Seven of them, numbered 13b, 14b, 15, 16, 17, 18, and 19, were naive (not used in experimental work prior to this experiment). Two animals, numbered 13 and 14, had been on a complex FR schedule in a previous experiment. All the animals were born on the same date, the seven naive rats being 144 days old at the beginning of the experiment and the other two rats being 154 days old, when they were brought for use in this experiment.

Apparatus

The apparatus consisted of a Skinner box measuring 9.5 by 8.5 by 8.25 ins., which was enclosed in a sound-resistant, light-tight, commercial ice-box hull. Ventilation was provided by a steady flow of air produced by an electric blower. The blower also provided a masking sound for extraneous noises. The box was dimly lighted by a shielded 6 watt light. Two other light sources were in the box, one red and one green, but these were not used in the present experiment.

The Skinner box also contained an electrically operated buzzer, a bar, and a dipper. The buzzer was a small direct-current relay which produced an audible, but not startling noise whenever the dipper presented the reinforcement. The bar (Gerbrands model), which was 2 in. long, 2.25 in. above floor level, and 2 in. to the left of the dipper, was activated by a pressure of approximately 20 grams. Bar-pressing responses were recorded by means of a magnetic counter and a graphic recorder which made a cumulative plot of responses against time. The number of reinforcements each subject received in each experimental session was also counted.

The dipper lay in a magazine outside the Skinner box and at the appropriate times was automatically raised to give .05cc of the reinforcing substance for a period of 2 sec. The reinforcing substance consisted of either water or sucrose solution; 4%, 8%, 16%, and 32% by weight sugar in tap water. Fresh solutions were prepared about every 5 days.

Habituation and feeding schedule

For 8 days prior to the first acquisition session the naive Subjects were habituated to handling and were fed and watered on a deprivation schedule. They were deprived of food and water for 23½ hours and fed and watered for the remaining ½ hour of a 24-hour period. This rhythm is designated HT23½. The other two Subjects, S13 and S14, were on a T23½ deprivation schedule for 8 days before being trained for experimental use prior to their use in this experiment. They were deprived of water for 23½ hours and watered for the remaining ½ hour of a 24-hour period, while food was always available in their home cages. In the previous experiment in which they were Subjects, these two animals had been on a complex FR schedule for 150 days.

At the beginning of the experiment the Subjects were put on the feeding and drinking rhythm designated HT22½. That is, they were deprived of food and water for 22½ hours of a 24-hour period and were fed 15 grams of food 1 hour prior to their daily experimental sessions, which lasted 30 minutes. Therefore their training sessions were run with the Subjects on a thirst deprivation schedule designated T22½. Free access to water was allowed for 30 min. every day 30 min. after each training session.

Procedure

This experiment consisted of four phases: (a) stabilization, (b) changes in magnitude of reinforcement, (c) drive level changes, and (d) subsidiary procedures. In phases (a) and (b) the sessions were run with the Subjects on a T22½ thirst deprivation schedule. In phase (c) the Subjects were run on a hunger-thirst deprivation schedule designated HT22½. That is, they were deprived of food and water for 22½ hours of a 24-hour period and were fed 15 grams of food ½ hour after their daily experimental sessions, at the same time they were allowed free access to water.

(a) Stabilization phase. The 7 naive Subjects were trained to bar-press in the Skinner box up to terminal reinforcement schedule FR12 over about 30 ½-hour sessions, and were maintained on FR12 throughout the experiment. FR12 is a schedule of reinforcement in which the twelfth response after the preceding reinforcement is reinforced. Training sessions to terminal reinforcement on FR12 were run daily with the Subjects reinforced under one of several magnitudes of reinforcement as shown in Table 1. This is known as the absolute method of experimentation. After reaching FR12, the Subjects were maintained on this regime for about 10 more sessions, appropriate measures being taken as soon as local response rates stabilized. Local rates of responding refer to the response rate of the last 10 responses in a set of 12 responses (FR12) before a reinforcement is given.

TABLE 1

Subjects' Magnitudes of Reinforcement in Stabilization Phase

Subjects	Magnitude of Reinforcement
13, 14, 17, 18	Water
13b, 14b	4% sucrose
15, 16, 19	16% sucrose

(b) Changes in reinforcement magnitude. After stabilization on terminal schedule FR12 over a period of about 10 days, reinforcement magnitudes for all Subjects were shifted according to the differential method of experimentation. The magnitudes for Subjects 13, 14, 17, and 18 were increased from water to 16% sucrose; that of Subject 14b from 4% to 16% sucrose, and those of Subjects 15, 16, and 19 from 16% to 32% sucrose. Subject 13b was put on a different schedule as will be explained later.

After stabilization on these reinforcement schedules (over a period of about 10 days), the reinforcement magnitude for Subject 14b was shifted from 16% to 32% sucrose for 8 days, and for Subjects 15 and 16 from 32% to 16% sucrose for 22 days.

A summary is given in Table II of these changes in magnitude of reinforcement all of which were made under a deprivation schedule of T22½, along with the number of sessions of experimentation with each change.

TABLE II

Changes in magnitude of reinforcement under the deprivation schedule of T22½

Changes in reinforcement magnitude	Subjects	Number of Sessions
A. First change		
1. water to 16%	13, 14 17, 18	8 13
2. 4% to 16%	14b	10
3. 16% to 32%	15, 16, 19	10
B. Second change		
1. 16% to 32%	14b	8
2. 32% to 16%	15, 16 19	22 14

(c) Drive level changes. Once the animals reached a stable rate of responding with the shifts in reinforcement magnitude, changes in the drive level were made for subjects 13, 14, 17, 18, 14b and 19 from a deprivation schedule of T22½ to one of HT22½, i.e. feeding before the experimental session was omitted.

Subjects 13, 14, 17, and 18 were maintained on the same sucrose concentration, 16%, as they had been in the first change of the phase of reinforcement magnitude changes. Subject 14b was maintained on 32% sucrose, the same concentration it had been on in the second change of the phase of reinforcement magnitude changes, while the magnitude of Subject 19 was shifted from 16% to 32%.

After a stabilization period of 14 days, the reinforcement magnitude for Subjects 13, 14, and 18 following the differential method, was increased to 32%, the HT22½ deprivation schedule being maintained, for a period of about 7 days. After stabilization, Subject 14b was put on a HT46½ deprivation schedule, and was maintained on this schedule for 3 sessions. On an HT46½ schedule, the Subject is deprived of food and water for 46½ hours before each experimental session.

A summary is given in Table III of these changes in drive level, along with the number of sessions of experimentation with each change and the reinforcement magnitude employed.

TABLE III

Changes in drive level with reinforcement magnitude employed

Changes in drive level	Subjects	Reinforcement magnitude			Number of sessions
		T22½	HT22½	HT46½	
A. First change					
1. T22½ to HT22½	13, 14	16%	16%		14
	17, 18	16%	16%		15
	14b	32%	32%		14
	19	16%	32%		3
2. " " "	13, 14, 18		32%		6, 7, 5
B. Second change					
1. HT22½ to HT46½	14b		32%	32%	3

(d) Subsidiary procedures. The effect of zero drive on local response rates was investigated in this experiment, using Subjects 15, 16, and 19. (In zero drive the Subject is watered as well as fed immediately before the experimental session is begun.) The Subjects were put on zero drive for 6 days with reinforcements of water the first day, 32% sucrose the second, third, and fourth days, and water again on the fifth and sixth days. Prior to these 6 days, Subjects 15 and 16 had been on a T22½ deprivation schedule with 16% reinforcement, and Subject 19 on a HT22½ deprivation schedule, also with 16% reinforcement.

The effect of experimental extinction on local response rates was also investigated in this experiment. (Extinction refers to the witholding of a reinforcement previously contingent upon a response.) Subject 13b, after being stabilized to a terminal schedule of FR12 with 4% sucrose reinforcement over a period of 29 days, and Subject 19, after being on an HT22½ schedule for 4 days, were put on experimental extinction for a period of 3 days. Then both Subjects were trained back up to previous performance and put on a Crf (continuous reinforcement) 10 min. FR12 20 min. schedule to observe behavioral changes under this schedule.

Response Measures

The measurements of the responses in this experiment were as follows:

1. The overall rate of responding was measured by the total number of responses within each experimental session divided by the

number of minutes in the session (r.p.m.).

2. Local rates of responding or the response rate of the last 10 responses before reinforcement was measured in terms of responses per second (r.p.s.).
3. The total number of reinforcements received were recorded under each concentration.

CHAPTER IV

Results - Reinforcement Changes

First reinforcement changes.

Figures 1a and 1b show sample cumulative records produced by Subject 13 under the reinforcement condition with which it was stabilized and under its first reinforcement change, water and 16% sucrose respectively. The Subject did not respond uniformly throughout the intervals between reinforcements, but paused after reinforcements for brief periods of time and then responded in a single burst of 12 responses. This was true with both water and 16% sucrose as reinforcing agents under the deprivation schedule of T22½. The records for Subjects 14, 17, and 18 are similar to those of Subject 13, although the pause length periods of Subjects 17 and 18 are typically longer than those of Subjects 13 and 14; that is, they made fewer bursts of 12 responses within the ½ hour daily experimental session.

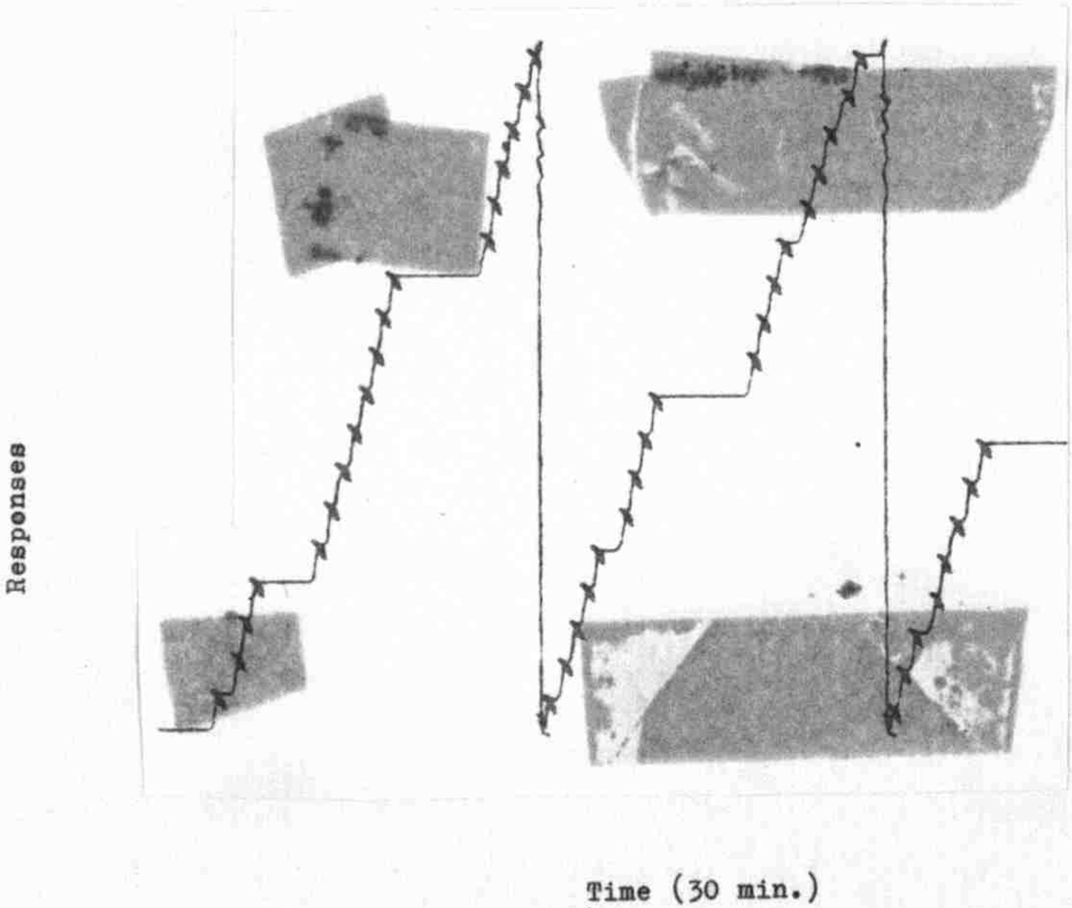

Fig. 1a. Sample cumulative graphic record of S13 with water reinforcement under T22½.

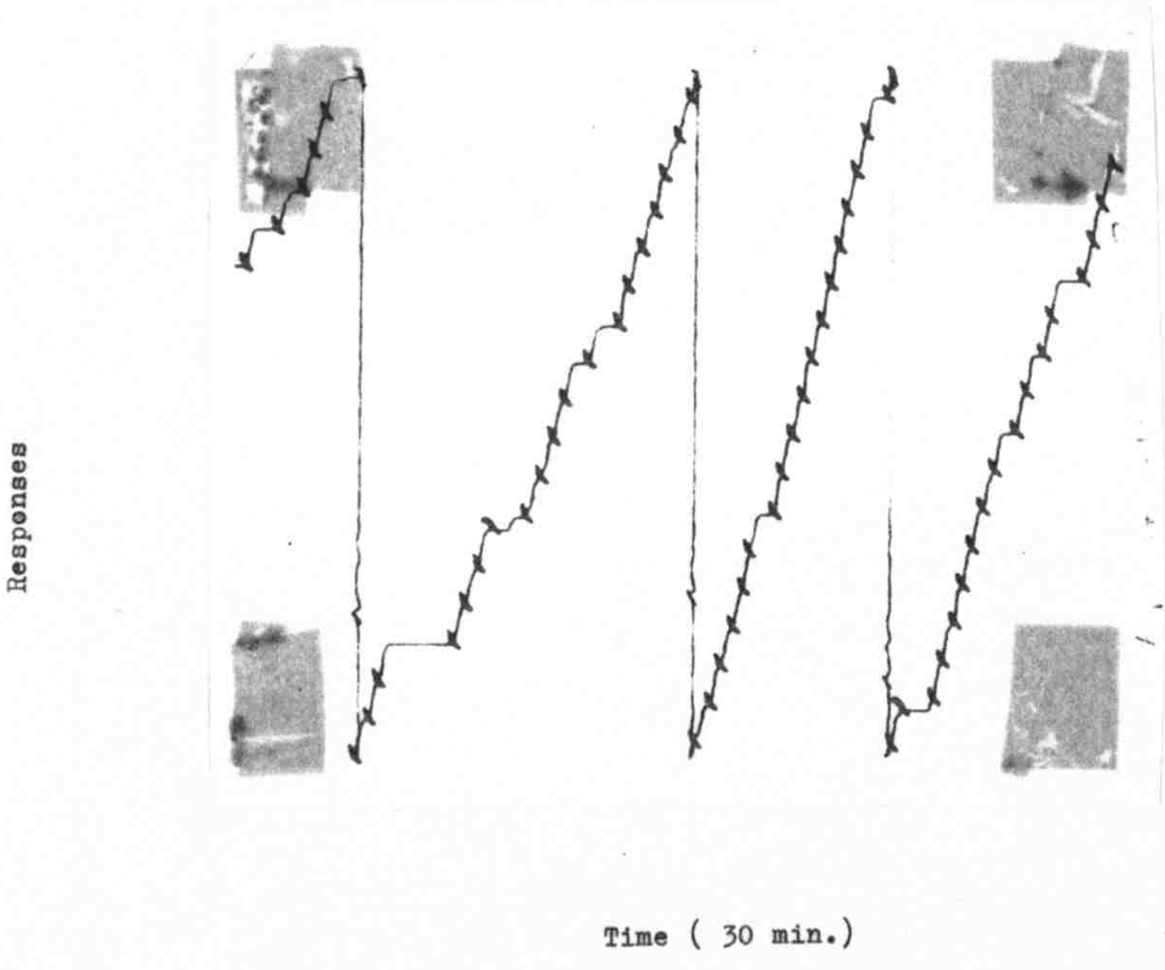

Fig. 1b. Sample cumulative graphic record of S13 with 16% sucrose reinforcement under T22½.

Figure 2 (phases 1 and 2) and Figure 3 (phases 1 and 2) show the daily number of responses emitted and the total number of reinforcements received by Subject 13 under its first reinforcement change from water to 16% sucrose under T22½. The mean overall rate

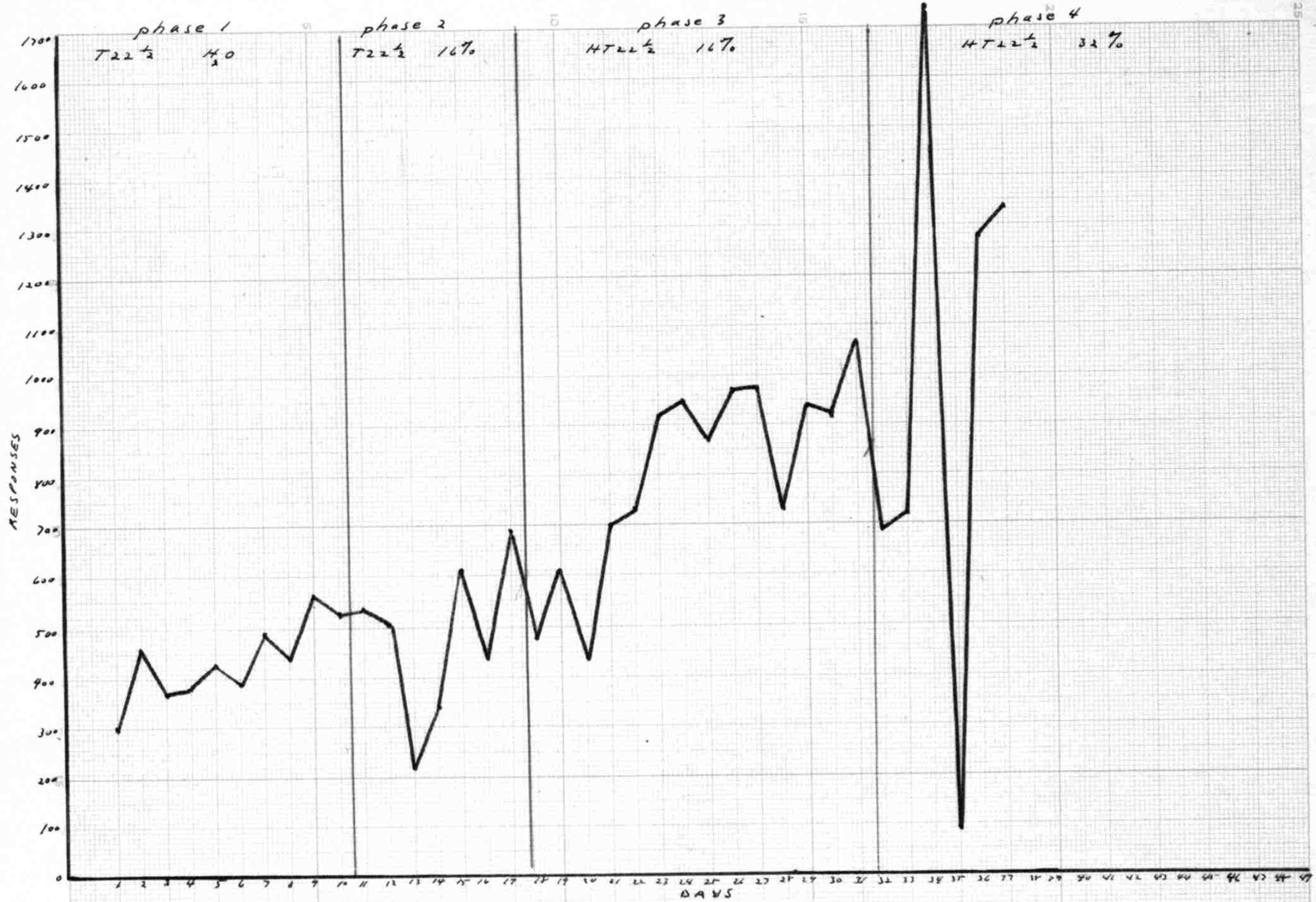

FIG. 2. Daily number of responses emitted by S13

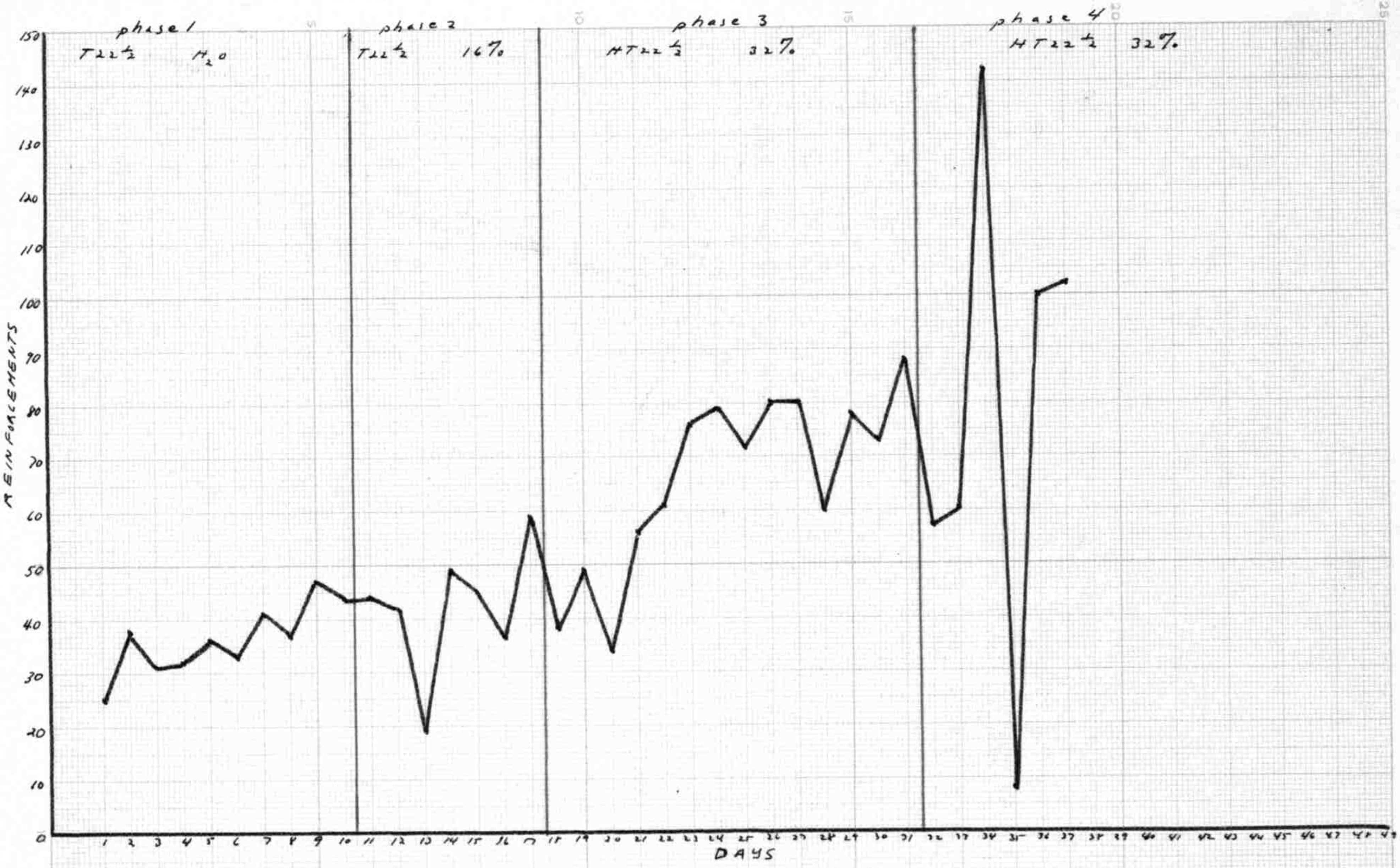

FIG. 3. Total number of reinforcements received by S13

was slightly affected by the increase in reinforcement magnitude, increasing from 14.6 r.p.m. to 15.9 r.p.m. The mean reinforcement increased from 36.4 to 39.3 reinforcements.

Figure 4 (phases 1 and 2) shows the daily mean local rates for Subject 13 for its first change in reinforcement magnitude under T22½. This increase in magnitude did not increase the mean local rate, but even decreased it slightly from 1.4 r.p.s. to 1.1 r.p.s.

The daily number of responses emitted and the total number of reinforcements received by Subject 14 under its first reinforcement change, from water to 16% sucrose under T22½, are shown in Figure 5 (phases 1 and 2) and Figure 6 (phases 1 and 2). Like Subject 13, Subject 14 increased its mean overall rate and mean reinforcement as a function of reinforcement magnitude. Its mean overall rate increased from 14.7 r.p.m. to 15.6 r.p.m. and its mean reinforcement from 36.3 to 38.8 reinforcements.

Figure 7 (phases 1 and 2) shows Subject 14's daily mean local rates for its first reinforcement change under T22½. Paralleling the results of Subject 13, the increased reinforcement magnitude did not increase Subject 14's mean local rate, but even decreased it slightly from 1.8 r.p.s. to 1.5 r.p.s.

As can be seen from Figure 8 (phases 1 and 2), Figure 9 (phases 1 and 2), Figure 10 (phases 1 and 2), and Figure 11 (phases 1 and 2), the daily number of responses emitted and the total number of reinforcements received by Subjects 17 and 18 on their first

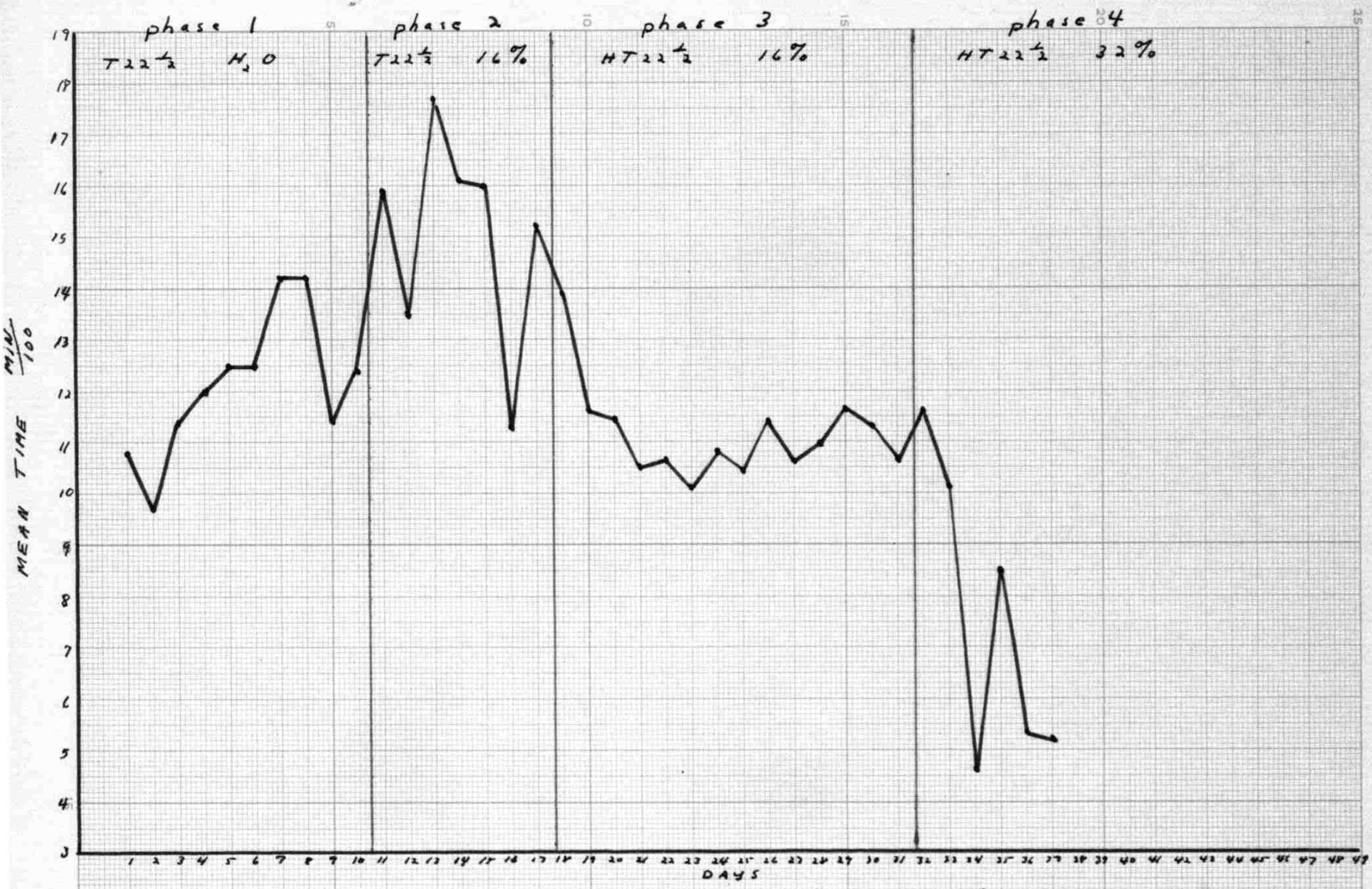

FIG. 4. Daily mean local rates of S13

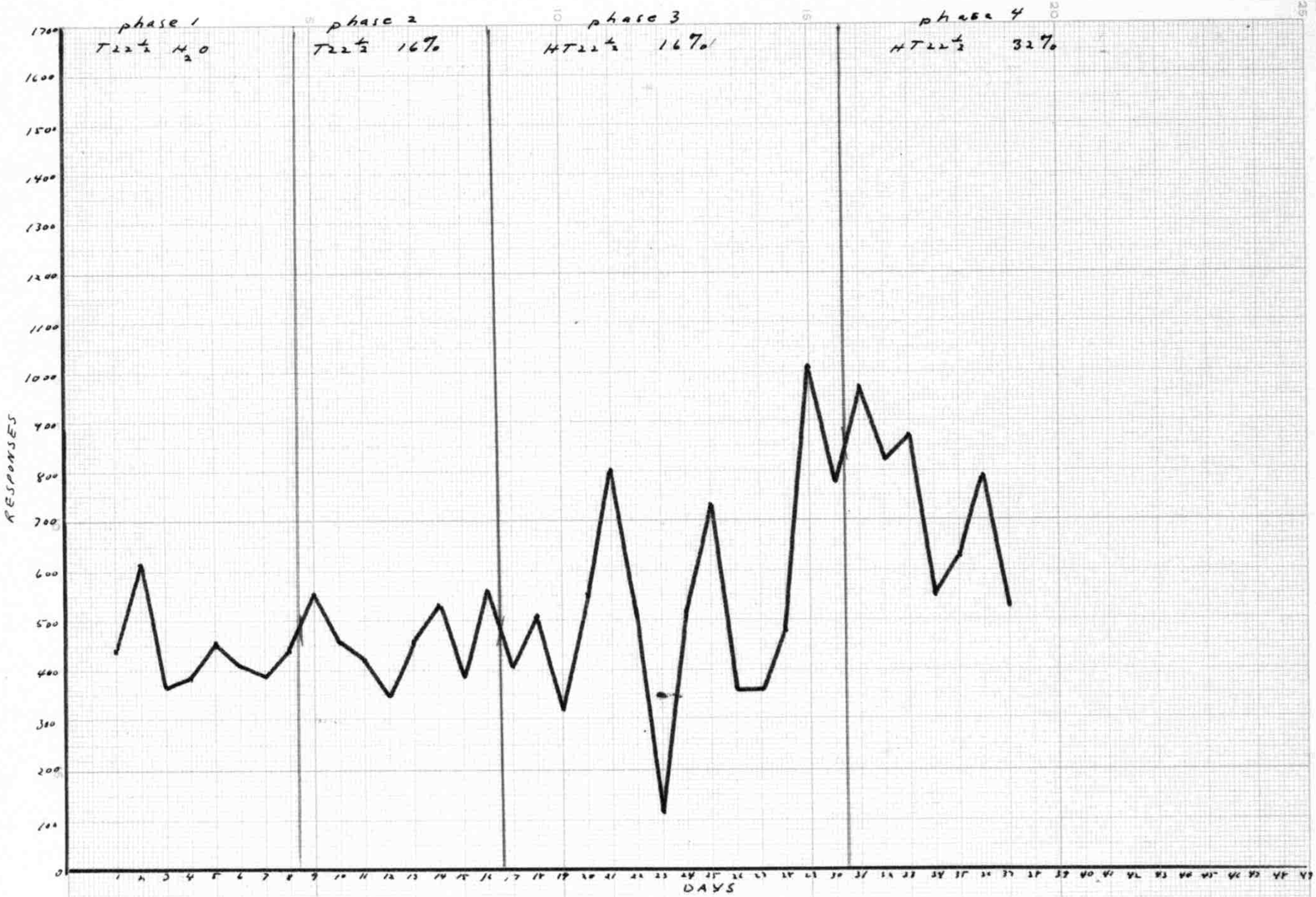

FIG. 5. Daily number of responses emitted by S/4

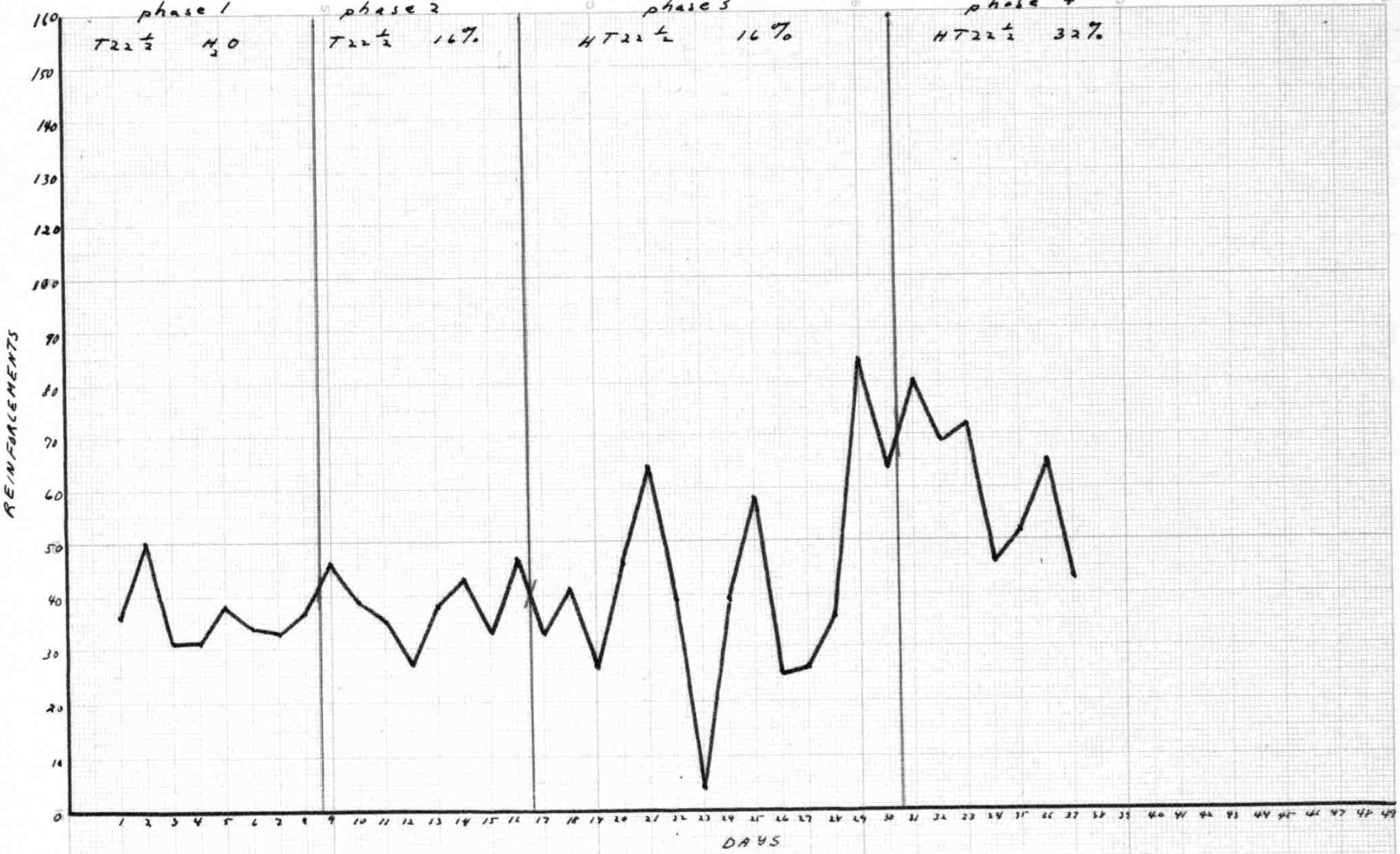

FIG. 6. Total number of reinforcements received by S14

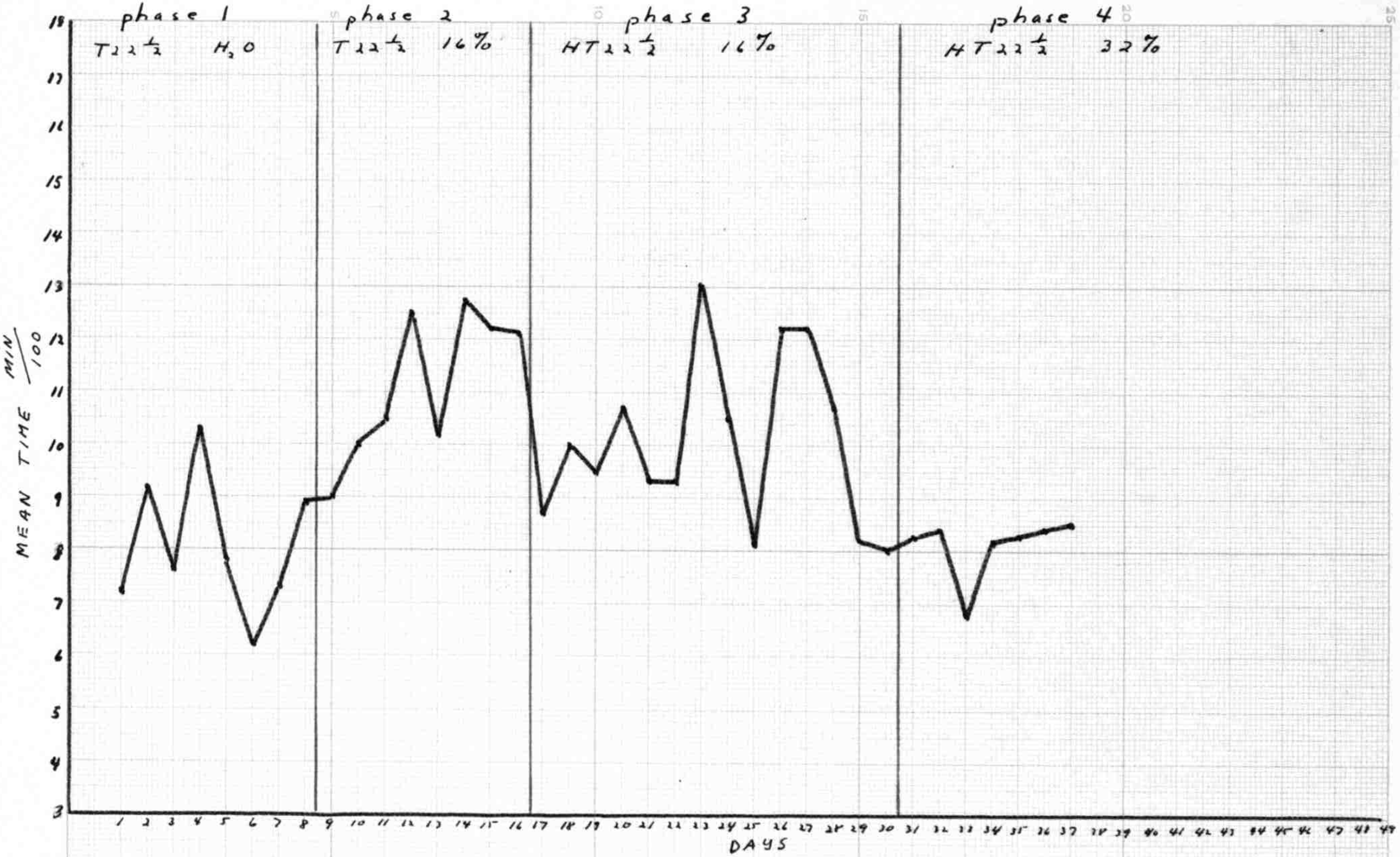

FIG. 7. Daily mean local rates of S14

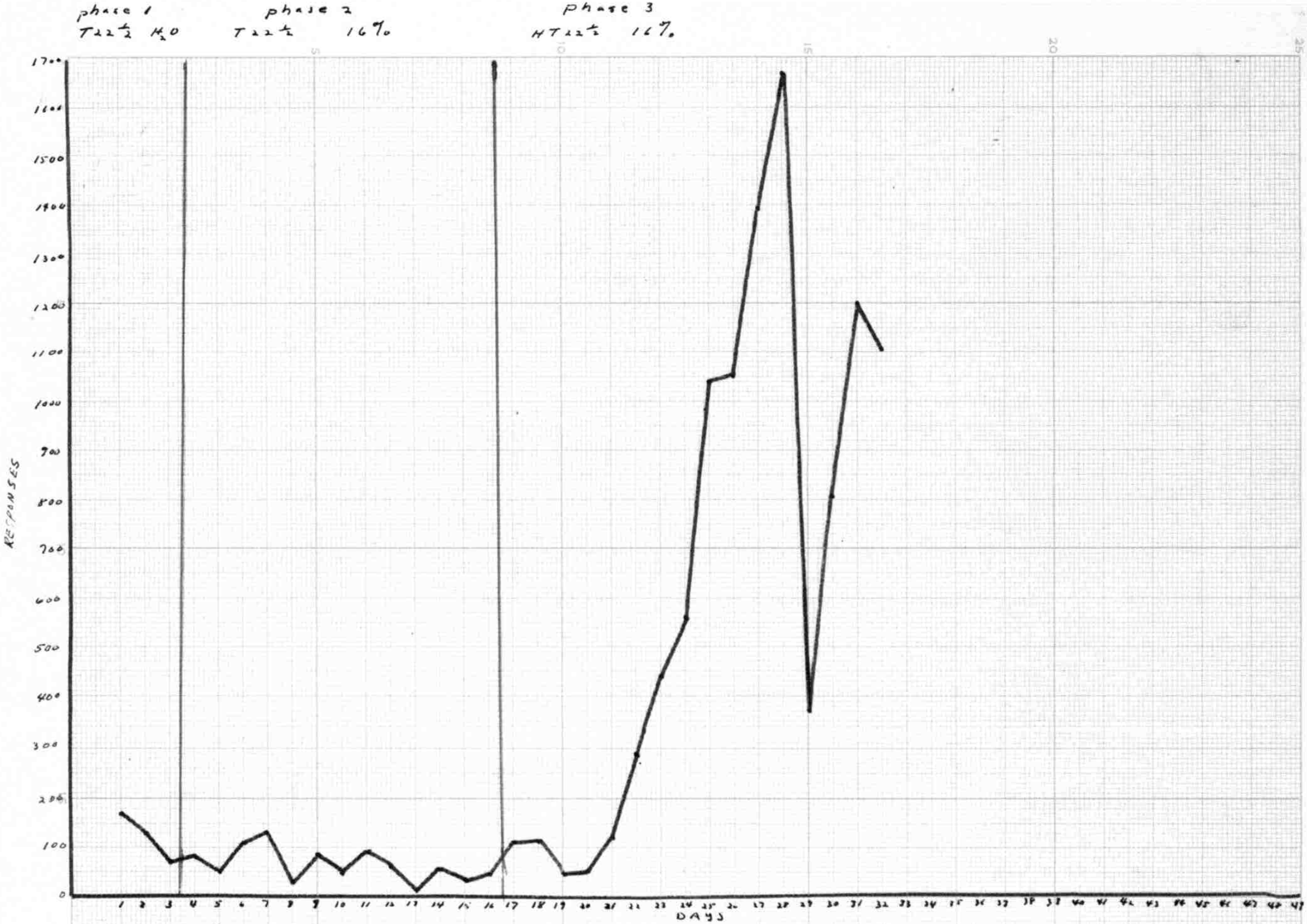

FIG. 8. Daily number of responses emitted by S17

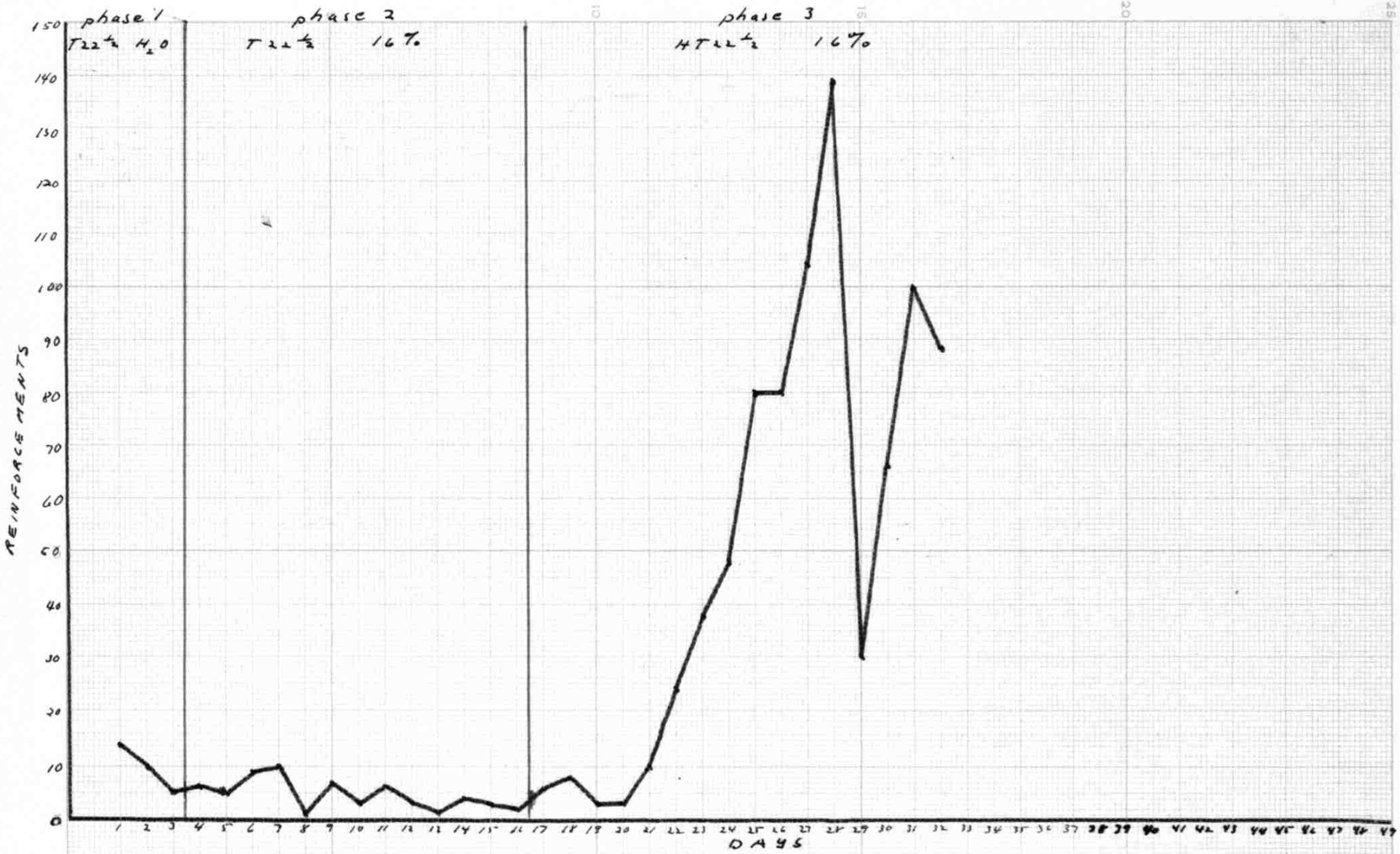

FIG. 9. Total number of reinforcements received by S17

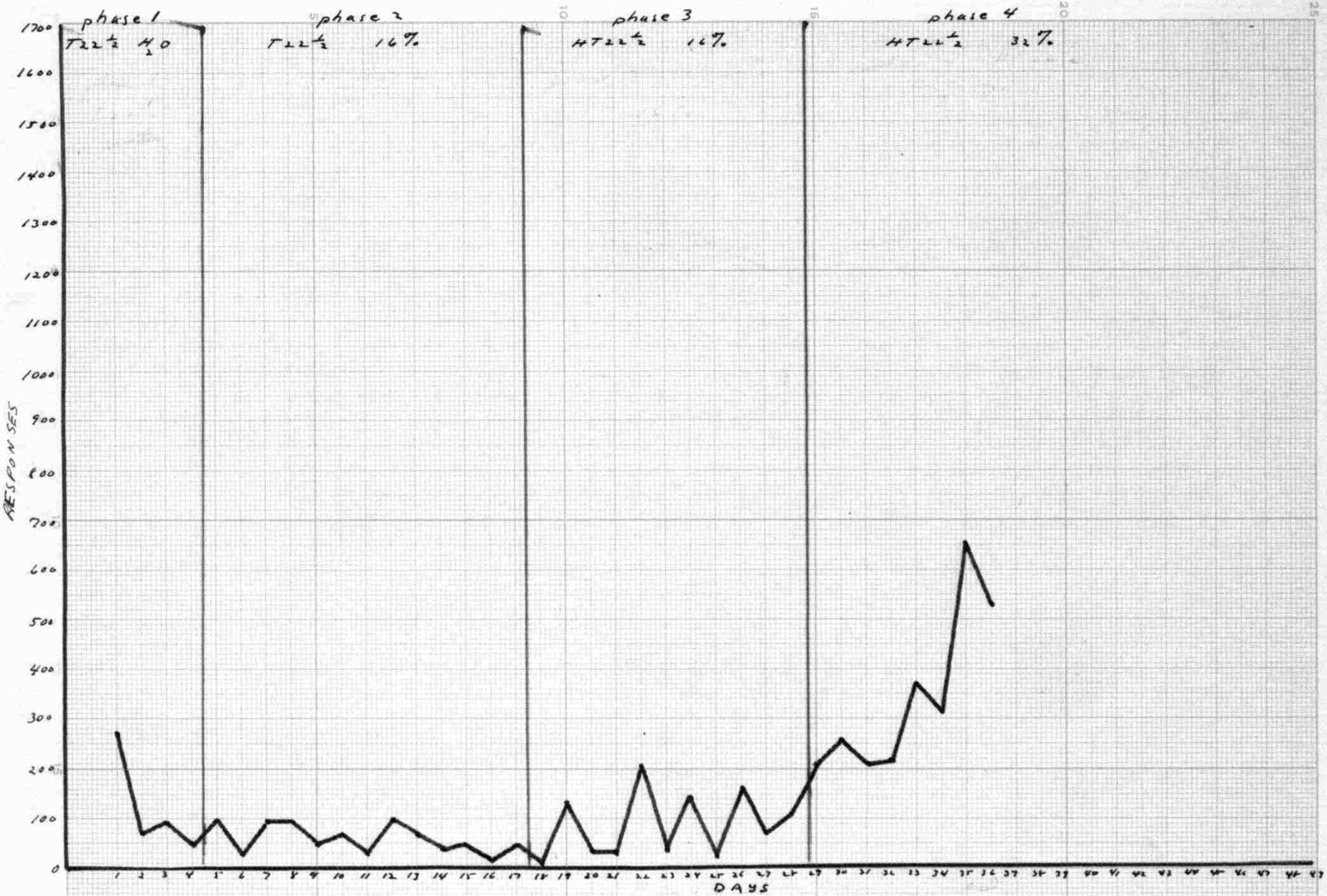

FIG. 10. Daily number of responses emitted by S18

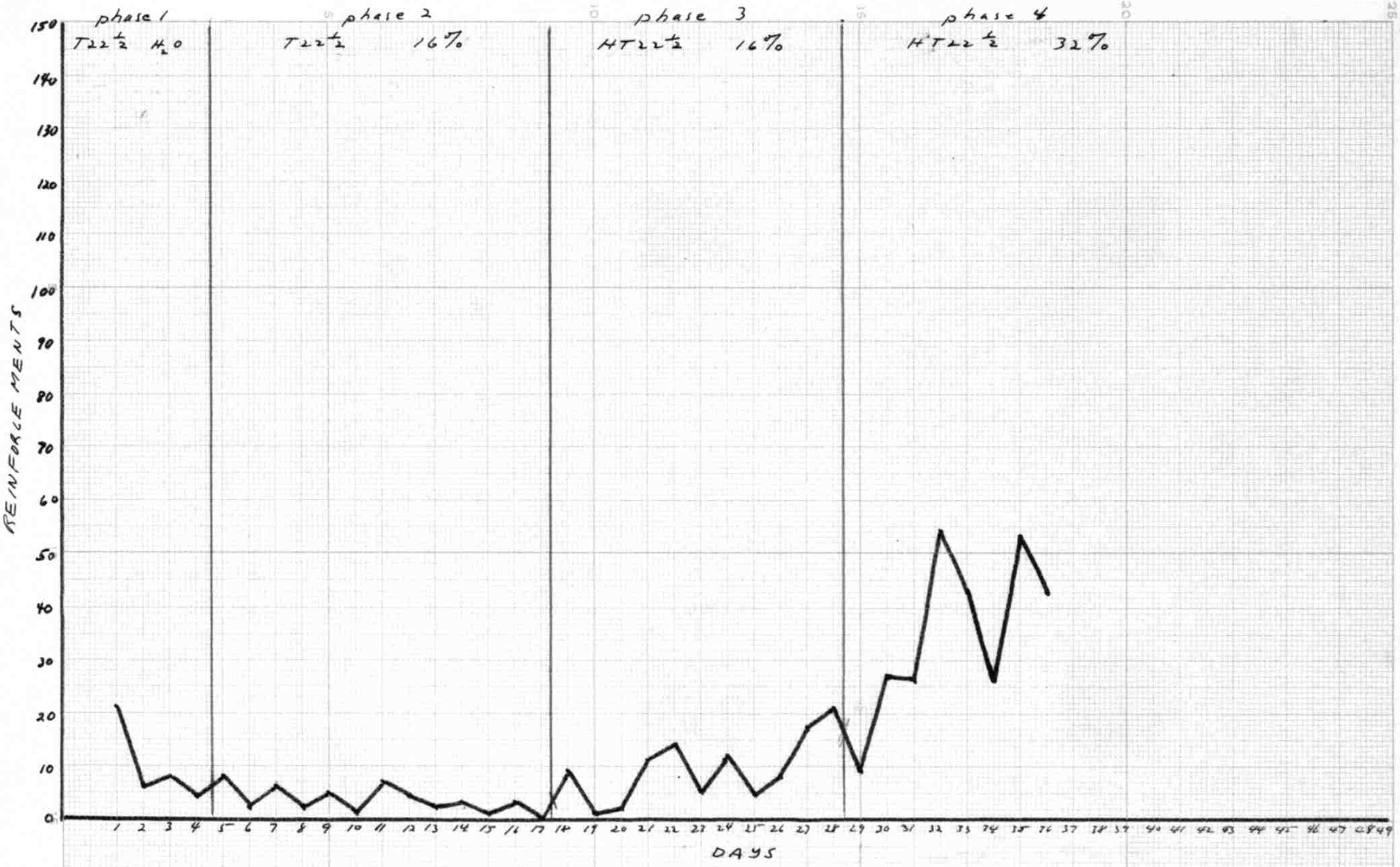

FIG. 11. Total number of reinforcements received by S18

reinforcement change, from water to 16% sucrose under T22$\frac{1}{2}$, were considerably less than those of Subjects 13 and 14. For Subject 17, the mean overall rate sharply increased from 4.0 r.p.m. to 14.2 r.p.m. Cumulative records of Subject 17 on water reinforcement and on 16% sucrose, which are shown in Figures 12a and 12b, clearly bring out this change in mean overall rate. For Subject 18 there was a decrease in both mean overall rate and mean reinforcement as a function of reinforcement magnitude. The mean overall rate decreased from 4.1 r.p.m. to 1.9 r.p.m. and the mean reinforcement from 9.8 to 3.5 reinforcements.

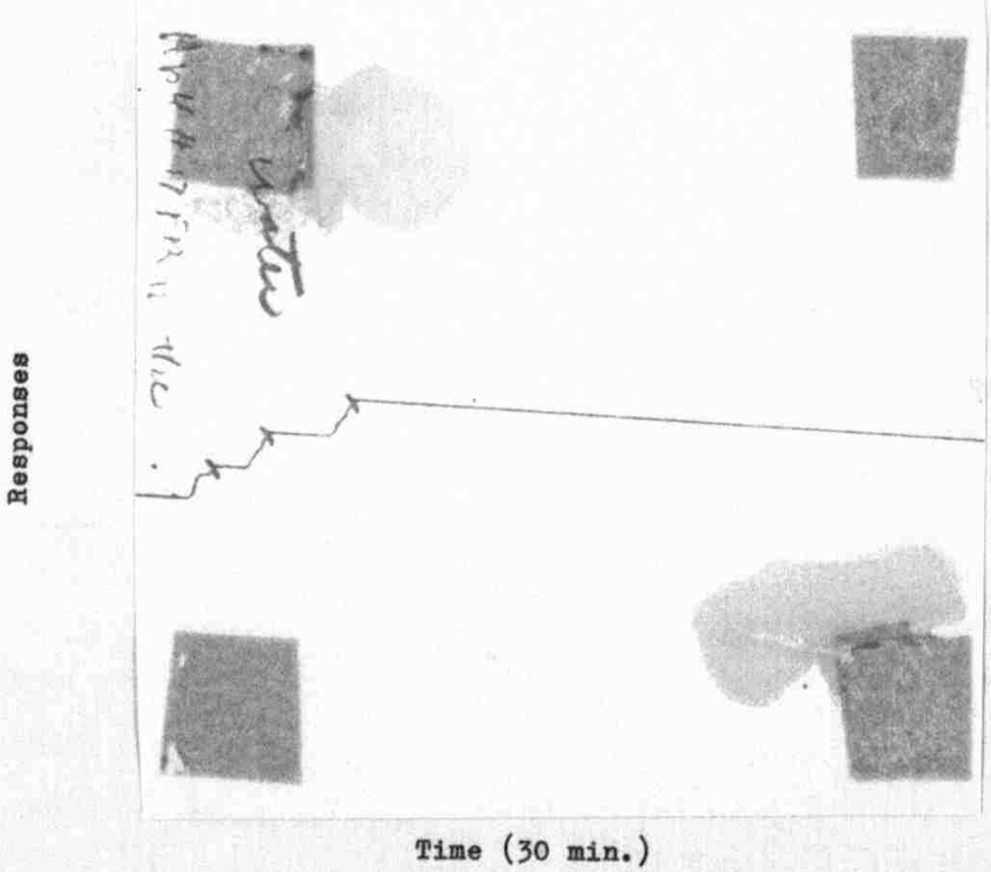

Fig. 12a. Sample cumulative graphic record of S17 with water reinforcement under T22$\frac{1}{2}$.

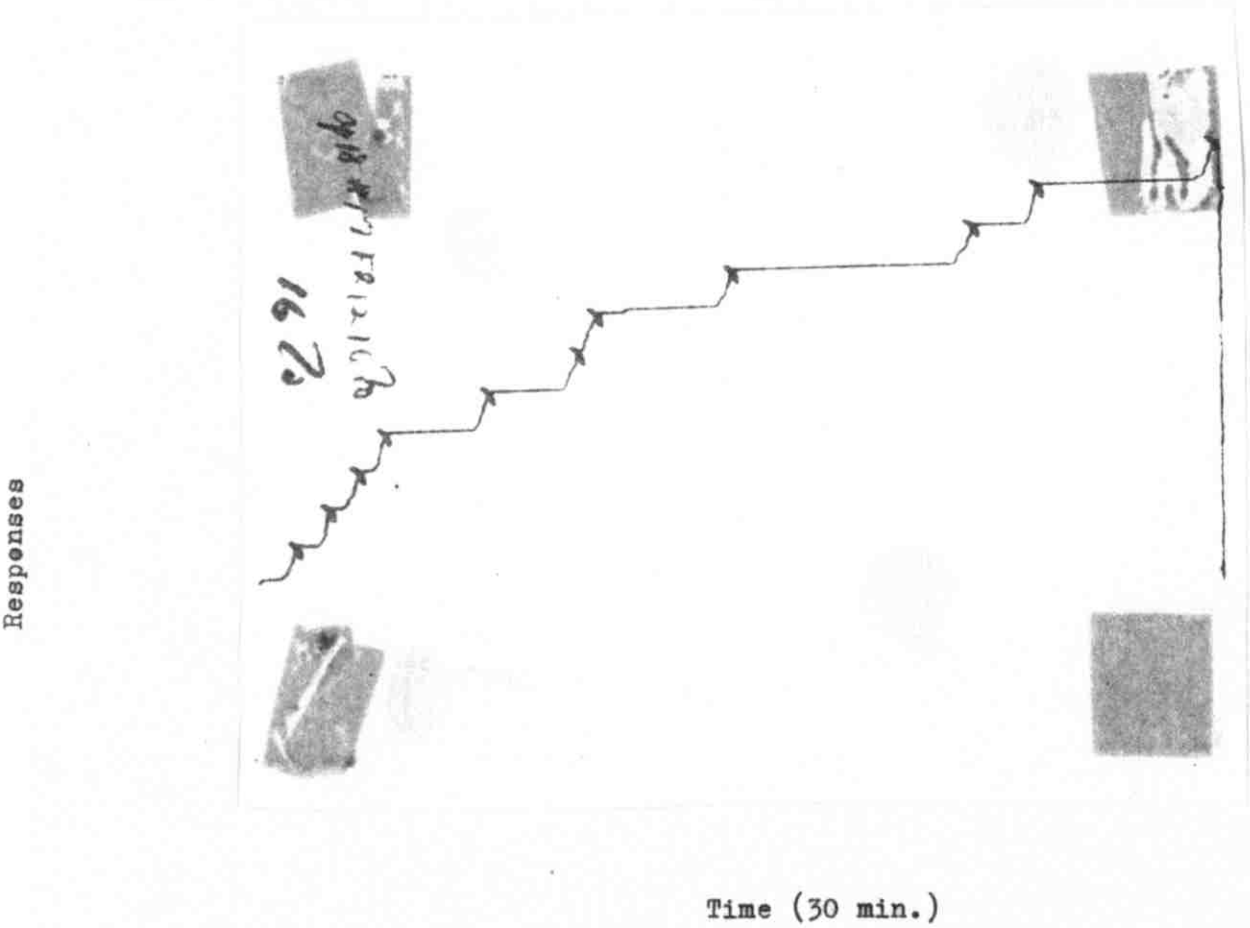

Fig. 12b. Sample cumulative graphic record of S17 with 16% sucrose reinforcement under T22½.

Figure 13 (phases 1 and 2) and Figure 14 (phases 1 and 2) show the daily mean local rates for Subjects 17 and 18 respectively with water and 16% sucrose as reinforcing agents under T22½. Their mean local rates remained constant at 0.6 r.p.s. with the shift in reinforcement magnitude. Therefore these findings provide further evidence for the results

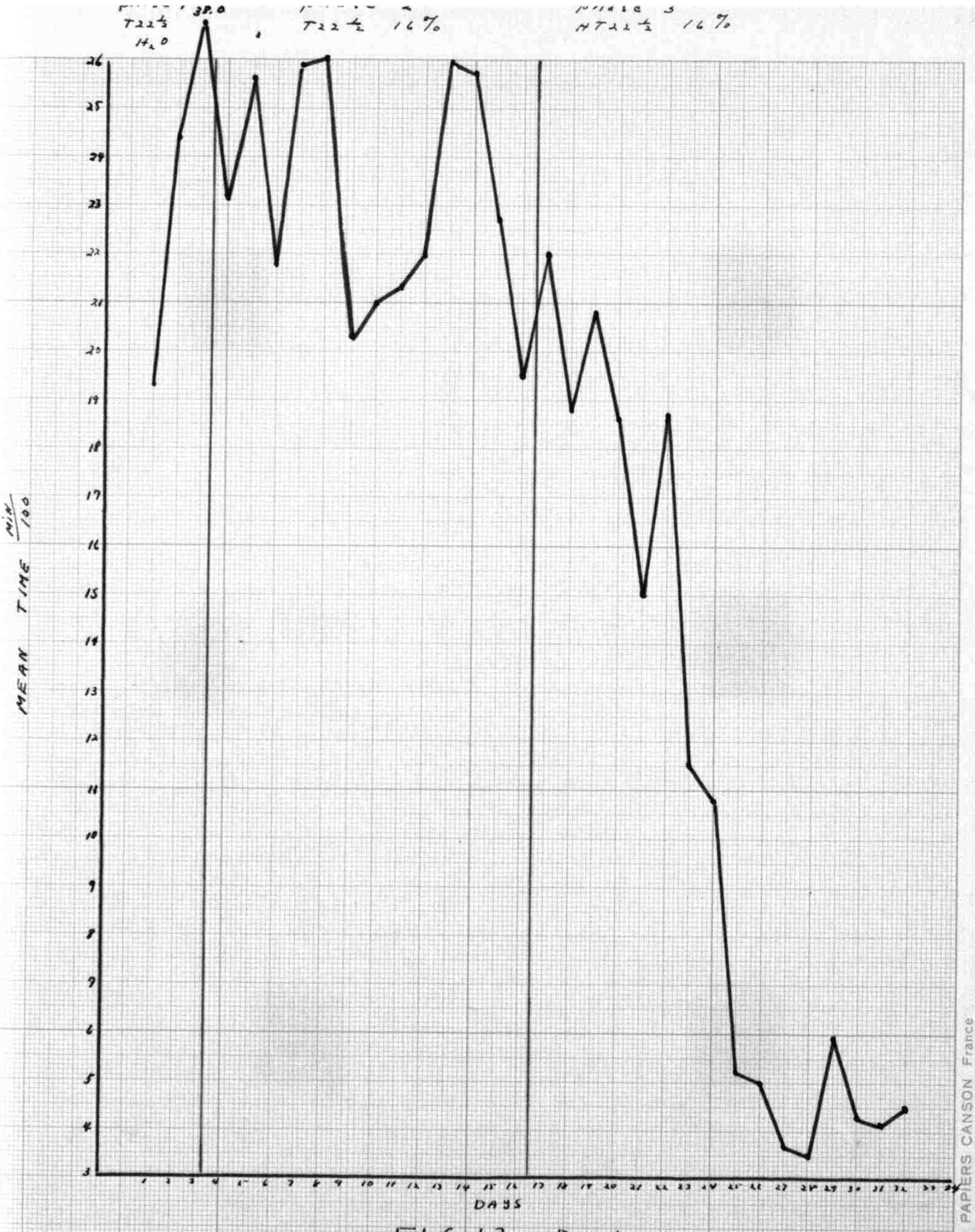

FIG. 13. Daily mean local rates of S17

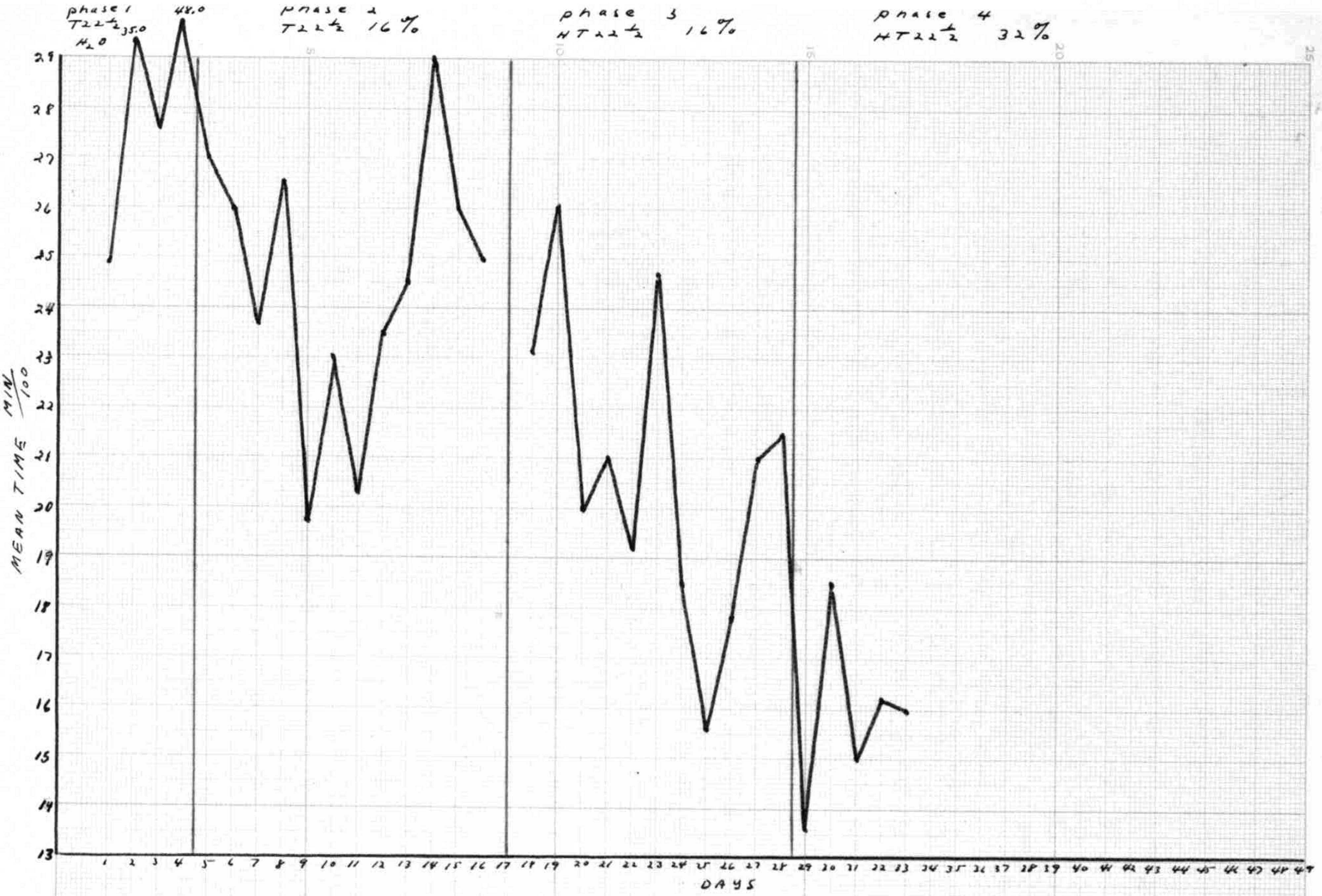

FIG. 14. Daily mean local rates of S 18

of Subjects 13 and 14, namely that mean local rates do not increase as a function of reinforcement magnitude.

The first reinforcement change for Subjects 13, 14, 17, and 18, from water to 16% sucrose under T22½, therefore, did not increase the mean local rate of responding, although the mean overall rate and mean reinforcement for all the Subjects, except Subject 18, increased as a function of reinforcement magnitude.

A shift from 4% to 16% sucrose under T22½ was the first reinforcement change for Subject 14b. Figure 15 (phases 1 and 2) and Figure 16 (phases 1 and 2) show the daily number of responses emitted and the total number of reinforcements received in this first shift of Subject 14b. Both measures increased slightly as a function of magnitude of reinforcement, from 2.3 r.p.m. to 2.9 r.p.m. and from 4.9 to 6.1 reinforcements respectively. In Figure 17 (phases 1 and 2), showing the daily mean local rates of Subject 14b for 4% and 16% sucrose under T22½, there is little change in the position of the curve on the graph, indicating little change in mean local rate as a function of reinforcement magnitude, and thus paralleling the results found for Subjects 13, 14, 17, and 18. The mean local rate for Subject 14b changed only from 0.6 r.p.s. to 0.7 r.p.s.

A shift from 16% to 32% sucrose under T22½ was the first reinforcement change for Subjects 15, 16, and 19. Figure 18 (phases 1 and 2), Figure 19 (phases 1 and 2), and Figure 20 (phases 1 and 2) show the daily number of responses emitted, the total number

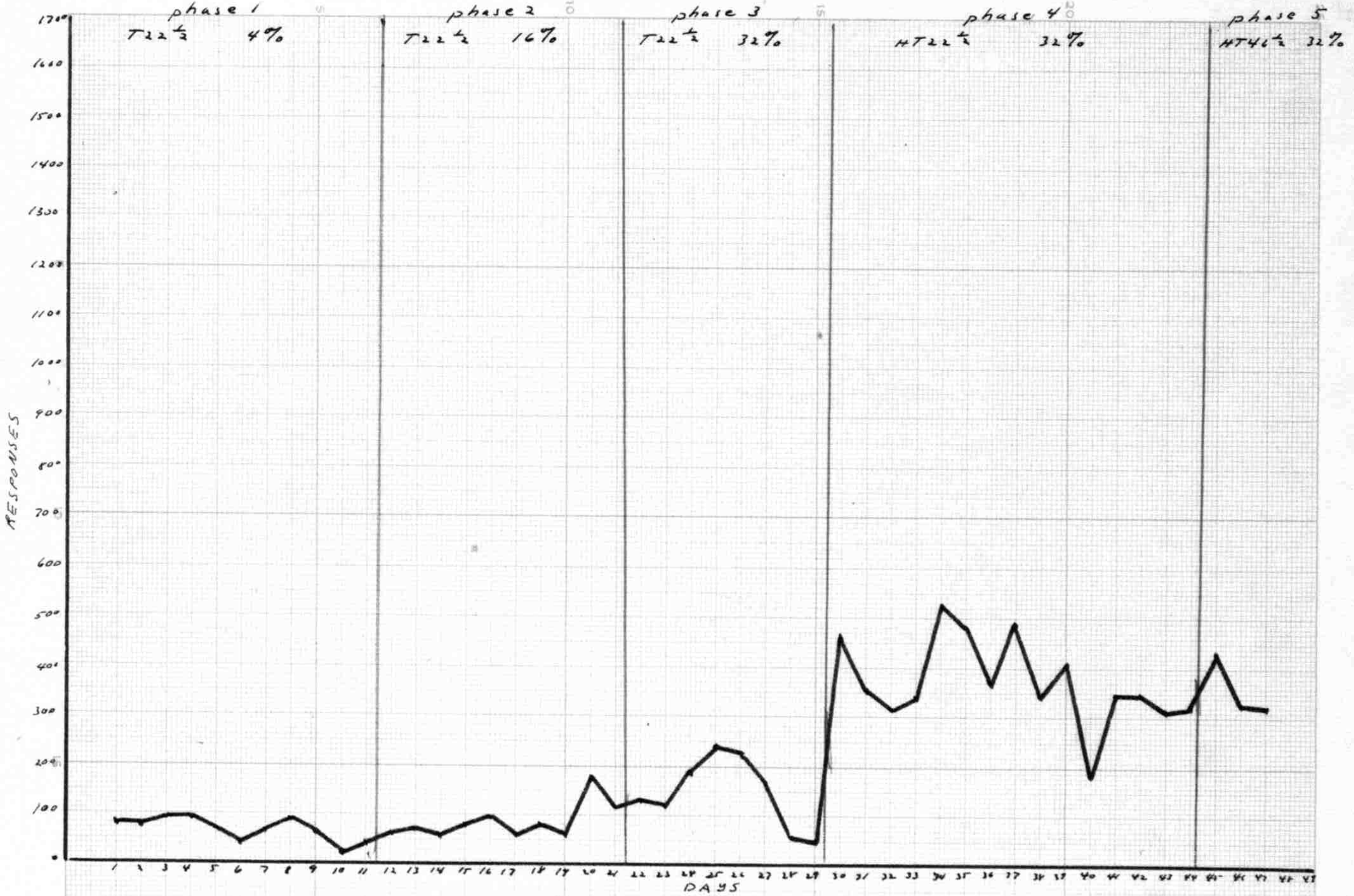

FIG. 15. Daily number of responses emitted by S146

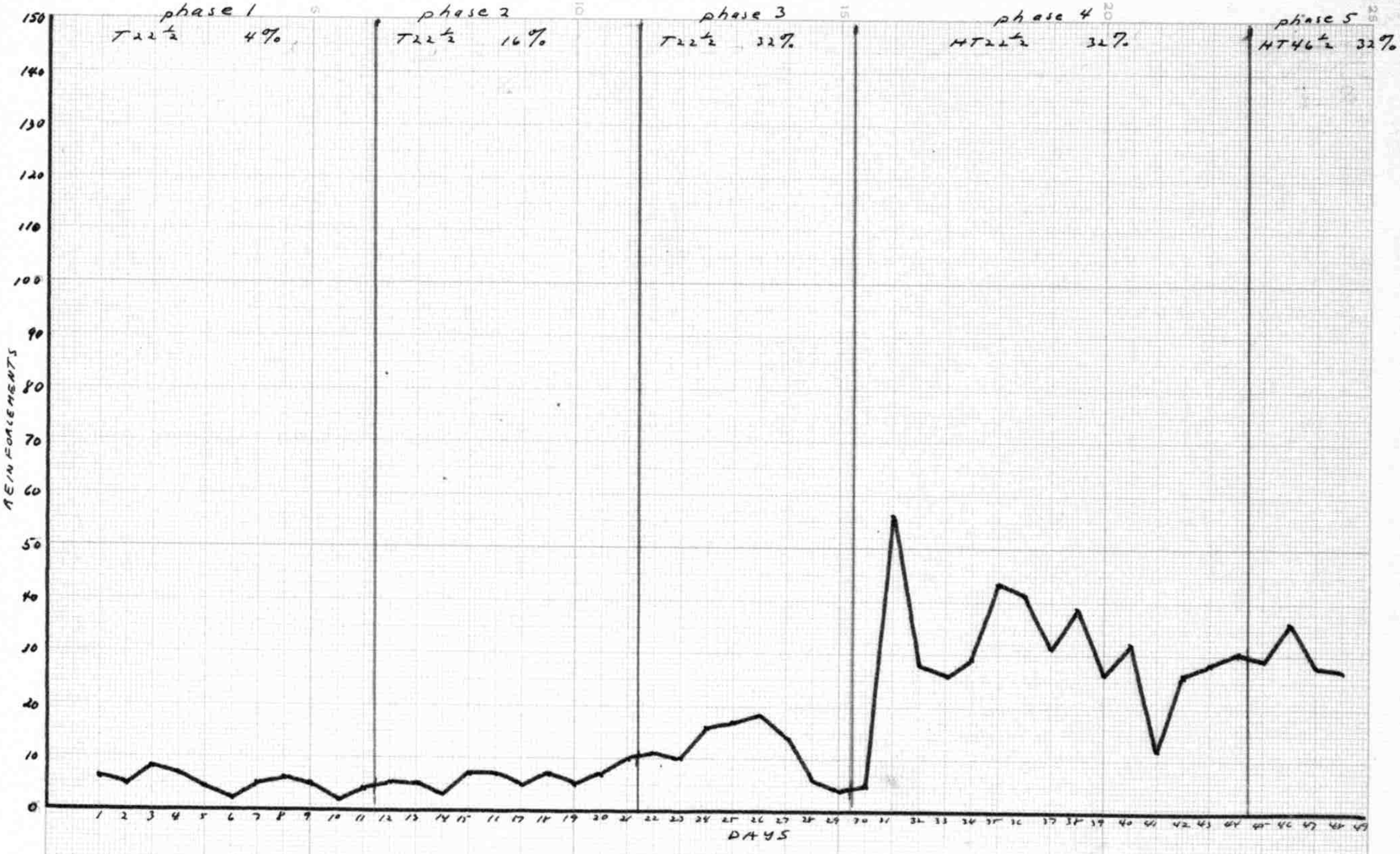

FIG. 16. Total number of reinforcements received by S146

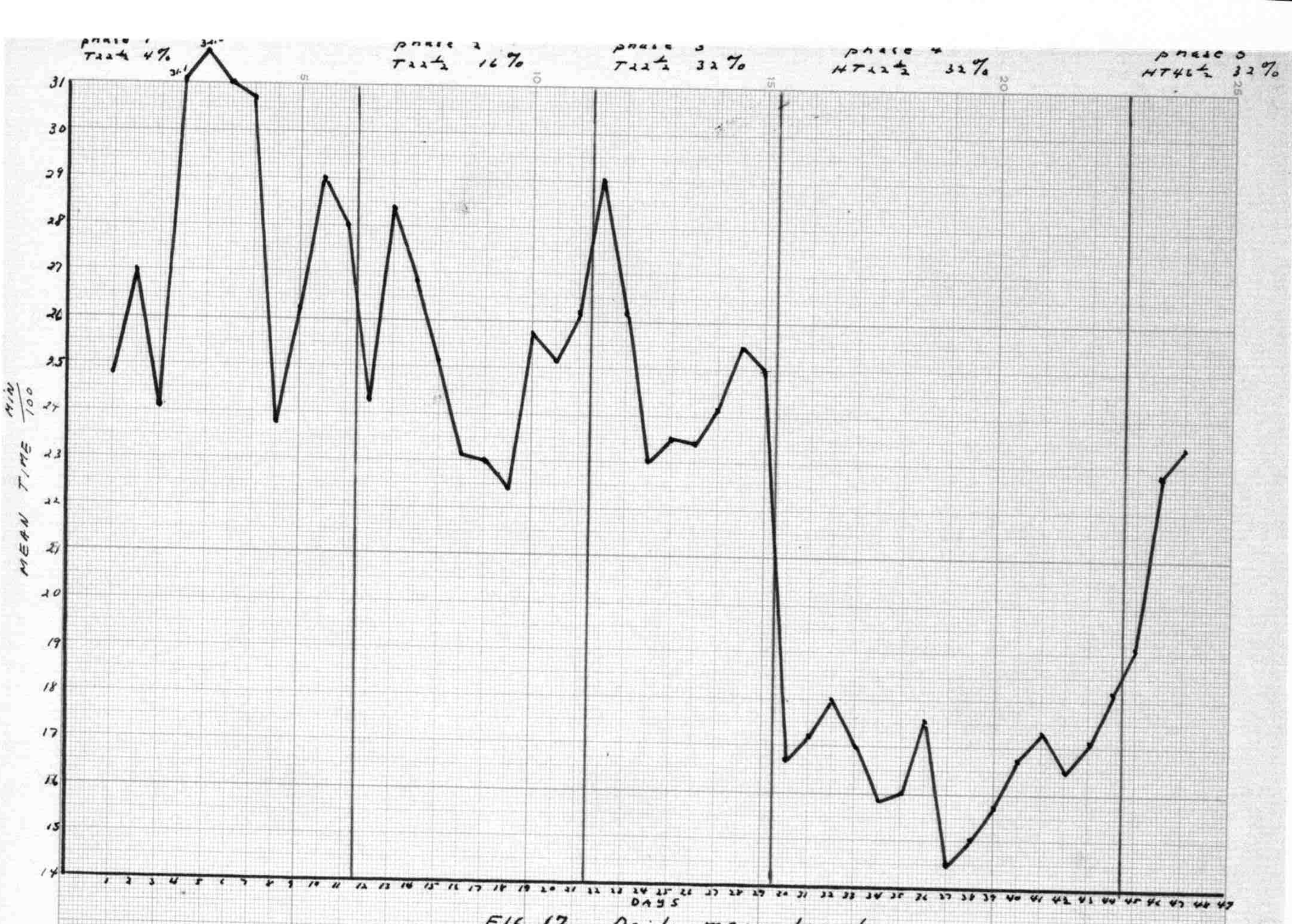

FIG. 17. Daily mean local rates of S146

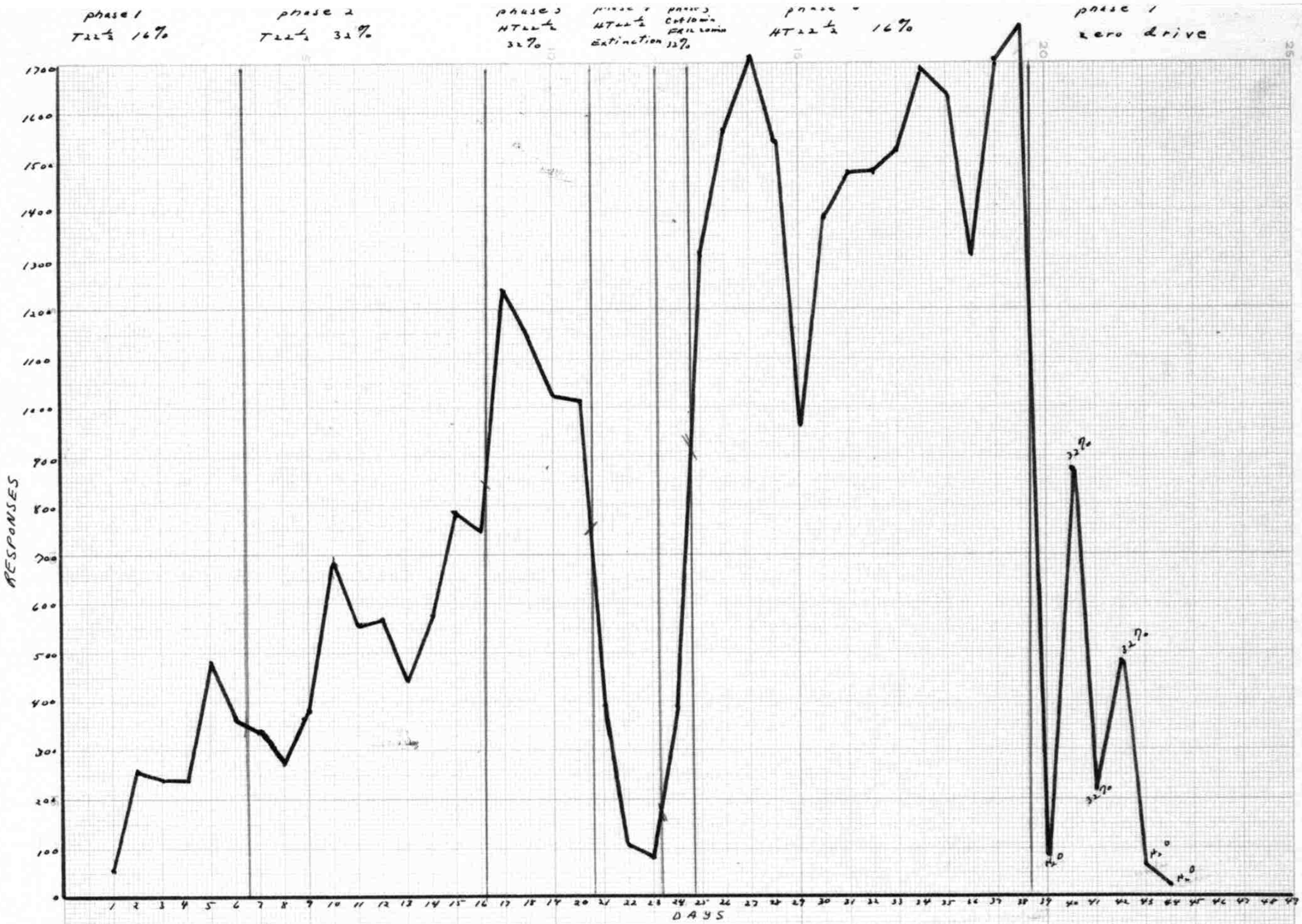

FIG. 18. Daily number of responses emitted by S19

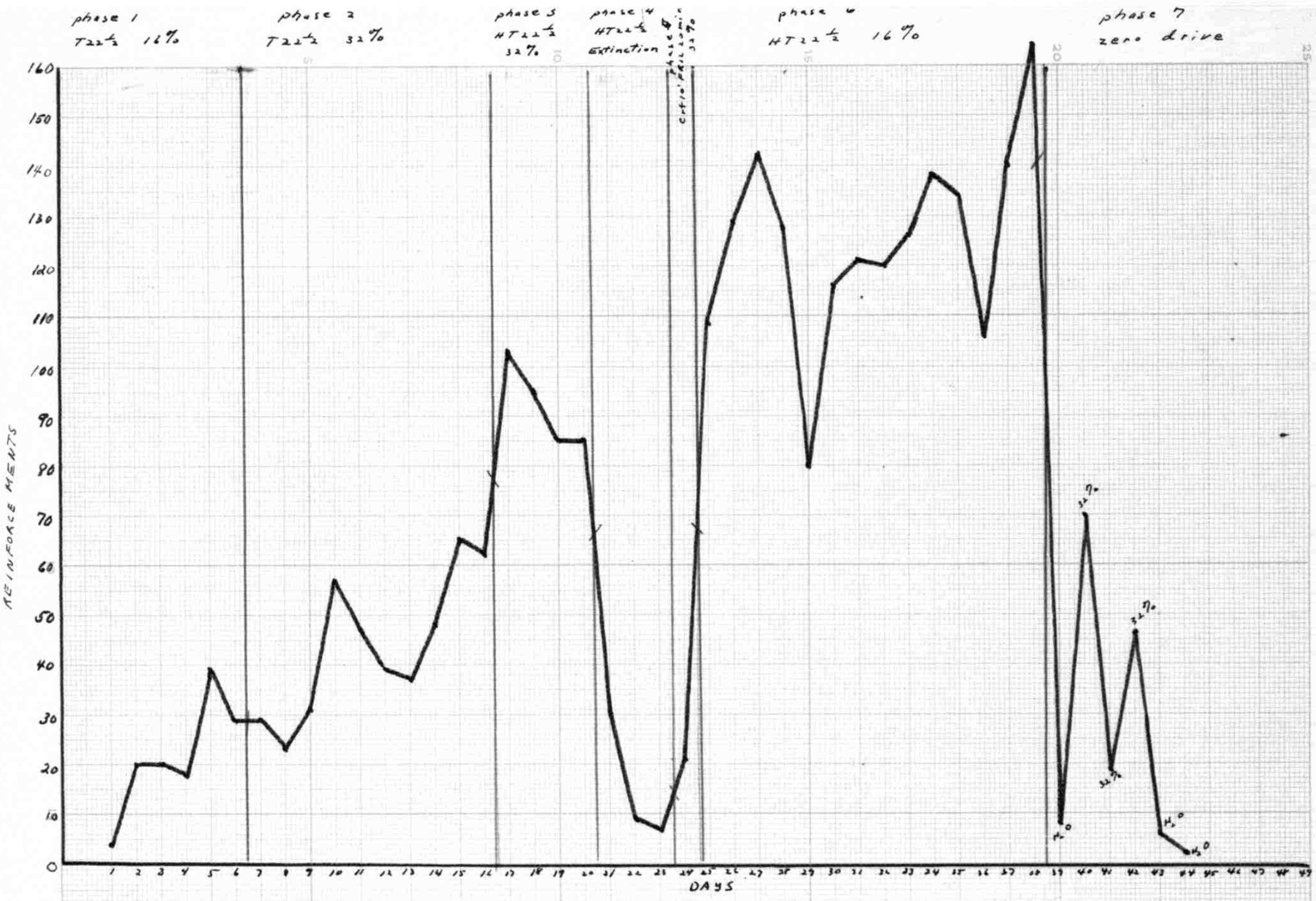

FIG. 19. Total number of reinforcements received by S19

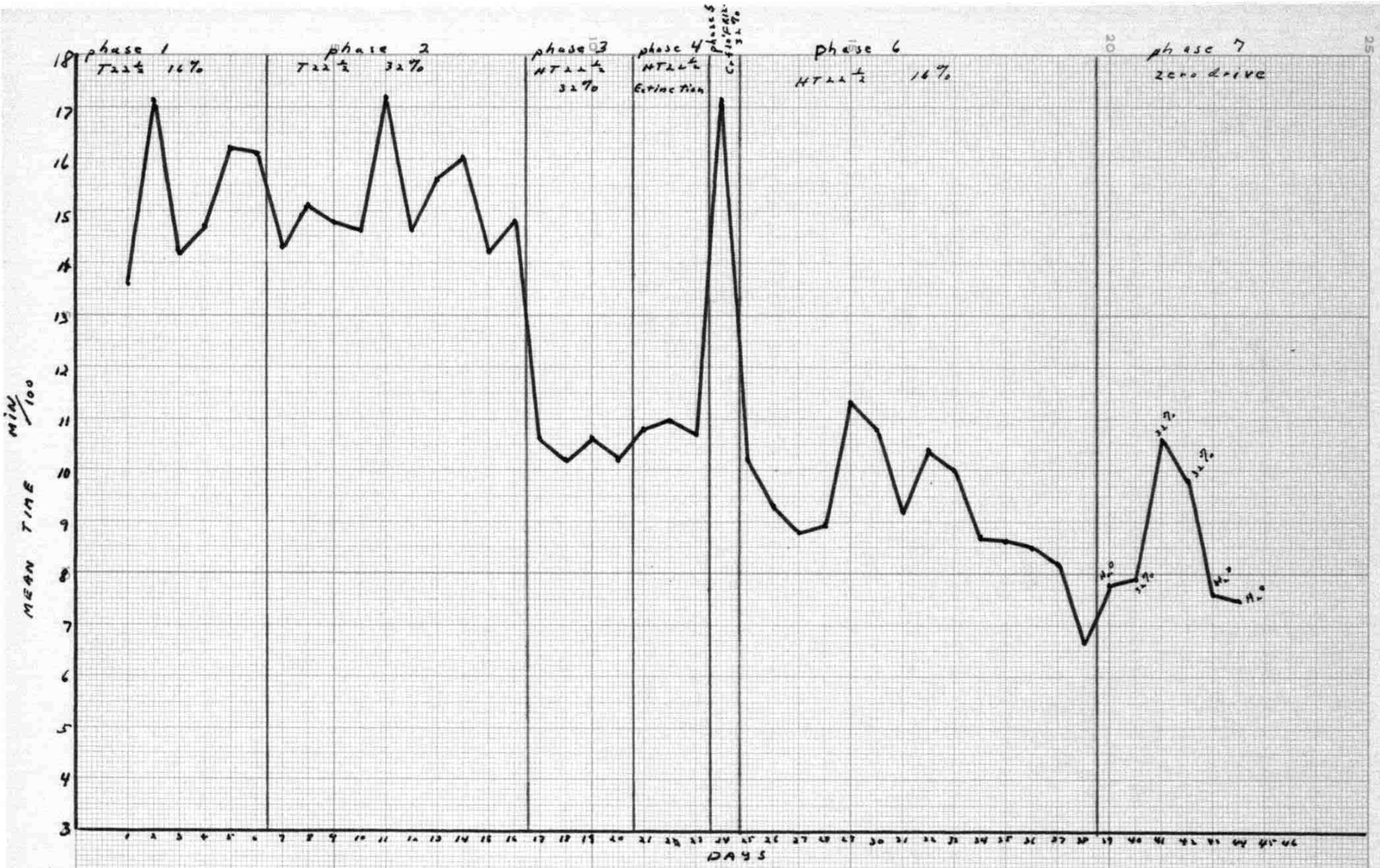

FIG. 20. Daily mean local rates of S19

of reinforcements received, and the daily mean local rates respectively for Subject 19 for the number of sessions it was reinforced with 16% and 32% sucrose. Its mean overall rate increased from 9.3 r.p.m. to 17.9 r.p.m. and its mean reinforcement from 21.6 to 43.8 reinforcements as a function of magnitude of reinforcement. Its mean local rate, however, remained constant at 1.1 r.p.s. with the shift from 16% to 32% sucrose under T22½. In other words, this animal's performance on local rate of responding further confirmed that of Subjects 13, 14, 17, 18, and 14b.

The daily number of responses emitted and the total number of reinforcements received for Subject 15 with 16% and 32% sucrose under T22½ may be seen from Figure 21 (phases 1 and 2) and Figure 22 (phases 1 and 2). This animal's mean overall rate increased from 12.9 r.p.m. to 32.0 r.p.m., and its mean reinforcement from 27.9 to 77.3 reinforcements with the increase in reinforcement magnitude. Its daily mean local rates are shown in Figure 23 (phases 1 and 2). The mean local rate also increased as a function of reinforcement magnitude, from 2.0 r.p.s. to 3.1 r.p.s. In other words, the mean local rate of responding of Subject 15 did not confirm the results found for the local response rates of Subjects previously discussed.

Figure 24 (phases 1 and 2), Figure 25 (phases 1 and 2), and Figure 26 (phases 1 and 2) show the daily number of responses emitted, the total number of reinforcements received, and the daily mean local rates of responding for the experimental sessions in which Subject 16

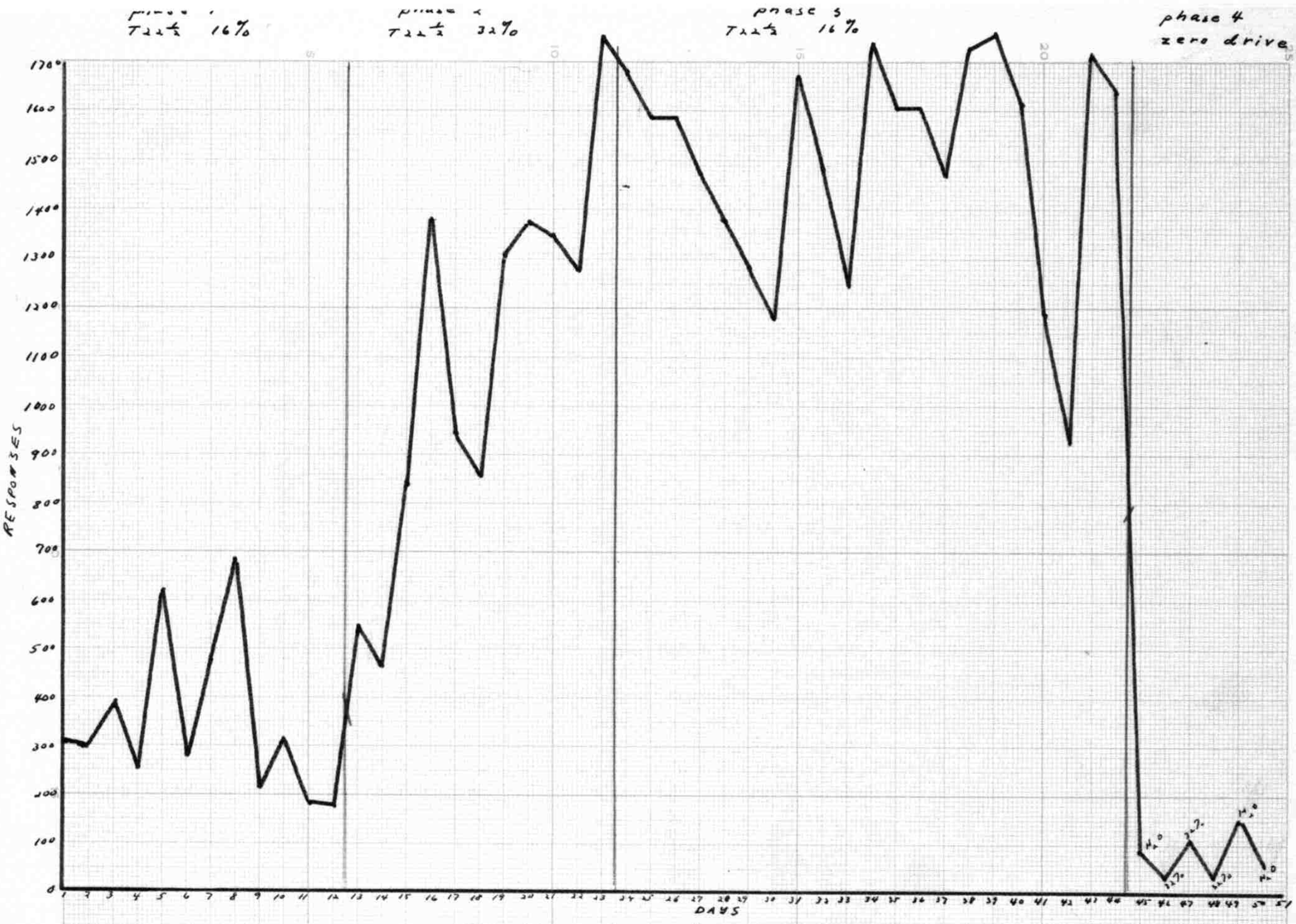

FIG. 21. Daily number of responses emitted by S15

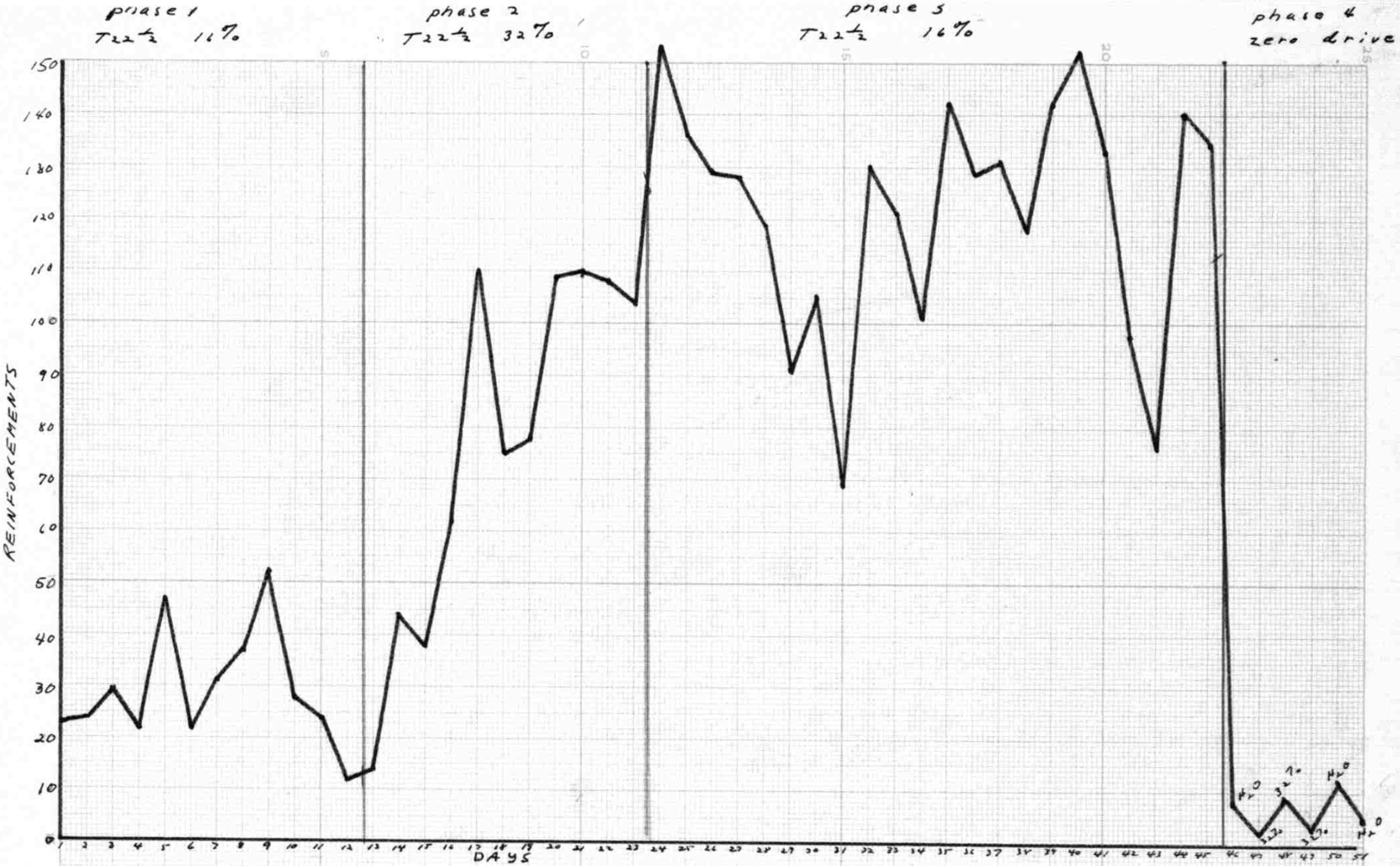

FIG. 22. Total number of reinforcements received by S15

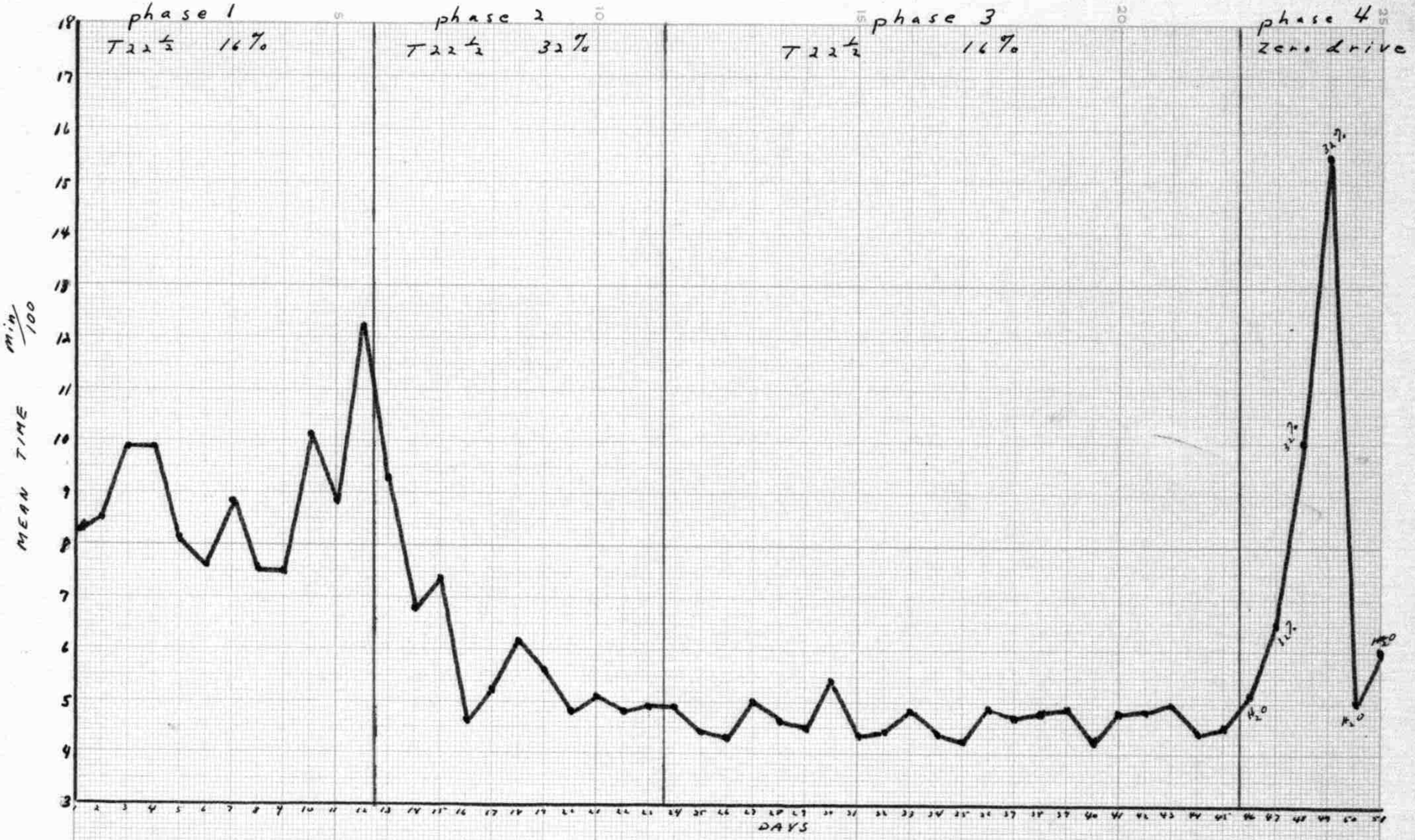

FIG. 23. Daily mean local rates of S/S

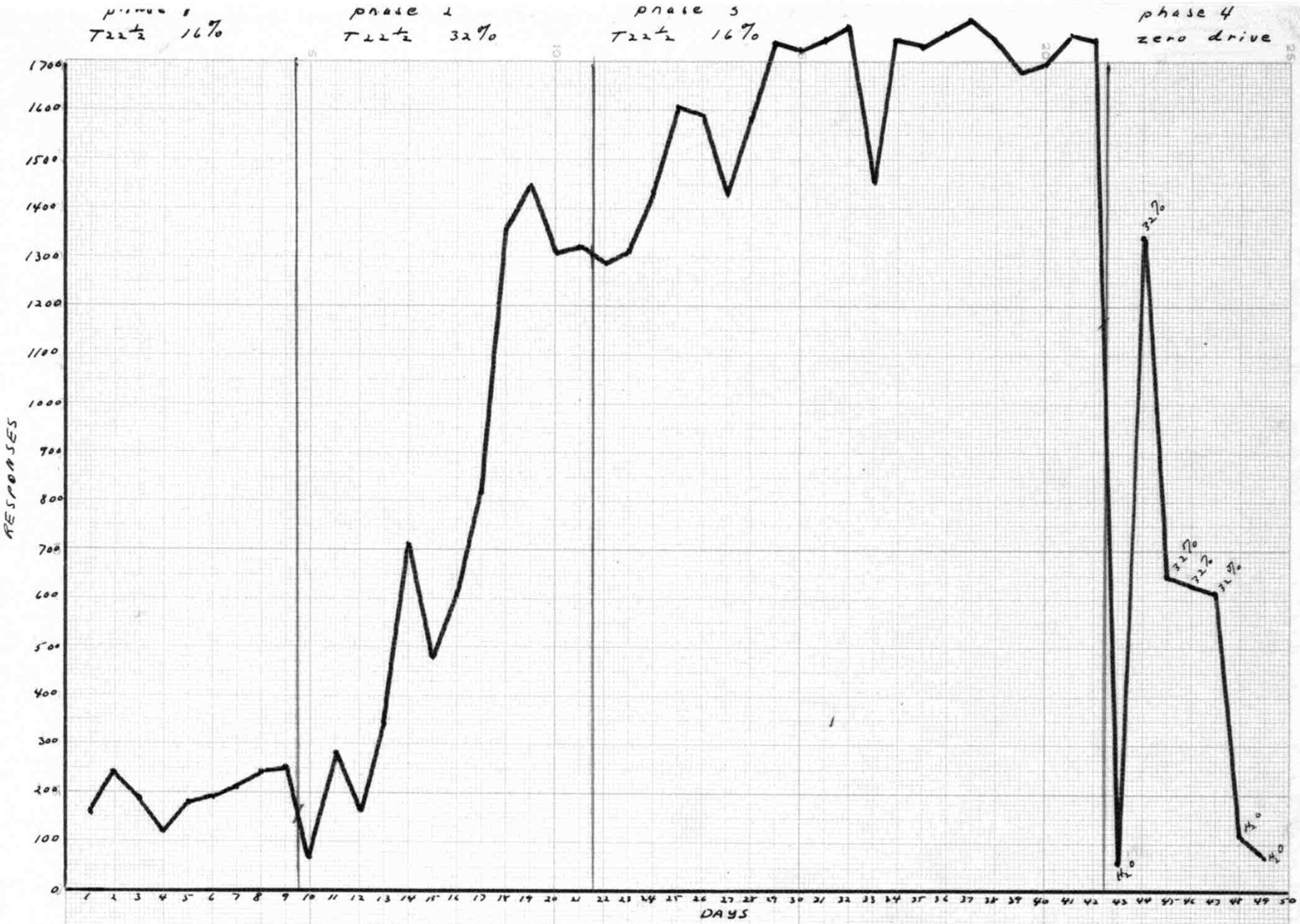

FIG. 24. Daily number of responses emitted by S16

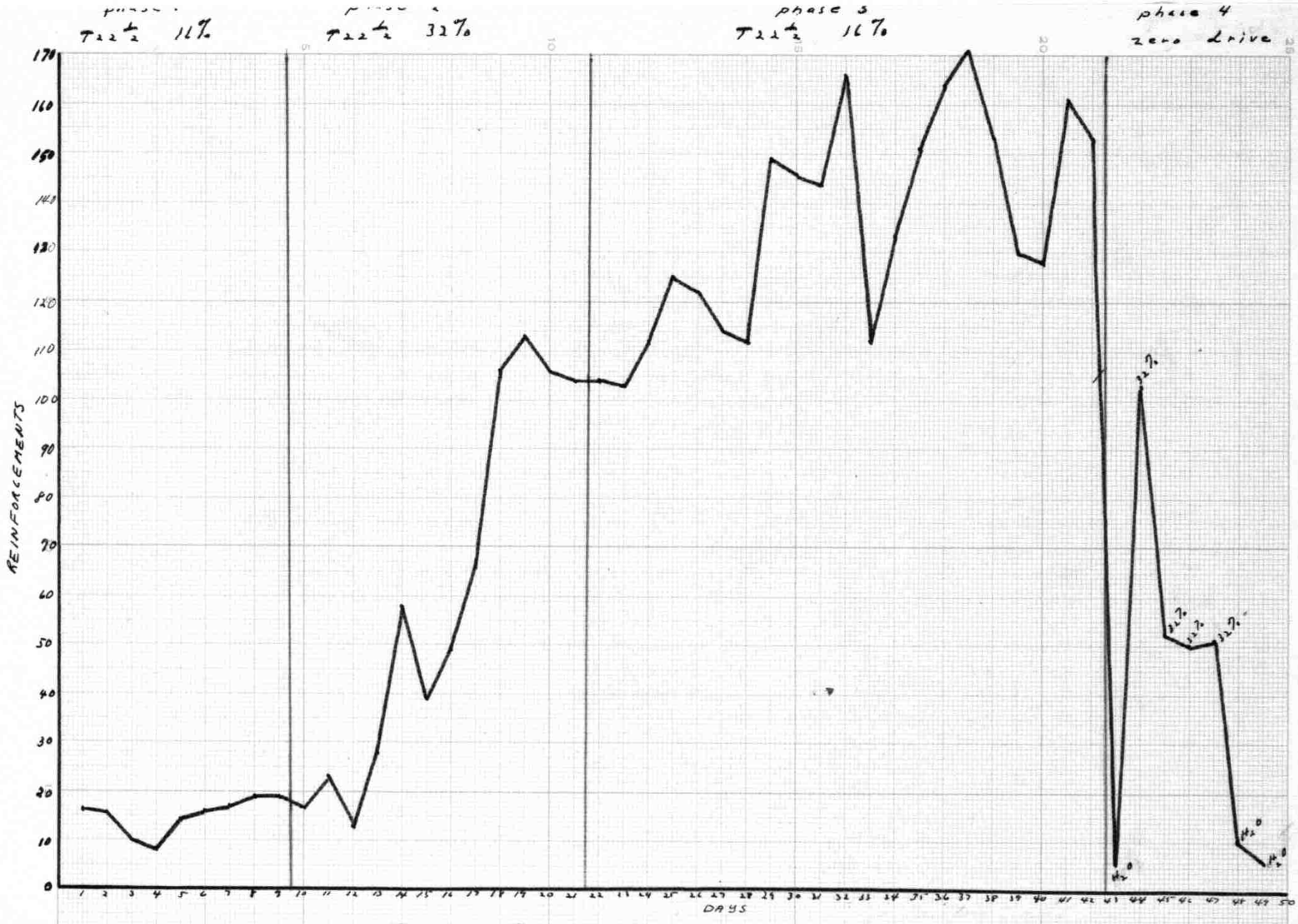

FIG. 25. Total number of reinforcements received by S16

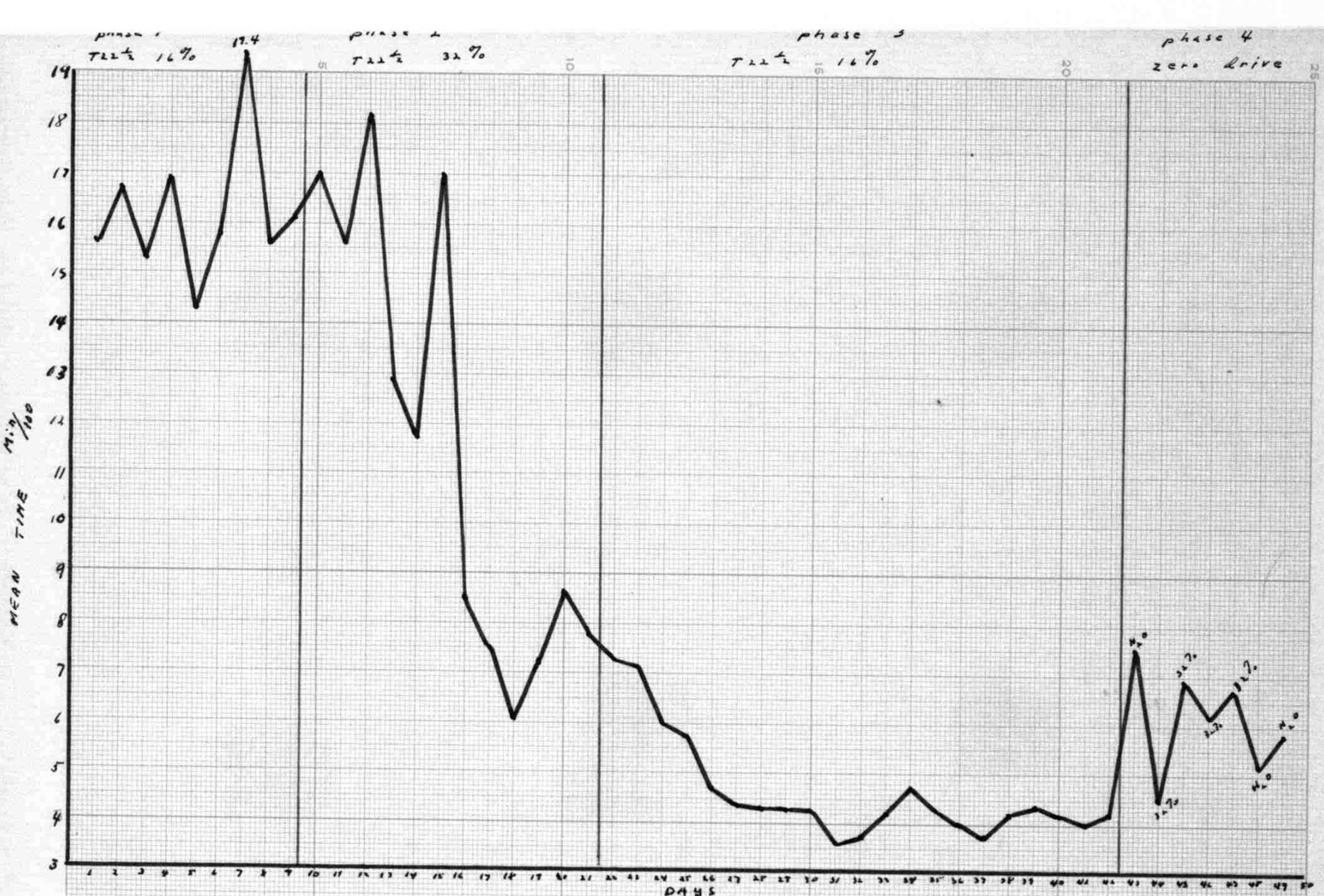

FIG. 26. Daily mean local rates of S16

was reinforced with 16% and 32% sucrose under T22½. Like Subject 15, all three response measures of Subject 16 increased as a function of reinforcement magnitude. Its mean overall rate increased from 6.8 r.p.m. to 24.8 r.p.m.; its mean reinforcement from 15.1 to 60.2 reinforcements; and its mean local rate from 1.0 r.p.s. to 1.9 r.p.s.

A summary of the first reinforcement changes under T22½ is given in Table IV.

TABLE IV

Results of the first reinforcement changes under the deprivation schedule of T22½

	Subject	Mean overall rate (r.p.m.)	Mean local rate (r.p.s.)	Mean reinforcement
1. water to 16% sucrose	13	14.6 to 15.9	1.1 to 1.1	21.6 to 43.8
	14	14.7 to 15.6	1.8 to 1.5	36.3 to 38.8
	17	4.0 to 14.2	0.6 to 0.6	9.7 to 4.6
	18	4.1 to 1.9	0.6 to 0.6	9.8 to 3.5
2. 4% to 16% sucrose	14b	2.3 to 2.9	0.6 to 0.7	4.9 to 6.1
3. 16% to 32% sucrose	15	12.0 to 32.0	2.0 to 3.1	27.9 to 77.3
	16	6.8 to 24.8	1.0 to 1.9	15.1 to 60.2
	19	9.3 to 17.9	1.1 to 1.1	21.6 to 43.8

Second reinforcement changes.

As Subjects 15 and 16 increased their mean local rate of responding when the magnitude of reinforcement was increased from 16%

to 32% sucrose under T22½, another Subject, 14b, was shifted from 16% to 32% under T22½ to observe whether its mean local response rate would also increase, or whether this increase with 32% sucrose was a peculiarity of Subjects 15 and 16. Figure 17 (phases 2 and 3) shows the daily mean local rates of Subject 14b as its reinforcement was changed from 16% to 32% sucrose. Its mean local rate remained the same as when it performed with 16% sucrose; that is, 0.7 r.p.s. which was the mean local rate for Subject 14b when it was reinforced with 16%, remained constant as a function of the shift in reinforcement magnitude from 16% to 32% sucrose.

Figure 15 (phases 2 and 3) and Figure 16 (phases 2 and 3) show the daily number of responses emitted and the total number of reinforcements received for Subject 14b with its second reinforcement change from 16% to 32% sucrose under T22½. Its mean overall rate and mean reinforcement followed a relationship consistent with previous findings, increasing as a function of reinforcement magnitude. The mean overall rate increased from 2.9 r.p.m. to 4.8 r.p.m. and the mean reinforcement from 6.1 to 12.0 reinforcements.

Previous studies have demonstrated that once a Subject's local rate of responding is stable, it is quite difficult to decrease this rate by decreasing the magnitude of reinforcement. This hypothesis was further tested in this experiment by shifting the sucrose concentration of Subjects 15 and 16 from 32% sucrose back to 16% and continuing with this reinforcement magnitude for 22 days.

These two Subjects had been the only two to have increased their local response rates under the deprivation schedule of T22$\frac{1}{2}$ as a function of reinforcement magnitude. Figures 27a and 27b show cumulative records of Subject 15 on its last day of 32% sucrose reinforcement and on its 22nd day of 16% sucrose reinforcement. Not only were bursts of responses made in a much shorter period of time with the 16% sucrose than with the 32%, but also pauses between reinforcing bursts became practically non-existant. The records for Subject 16 are similar.

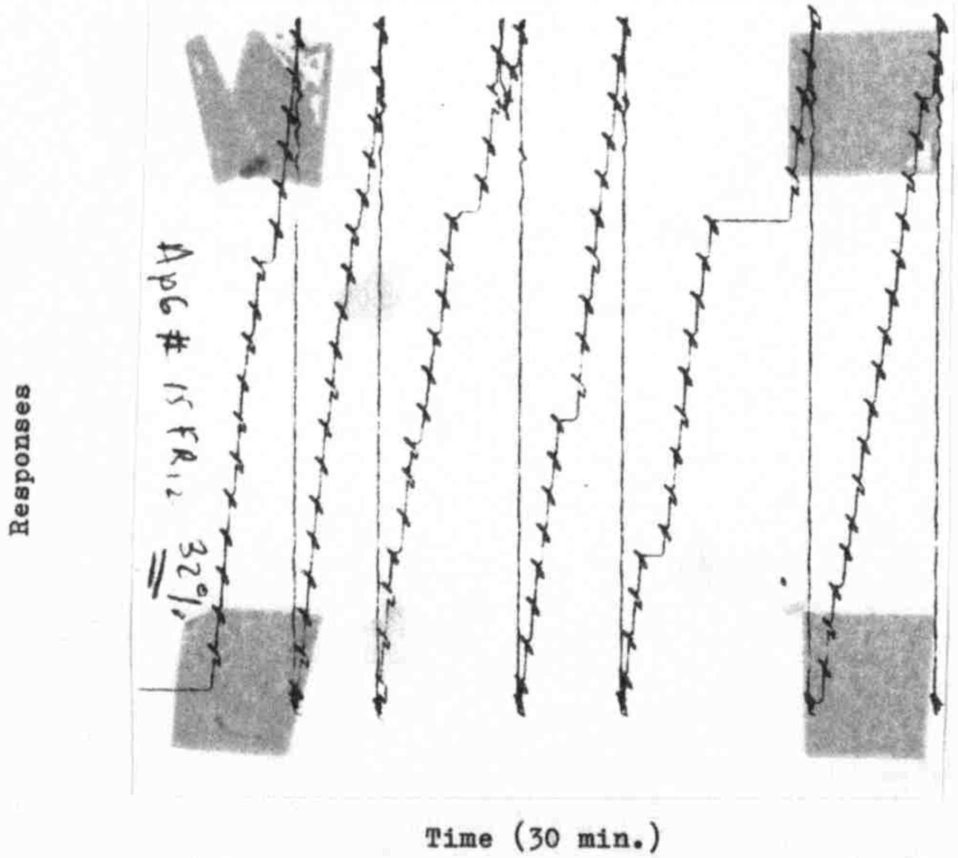

Fig. 27a. Cumulative graphic record of S15 on its last day of 32% sucrose reinforcement under T22$\frac{1}{2}$.

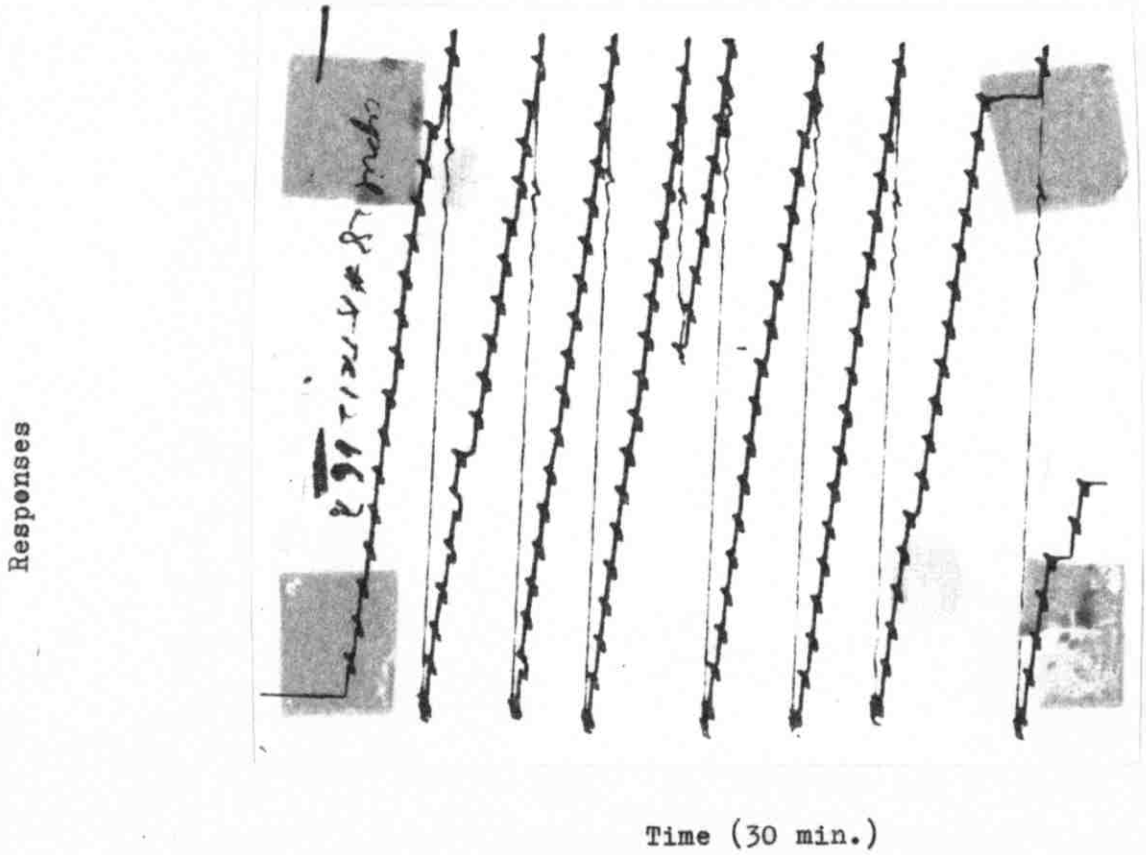

Fig. 27b. Cumulative graphic record of S15 on its 22nd day of 16% sucrose reinforcement under T22½.

Figures 23 (phases 2 and 3) and Figure 26 (phases 2 and 3) show the daily mean local rates for Subjects 15 and 16 respectively, for their second reinforcement change from 32% to 16% sucrose under T22½. The decrease in sucrose reinforcement failed to reduce the local rate of responding. On the contrary, Subject 15 increased its mean local rate from 3.1 r.p.s. to 3.6 r.p.s., and Subject 16 from 1.9 r.p.s. to 3.7 r.p.s. Mean overall rates and mean reinforcements also increased with the decrease in reinforcement magnitude. Figure 21 (phases 2 and 3) and Figure 22 (phases 2 and 3) show the daily number of responses emitted and the total number of reinforcements received respectively for Subject 15 for its second reinforcement change from 32% to 16% sucrose under T22½; Figure 24 (phases 2 and 3) and Figure 25 (phases 2 and 3) show the same measures for Subject 16. Subject 15's mean overall rate increased from 32.0 r.p.m. with 32% sucrose to 51.0 r.p.m. with 16%, and its mean reinforcement from 77.3 to 121.77 reinforcements. The mean overall rate of Subject 16 increased from 24.8 r.p.m. with 32% to 59.3 r.p.m. with 16% and its mean reinforcement from 60.2 to 135.85 reinforcements.

Subject 19 was also shifted from 32% to 16% sucrose under T22½, but not immediately after its first reinforcement change. This Subject, after being reinforced with 16% and 32% sucrose under T22½, was run under the increased deprivation condition of HT22½ for 4 days, under experimental extinction for 3 days, under a schedule of Crf 10 min. FR12 20 min. for 1 day, and then was changed back to 16% sucrose under HT22½. Phase 6 of Figure 18, Figure 19, and Figure 20 show the animal's performance with 16% sucrose under HT22½. All three response measures increased with the decrease in reinforcement magnitude from 32% to 16% sucrose.

The mean overall rate increased from 17.9 r.p.m. with 32% to 50.9 r.p.m. with 16%; the mean reinforcement from 43.8 to 125.3 reinforcements; and the mean local rate from 1.1 r.p.s. to 1.8 r.p.s. These results are consistent with those of Subjects 15 and 16, namely that they fail to show decreasesin performance level with decreases in reinforcement magnitude.

A summary of the second reinforcement changes under T22½ is given in Table V.

TABLE V

Results of the second reinforcement changes under the deprivation schedule of T22½

	Subject	Mean overall rate (r.p.m.)	Mean local rate (r.p.s.)	Mean reinforcement
1. 16% to 32% sucrose	14b	2.9 to 4.8	0.7 to 0.7	6.1 to 12.0
2. 32% to 16% sucrose	15	32.0 to 51.0	3.1 to 3.6	77.3 to 121.8
	16	24.8 to 59.3	1.9 to 3.7	60.2 to 135.9
	19	17.9 to 50.9	1.1 to 1.8	43.8 to 125.3

CHAPTER V

Results - Drive Level Changes

It has been shown in this experiment that reinforcement magnitude did not increase local response rates, except in the case of Subjects 15 and 16. Therefore changes were made in the deprivation schedules from one of thirst-deprivation to one of hunger-thirst deprivation with the hypothesis that these changes in drive level would increase local, as well as, overall rates of responding.

First drive change.

The first drive change was made from a T22½ deprivation schedule to one of HT22½. In other words, the Subjects which previously had been given food before their daily experimental sessions, were now given food ½ hour after the sessions, at the same time water was given.

Phases 2 and 3 of Figure 2, Figure 3, and Figure 4 show the change in performance of Subject 13 reinforced with 16% sucrose from the T22½ deprivation schedule to the one of HT22½. There is an increase in this animal's mean overall rate from 15.9 r.p.m. under T22½ to 26.9 r.p.m. under HT22½; in its mean reinforcement from 39.3 to 66.0 reinforcements; and in its mean local rate from 1.1 r.p.s. to 1.5 r.p.s. The mean local rate of responding of Subject 13, while not increasing as a function of reinforcement magnitude, did increase as a function of drive.

Figure 5 (phase 3), Figure 6 (phase 3), and Figure 7 (phase 3) show the daily number of responses emitted, the total number of reinforcements received, and the daily mean local rates respectively for Subject 14 on the deprivation schedule of HT22½ with the reinforcement magnitude of 16% sucrose. Its mean overall rate increased from 15.6 r.p.m. under T22½ to 17.8 r.p.m. under HT22½; its mean reinforcement from 38.8 to 41.8 reinforcements; and its mean local rate from 1.5 r.p.s. to 1.8 r.p.s. Its behavior paralleled that of Subject 13, showing an improvement in performance for all three response measures as a function of drive.

Subjects 17 and 18, like Subjects 13 and 14, were on a T22½ deprivation schedule with 16% sucrose reinforcement, when they were changed to the deprivation schedule of HT22½. Figure 8 (phase 3) and Figure 10 (phase 3) show the daily number of responses for Subjects 17 and 18 respectively under the increased deprivation schedule of HT22½. The mean overall rate of Subject 17 increased from 14.2 r.p.m. under T22½ to 21.1 r.p.m. under HT22½ and that of Subject 18 from 1.9 r.p.m. to 4.1 r.p.m. Phase 3 of Figure 9 and Figure 11 show the total number of reinforcements received by these two Subjects under HT22½. The mean reinforcement of Subject 17 increased from 4.6 under T22½ to 51.7 reinforcements under HT22½, and that of Subject 18 from 3.5 to 9.6 reinforcements. The daily mean local rates of these Subjects, phase 3 of Figures 13 and 14, parallel the findings of Subjects 13 and 14. Subject 17's mean local rate increased sharply from 0.7 r.p.s. under T22½ to 3.2 r.p.s.

under HT22½. Subject 18 failed to show such a big change in performance, but increased its mean local rate slightly from 0.6 r.p.s. to 0.8 r.p.s. Both Subjects, however, did increase their mean local rates as a function of drive, thus further confirming the results of Subjects 13 and 14.

Subjects 14b and 19 were also shifted to the HT22½ schedule but were reinforced with 32% sucrose instead of 16%. Their performance on the three response measures increased as a function of drive, as did those of Subjects 13, 14, 17, and 18. Figure 15 (phase 4), Figure 16 (phase 4), and Figure 17 (phase 4) show the daily number of responses emitted, the total number of reinforcements received, and the daily mean local rates respectively for Subject 14b on 32% reinforcement under HT22½. Its mean overall rate increased from 4.8 r.p.m. under T22½ to 12.8 r.p.m. under HT22½; its mean reinforcement from 12.0 to 31.7 reinforcements; and its mean local rate from 0.7 r.p.s. under T22½ to 1.0 r.p.s. under HT22½. The daily number of responses emitted, the total number of reinforcements received and the daily mean local rates of Subject 19 under the increased deprivation condition of HT22½ are shown in phase 3 of Figure 18, Figure 19, and Figure 20 respectively. The mean overall rate of Subject 19 increased from 17.9 r.p.m. under T22½ to 37.0 r.p.m. under HT22½; its mean reinforcement from 43.8 to 92.0 reinforcements; and its mean local rate from 1.1 r.p.s. to 1.6 r.p.s.

A summary of the first drive change is given in Table VI.

TABLE VI

Results of the first drive level change from the deprivation schedule of T22½ to one of HT22½

Subject	% Sucrose	Mean overall rate (r.p.m.)	Mean local rate (r.p.s.)	Mean reinforcement
13	16	15.9 to 26.9	1.1 to 1.5	39.3 to 66.0
14	16	15.6 to 17.8	1.5 to 1.8	38.8 to 41.8
17	16	14.2 to 21.1	0.7 to 3.2	4.6 to 51.7
18	16	1.9 to 4.1	0.6 to 0.8	3.5 to 9.6
14b	32	4.8 to 12.8	0.7 to 1.0	12.0 to 31.7
19	32	17.9 to 37.0	1.1 to 1.6	43.8 to 92.0

Second drive change.

The second drive change was from the deprivation schedule of HT22½ to one of HT46½; that is, now Subjects were deprived of food and water for 46½ hours before their experimental sessions and were given food and water ½ hour after their sessions were finished. Only one Subject, 14b, was run under this condition, so any data found was regarded as extremely tentative. It was expected that by increasing the deprivation conditions to HT46½, Subject 14b would increase both its local and overall response rates. In fact the reverse occurred. Figure 15 (phase 5) shows the daily number of responses emitted by Subject 14b with 32% sucrose under HT46½. Its mean overall rate decreased from 12.8 r.p.m. under HT22½ to 12.1 r.p.m.

under HT46½. Phase 5 of Figure 16 shows this Subject's total number of reinforcements received under the increased deprivation condition of HT46½ with the reinforcement magnitude of 32% sucrose. Its mean reinforcement decreased from 31.7 under HT22½ to 30.3 reinforcements under HT46½. Its daily mean local rates are seen in phase 5 of Figure 17. The mean local rate of Subject 14b also decreased from 1.0 r.p.s. under HT22½ to 0.8 r.p.s. under HT46½. Along with its decrease in performance, Subject 14b also decreased its weight in the shift from HT22½ to HT46½, as can be seen in Figure 28.

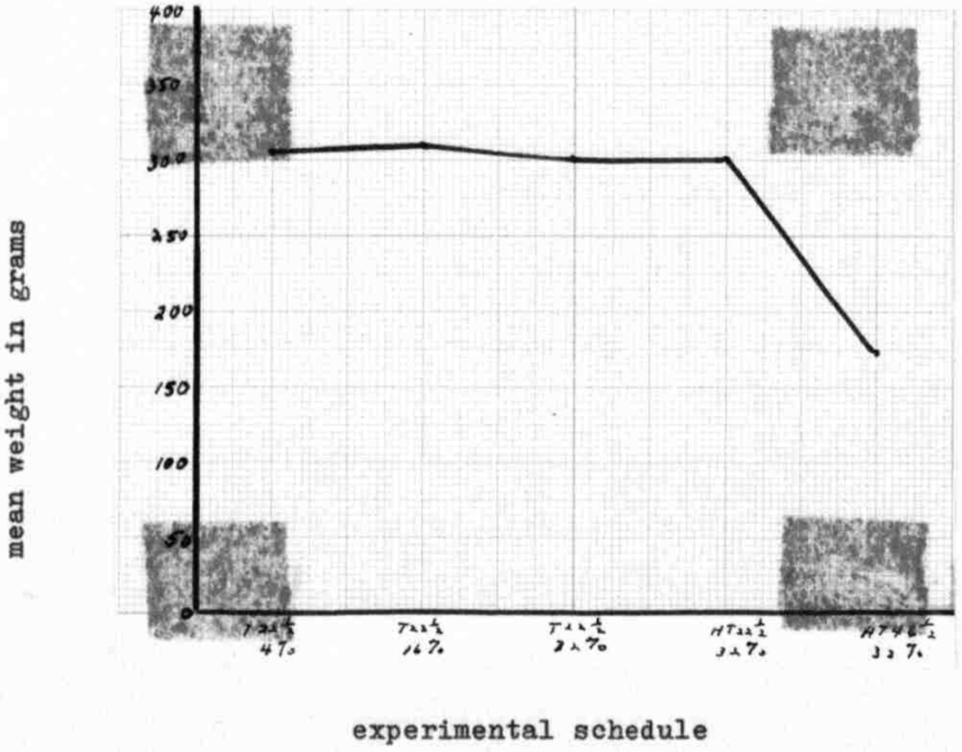

Fig. 28. The mean weight in grams of Subject 14b under each of its experimental schedules: T22½ with 4% sucrose reinforcement; T22½ with 16% sucrose reinforcement; T22½ with 32% sucrose reinforcement; HT22½ with 32% sucrose reinforcement; and HT46½ with 32% sucrose reinforcement.

A summary of the second drive change is given in Table VII.

TABLE VII

Results of the second drive level change from the deprivation schedule of HT22½ to one of HT46½

Subject	% Sucrose	Mean overall rate (r.p.m.)	Mean local rate (r.p.s.)	Mean reinforcement
14b	32	12.8 to 12.1	1.0 to 0.8	31.7 to 30.3

Increasing reinforcement magnitude under the increased deprivation condition of HT22½.

Although it was found that changes in reinforcement magnitude under the deprivation condition of T22½ were not very influential in increasing local rates of responding, it was expected that changes in reinforcement magnitude under the deprivation condition of HT22½ would increase local response rates. Subjects 13, 14, and 18 were shifted from 16% sucrose to 32% while under the deprivation condition of HT22½. Phase 4 of Figure 4, Figure 7, and Figure 14 show the daily mean local rates of Subjects 13, 14, and 18 respectively with 32% sucrose under HT22½. The mean local rate for all three animals increased as a function of reinforcement magnitude under the increased deprivation condition of HT22½; that of Subject 13 from 1.5 r.p.s. with 16% sucrose to 2.5 r.p.s. with 32%; that of Subject 14 from 1.8 r.p.s. with 16% to 2.0 r.p.s. with 32%; and that of Subject 18 from 0.8 r.p.s. with 16% to 1.1 r.p.s. with 32%.

Phase 4 of Figure 2, Figure 5, and Figure 10 show the daily number of responses emitted and phase 4 of Figure 3, Figure 6, and Figure 11 the total number of reinforcements received for Subjects 13, 14, and 18 respectively under HT22½ with 32% sucrose as reinforcement magnitude. The mean overall rate for Subject 13 increased from 26.9 r.p.m. with 16% sucrose to 32.7 r.p.m. with 32%; that of Subject 14 from 17.8 r.p.m. with 16% to 24.6 r.p.m. with 32%; and that of Subject 18 from 4.1 r.p.m. with 16% to 13.1 r.p.m. with 32%. The mean reinforcement increased correspondingly from 66.0 with 16% to 78.2 reinforcements with 32% for Subject 13; from 41.8 to 61.0 reinforcements for Subject 14; and from 9.6 to 31.6 reinforcements for Subject 18.

A summary of these changes is given in Table VIII.

TABLE VIII

Results of increasing reinforcement magnitude
from 16% to 32% sucrose under the deprivation schedule of HT22½

Subject	% Sucrose	Mean overall rate (r.p.m.)	Mean local rate (r.p.s.)	Mean reinforcement
13	16	26.9	1.5	66.0
"	32	32.7	2.5	78.2
14	16	17.8	1.8	41.8
"	32	24.6	2.0	61.0
18	16	4.1	0.8	9.6
"	32	12.1	1.1	31.6

CHAPTER VI

Results - Subsidiary Procedures

Zero Drive

It has been shown by the data in this study that magnitude of reinforcement does not affect local response rates but that changes in drive level do. In zero drive the animal is fed and watered ½ hour immediately before its daily experimental session and therefore it would be expected that its overall rate of responding would sharply decrease. The animal's local response rate, however, was expected to remain the same; that is, it was hypothesized that once the Subject had learned to run off 12 responses in a single burst of speed, it would continue to perform in these bursts of responses although its drive was considerably lessened. Subjects 15, 16, and 19 were run on zero drive for 6 days with water as reinforcing agent the first, fifth and sixth days, and 32% sucrose as reinforcing agent the second, third, and fourth days.

Figure 21 (phase 4) shows the daily number of responses emitted by Subject 15 under zero drive. This subject responded more for water than for 32% sucrose. Its mean overall rate for water was 3.4 r.p.m. while for 32% sucrose it was 1.9 r.p.m. The total number of reinforcements received by Subject 15 under zero drive is shown in Figure 22 (phase 4). Its mean reinforcement was greater for water than for 32% sucrose, being 8.3 reinforcements for water and only 4.3 reinforcements for 32% sucrose.

Figure 23 (phase 4) shows the daily mean local rates for Subject 15 under zero drive. While with 32% sucrose the animal's performance declined, with water as reinforcing agent, its daily mean local rates of responding increased with the decrease in drive. The mean local rate decreased from 3.6 r.p.s. under T22½ (before it was put on zero drive) to 1.4 r.p.s. under zero drive with 32% sucrose, and then increased back to 3.2 r.p.s. with water as reinforcing agent under the same zero drive condition.

Subject 16 was also put on zero drive with water and 32% sucrose as reinforcing agents. Figure 24 (phase 4) and Figure 25 (phase 4) show the daily number of responses emitted and the total number of reinforcements received for this Subject under zero drive. Contrary to Subject 15, Subject 16's mean overall rate and mean reinforcement were greater for 32% sucrose than for water. For 32% sucrose the two measures were 27.0 r.p.m. and 64.0 reinforcements, while for water they were 2.9 r.p.m. and 7.3 reinforcements. The daily mean local rates for Subject 16 under zero drive are shown in Figure 26 (phase 4). Its mean local rate remained about the same for both reinforcing agents, 2.9 r.p.s. with 32% sucrose and 2.8 r.p.s. with water. This response measure, however, did decrease from 3.7 r.p.s. which is what it had been under the T22½ deprivation schedule before the animal was run under zero drive.

Phase 7 of Figure 18, Figure 19, and Figure 20 show the daily number of responses emitted, the total number of reinforcements received, and the daily mean local rates respectively for Subject 19 under zero drive. Like Subject 16, the mean overall rate and mean reinforcement were greater with 32% sucrose than with water as reinforcing agent. With 32% sucrose the mean overall rate and mean reinforcement of Subject 19 were 18.6 r.p.m. and 45.3 reinforcements, while with water the two measures were 2.0 r.p.m. and 5.3 reinforcements. The daily mean local rate for Subject 19, however, was greater with water than with 32% sucrose, paralleling the results of Subject 15. The mean local rate of Subject 19 decreased from 1.8 r.p.s. under HT22½ (before it was put on zero drive) to 0.8 r.p.s. with 32% sucrose under zero drive, and then increased to 2.2 r.p.s. with water under the same zero drive condition.

A summary of the results obtained under zero drive is given in Table IX.

TABLE IX

Results of performance under zero drive with reinforcement magnitudes of water and 32% sucrose

Subject	% Sucrose	Mean overall rate (r.p.m.)	Mean local rate (r.p.s.)	Mean reinforcement
15	0% (water)	3.4	3.2	8.3
"	32	1.9	1.4	4.3
16	0% (water)	2.9	2.8	7.3
"	32	27.0	2.9	64.0
19	0% (water)	2.0	2.2	5.3
"	32	18.6	0.8	45.3

Experimental Extinction

Subject 13b was stabilized on 4% reinforcement under T22½ and maintained a very high rate of responding with this reinforcement magnitude. Figure 29 (phase 1) and Figure 30 (phase 1) show its daily number of responses emitted and its total number of reinforcements received with 4% sucrose as reinforcing agent under T22½. Its mean overall rate was 52.8 r.p.m. while its mean reinforcement was 132.0 reinforcements. Its daily mean local rate under T22½ can be seen from Figure 31 (phase 1). The mean local rate was also very high, at 4.3 r.p.s. Therefore further improvement by increasing reinforcement magnitude or drive conditions was unlikely and this Subject was put on experimental extinction for 3 days. Phase 2 of Figure 29, Figure 30, and Figure 31 show the daily number of responses emitted, the total number of reinforcements received, and the daily mean local rates respectively for Subject 13b under experimental extinction. As was expected, the animal's mean overall rate decreased from 52.8 r.p.m. under T22½ with 4% sucrose as reinforcing agent to 3.9 r.p.m. under extinction, and its mean reinforcement from 132.0 to 9.3 reinforcements. Also its mean local rate did not decrease with the absence of reinforcement, but even increased slightly from 4.3 r.p.s. under T22½ with 4% sucrose as reinforcing agent to 4.4 r.p.s. under extinction.

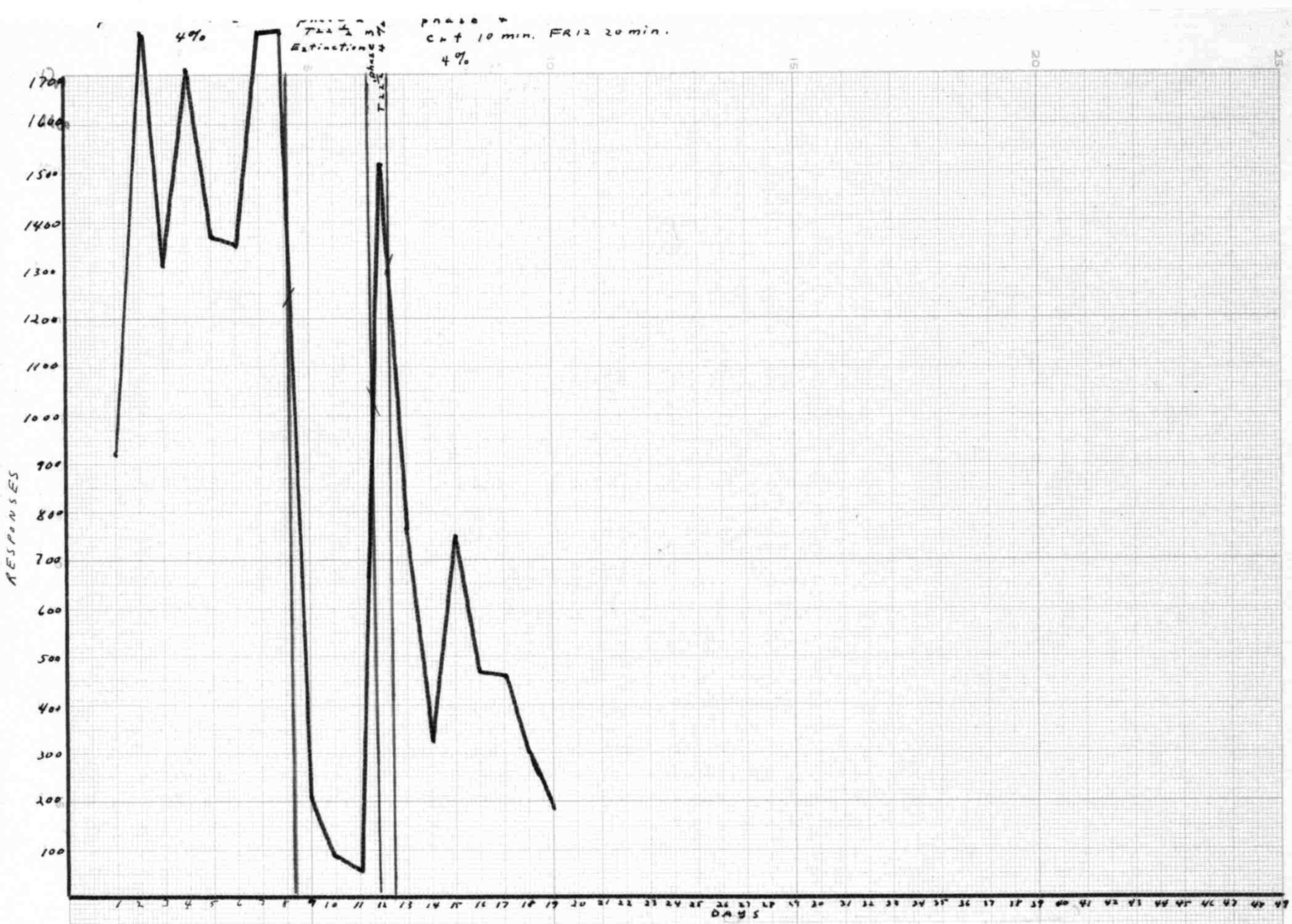

FIG. 29. Daily number of responses emitted by S136

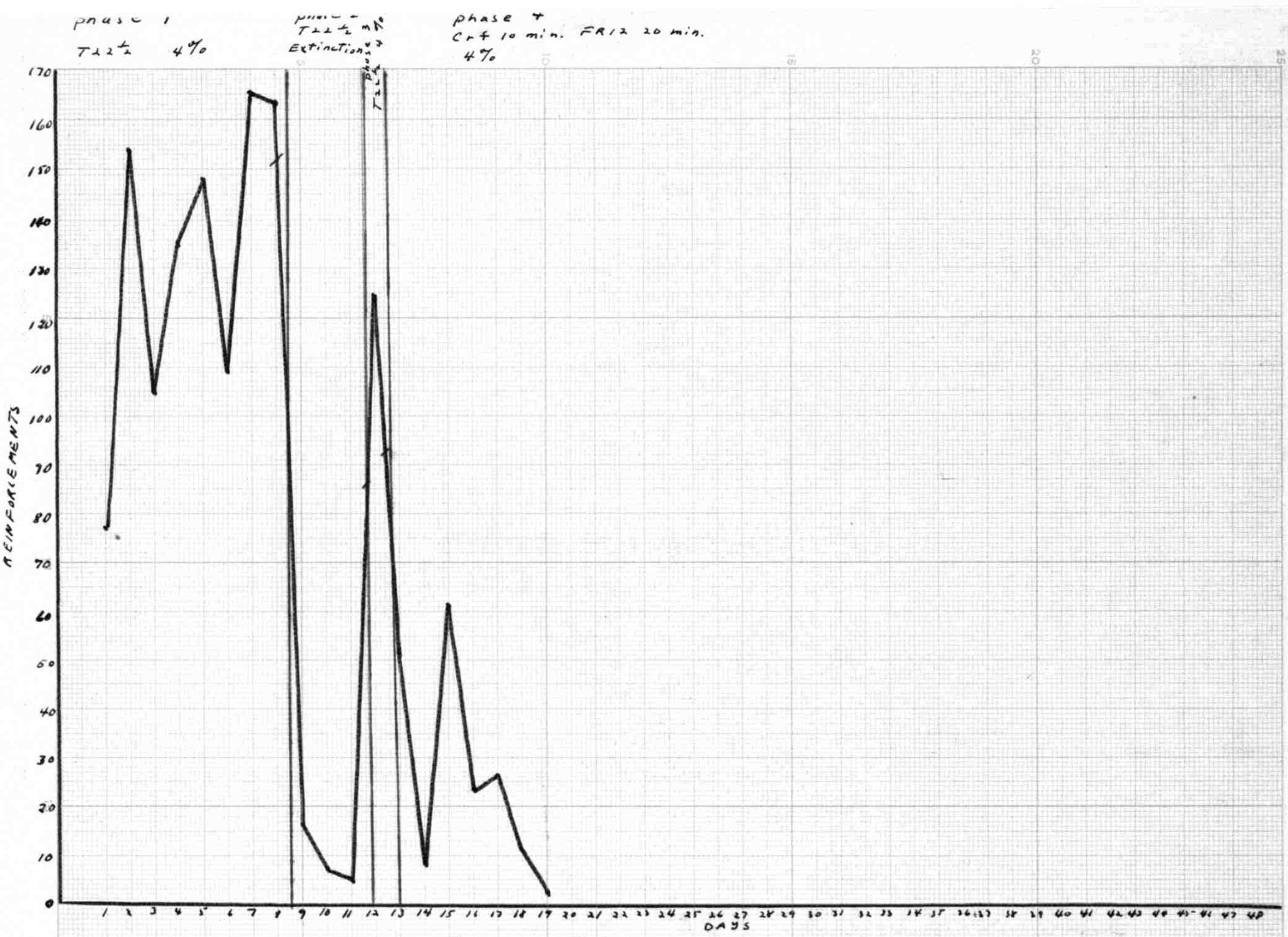

FIG. 30. Total number of reinforcements received by S136

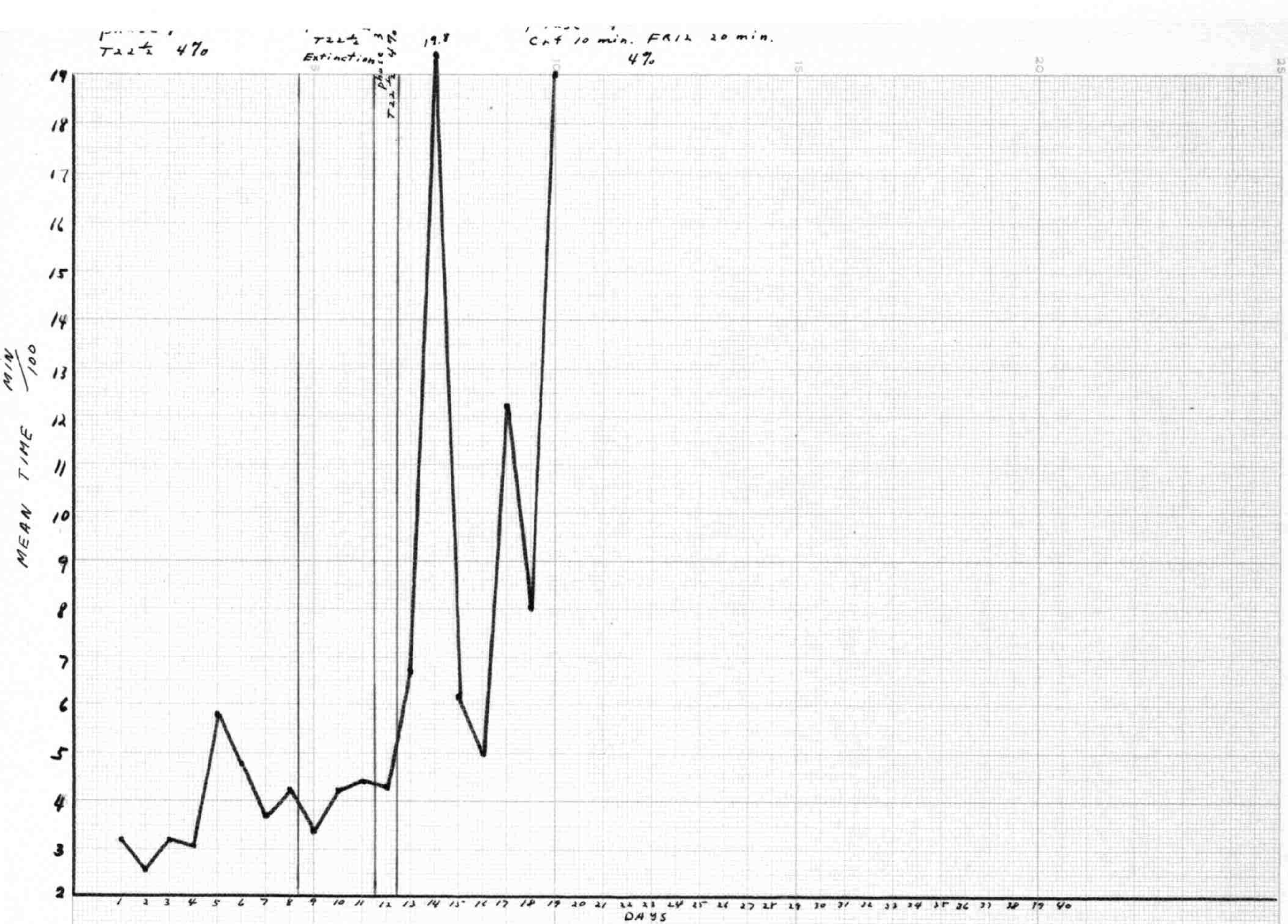

FIG. 31. Daily mean local rates of S136

Subject 19, after being on an HT22½ deprivation schedule for 4 days, was also puton extinction for 3 days. Phase 4 of Figure 18, Figure 19, and Figure 20 show its performance under this condition. Its mean overall rate decreased from 37.9 r.p.m. under HT22½ with 32% sucrose as reinforcing agent to 6.6 r.p.m. under extinction and its mean reinforcement from 92.0 to 15.3 reinforcements. Its mean local rate, like that of Subject 13b, failed to decrease with the absence of reinforcement and even increased considerably from 1.6 r.p.s. under HT22½ with 32% sucrose as reinforcing agent to 4.3 r.p.s. under extinction.

A summary of the change under experimental extinction is given in Table X.

TABLE X

Changes in performance under experimental extinction

Subject	Drive	% Sucrose	Mean overall rate (r.p.m.)	Mean local rate (r.p.s.)	Mean reinforcement
13b	T22½	4% to nothing	52.8 to 3.9	4.3 to 4.4	132.0 to 9.3
19	HT22½	32% to nothing	37.9 to 6.6	1.6 to 4.3	92.0 to 15.3

Crf 10 min FR12 20 min schedule.

Because the local rates of responding of Subject 13b did not decrease under experimental extinction, the animal was brought back up to previous performance with 4% sucrose as reinforcing agent (phase 3 of Figures 29, 30 and 31) and then put on a schedule of

Crf 10 min FR12 20 min; that is, a reinforcement followed every response for 10 min. of the daily 30 min. experimental session and then every 12th response for the remaining 20 min. of the session. This schedule was expected to completely disrupt the animal's local rate of responding. Phase 4 of Figure 31 shows the daily mean local rates of Subject 13b under this condition with the reinforcement magnitude of 4% sucrose. Although the animal was run for 18 days under this condition, it failed to make even one burst of 12 responses after 7 days, thus making a zero number of reinforcements for the final 11 days. Subject 19 was put on this same schedule for 1 day with the reinforcement magnitude of 32% sucrose and greatly decreased its daily mean local rates (phase 5 of Figure 20), thus showing the same disruption of behavior as Subject 13b.

Table XI summarizes the mean local and overall rates for all Subjects for the entire experiment.

TABLE XI

Mean local and overall rates, in responses per second and per minute respectively, according to Subject, drive, reinforcement schedule, and reinforcement magnitude.

			MEAN LOCAL RATES (r.p.s.)					MEAN OVERALL RATES (r.p.m.)				
Subject	Schedule	Drive	Reinforcement									
			Ext.	Water	4%	16%	32%	Ext.	Water	4%	16%	32%
13	FR12	T22½	-	1.4	-	1.1	-	-	14.6	-	15.9	-
"	"	HT22½	-	-	-	1.5	2.5	-	-	-	26.9	32.7
14	"	T22½	-	1.8	-	1.5	-	-	14.7	-	15.6	-
"	"	HT22½	-	-	-	1.8	2.0	-	-	-	17.8	24.6
17	"	T22½	-	0.6	-	0.6	-	-	4.0	-	14.2	-
"	"	HT22½	-	-	-	3.2	-	-	-	-	21.1	-
18	"	T22½	-	0.6	-	0.6	-	-	4.1	-	1.9	-
"	"	HT22½	-	-	-	0.8	1.1	-	-	-	4.1	13.1
15	"	T22½	-	-	-	2.0 3.6	3.1	-	-	-	12.0	32.0 51.0
"	"	0	-	3.2	-	-	1.4	-	3.4	-	-	1.9

			MEAN LOCAL RATES (r.p.s.)					MEAN OVERALL RATES (r.p.m.)				
Subject	Schedule	Drive	Reinforcement									
			Ext.	Water	4%	16%	32%	Ext.	Water	4%	16%	32%
16	FR12	T22½	-	-	-	1.0 3.7	1.9	-	-	-	6.8 59.3	24.8
"	"	0	-	2.8	-	-	2.9	-	2.9	-	-	27.0
19	"	T22½	-	-	-	1.1	1.1	-	-	-	9.3	17.9
"	"	HT22½	4.3	-	-	1.8	1.6	6.6	-	-	50.9	37.0
"	"	0	-	2.2	-	-	0.8	-	2.0	-	-	18.6
13b	"	T22½	4.4	-	4.3	-	-	3.9	-	52.8	-	-
14b	"	T22½	-	-	0.6	0.7	0.7	-	-	2.3	2.9	4.8
"	"	HT22½	-	-	-	-	1.0	-	-	-	-	12.8
"	"	HT46½	-	-	-	-	0.8	-	-	-	-	12.1

T22½ means 22½ hr. water deprivation, HT22½ means 22½ hr. food and water deprivation, HT46½ means 46½ hr. food and water deprivation at the time of each experimental session.
In rows marked "0" rates are taken with the Subjects fed and watered for 30 mins. immediately before an experimental session.

CHAPTER VII

General Discussion and Interpretation of Results

A significant task facing psychologists is the investigation of factors controlling behavior. With this in mind one would expect to find much experimentation concerned with the production of certain specified behavior on the part of organisms but, in fact, this is seldom the case. Two important variables that control behavior are reinforcement and drive. There have been many studies (cf. part I), but instead of manipulating these parameters so as to produce particular kinds of activities, most psychologists have been content with varying them and observing gross behavioral changes. Typically increasing drive or reinforcement increases the overall amount of a certain act that will occur in a given time; that is, overall rates of responding increase up to a point, with increasing drive and reinforcement. But there is evidence (Barakat[107]) that these increases come about by changing perseveration (Gilbert[108]); local rates, or rates of responding when the organism is indulging in the behavior in question, are not materially affected by drive and reinforcement changes.

In this study we have been concerned with possible ways of altering local and overall response rates by drive and reinforcement manipulation. Particularly the interest has been to see how drive

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[107] Ibid., p. 60.

[108] Gilbert, op. cit.

and reinforcement must be varied to increase or decrease overall rates of behavior, and how, if at all, local rates can be made to increase or decrease.

Overall rate of responding. In this experiment we were able to increase overall rate of responding as a function of reinforcement magnitude under the thirst drive of T22½ (all Subjects) and under the hunger and thirst drive of HT22½ (Subjects 13, 14, and 18). We were also able to increase overall response rates by increasing deprivation conditions from a thirst schedule of T22½ to a hunger-thirst schedule of HT22½ and holding reinforcement magnitude constant at the concentration which it had been under T22½ (Subjects 13, 14, 17, 18, 19). We were not, however, able to increase overall rate of responding by increasing the deprivation time to 46½ hr. (Subject 14b).

Barakat[109] did not find an increase in overall rate of responding as a function of reinforcement magnitude under the thirst drive of T22½. She found a preference for water and low sucrose concentrations over higher concentrations under T22½ and attributed this preference to the reasoning that the lower sucrose concentrations counteracted more quickly than did higher concentrations the effects of certain levels of dehydration. Since the present study clearly contradicts Barakat's results (See Table XI), except for Subject 18,

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[109] Barakat, op. cit., p. 46.

the reasoning that different sucrose solutions are not differentially reinforcing for thirsty animals may be questioned.

Several reasons may account for the difference in results for overall rate of responding under the thirst drive of T22½ in this and Barakat's experiments. One factor to be considered is the difference in experimental procedure employed in the two studies. While the absolute method of experimentation was used in the stabilization phase of this experiment and a simple fixed ratio (FR) schedule throughout the study, complex tandem and conjunctive schedules were used throughout Barakat's study and the differential method of experimentation was employed in the stabilization phase of her experiment. These differences in experimental procedure could account, at least in part, for the differences found in the results for overall rate of responding under T22½.

Also the shifts in reinforcement magnitude under T22½ in this experiment were of a greater range than those in Barakat's study. The shift in reinforcement magnitude for Barakat's Subjects under T22½ was from water to 4% to 8% to 16% to 8% to 4% sucrose. The Subjects in this experiment were shifted either from water to 16% sucrose, from 4% to 16% sucrose or from 16% to 32% sucrose, under T22½. Therefore a discrimination problem enters in. As it is more difficult to discriminate between more similar than less similar things, it seems possible that the Subjects in

Barakat's study would have had more difficulty in discriminating the change in reinforcement magnitude from, say, 4% to 8% sucrose or from 8% to 16%, than from water to 16%, from 4% to 16%, or from 16% to 32% sucrose which were the shifts in reinforcement magnitude used in the present experiment. This being the case, Barakat's Subjects would not have responded more for greater magnitudes than for less under the thirst drive because they would not have found any difference between the two magnitudes. This reasoning, of course, may only be applied when the shifts in reinforcement magnitude are fairly small, from water to 4%, or 4% to 8%, or 8% to 16% sucrose, so that discrimination would be somewhat difficult.

It is to be noted, moreover, that the sucrose concentration used in the first shift under T22½ in this study for Subjects 15, 16, and 19 (from 16% to 32% sucrose) was of a greater magnitude than that used for any of the thirsty animals in Barakat's experiment. If her thirsty animals had been run with 32% sucrose, perhaps they would have shown the same increase in overall rate of responding under T22½ as did the Subjects in this experiment.

In general the animals in Barakat's study showed an increase in overall rate of responding as a function of reinforcement magnitude under the hunger and thirst drive of HT22 when the shift in reinforcement magnitude was from 16% to 32% sucrose. This is in agreement with the second way we were able to increase overall rate of responding, namely as a function of reinforcement magnitude under the hunger and thirst drive of HT22½ (Subjects 13, 14, and 18).

The influence of the magnitude of reinforcement on overall rate of responding as a function of the increased deprivation condition of HT22½ is probably due to the greater effect of the sucrose concentration and its nutritive value on the hunger drive than on the thirst drive alone.

Since our data shows an increase in overall response rates with the reinforcing agents of 16% and 32% sucrose under T22½ and under HT22½ and since Barakat's Subjects show the same increase under HT22, it seems probable that, if her thirsty Subjects had been run with the reinforcing agent of 32% under T22½, they would have also shown the increase in overall rate of responding as a function of reinforcement magnitude, as did the thirsty Subjects in this study.

The third way we were able to increase overall response rates was by increasing the deprivation conditions from T22½ to HT22½, holding reinforcement magnitude constant at the amount it had been under T22½. Barakat's data is in agreement with ours. Therefore it seems that overall rate of responding increases as a function of increasing deprivation conditions from T22½ to HT22½.

When we consider the matter of increasing deprivation conditions to HT46½, our results are contrary to those of Barakat.

Her data, using three Subjects, supports the view that increasing overall rates parallel increasing deprivation conditions at least up to HT46 hr., while we found (Subject 14b) that the increased deprivation condition of HT46½ did not increase overall response rates. Inconsistencies in these findings may be due to a number of factors: (1) The Subject in this experiment was slow in responding throughout the entire experiment (See Figure 15), which suggests physiological factors entering in, such as aversion to sucrose solution, too little strength to press the bar, loss of weight (See Figure 28), etc. (2) Subject 14b was run under HT46½ for only three experimental sessions. It is quite possible that it might have increased its overall rate of responding with further experimentation. (3) Definite conclusions regarding data found using only one Subject may never be made. What is needed, of course, is further research with this increased deprivation schedule using a greater number of animals.

In this experiment we were successful in decreasing overall rate of responding in three ways: with experimental extinction under T22½ (Subject 13b) and under HT22½ (Subject 19); with zero drive using the reinforcing magnitudes of water and 32% sucrose (Subjects 15, 16, 19); and with the schedule of Crf 10 min. FR12 20 min. (Subjects 13b and 19). We were not, however, able to reduce overall response rate by decreasing the magnitude of reinforcement from a greater to a less sucrose concentration (from 32% to 16%) under T22½ (Subjects 15 and 16) or under HT22½ (Subject 19).

Our results for overall response rates in experimental extinction parallel those of Barakat, showing, as expected, a great drop in overall response rate due to the absence of reinforcement. These findings have been too often confirmed to necessitate further mention here.

In zero drive where the Subjects were fed and watered ½ hour immediately before their daily experimental sessions, we also found, as expected, a decrease in overall rate of responding. Water and 32% sucrose were used as reinforcing agents and it was expected that the overall rate of responding would be greater for the 32% than for water. This was found to be so with two of the three Subjects run under zero drive (Subjects 16 and 19) but not with the third Subject (Subject 15), who responded slightly more for water than for 32% sucrose. Subjects 16 and 19 (See Table XI), however, responded a great deal more for 32% sucrose than for water reinforcement. The main concern here, however, is with the fact that overall rate of responding may be decreased by 'zeroing' drive.

The third way we were successful in decreasing overall rate of responding was by employing the schedule of Crf 10 min. FR12 20 min. (Subjects 13b and 19). It was expected that the Subjects, going to the magazine continuously after each bar-press for the first 10 min. of the daily 30 min. experimental session, would become confused when the reinforcement schedule was changed to FR12 so that they would have to press the bar 12 times before each reinforcement. This was found to be the case, as the two animals' behavior became completely disrupted, and Subject 13b, after seven days on this schedule, failed to make enough responses to obtain even one reinforcement and thus greatly reduced its overall rate of responding.

We were not successful in decreasing overall response rates by decreasing reinforcement magnitude from 32% to 16% sucrose once the rate of responding was stable with the 32% reinforcing agent. This was so under both T22½ (Subjects 15 and 16) and under HT22½ (Subject 19). It seems that once an animal's response rate is stable, it is not decreased, at least for a reasonable period of time, by decreasing reinforcement magnitude from, say, 32% to 16% sucrose. It may, however, be decreased if the decrease in reinforcement magnitude was greater, say, from 32% to water. However, this was not tested in this study. Barakat's data is in agreement with ours, namely that overall rate of responding does not decrease with this decrease in reinforcement magnitude. There is even a slight increase in overall response rates with the decrease in reinforcement magnitude, in this and Barakat's studies.

<u>Local rate of responding</u>. In this experiment we were not successful in increasing local rate of responding as a function

of reinforcement magnitude under the thirst drive of T22½, except with two Subjects (Subjects 15 and 16). However, we were able to increase local response rates as a function of reinforcement magnitude under the hunger and thirst drive of HT22½ (Subjects 13, 14, and 18), and as a function of the increase deprivation condition of HT22½, holding reinforcement magnitude constant at the concentration which it had been under T22½ (Subjects 13, 14, 17, 18, and 19). Increasing deprivation conditions up to 46½ hr., however, failed to produce a faster local rate of responding (Subject 14b).

Barakat[110] also failed to find an increase in local response rates of thirsty rats as a function of reinforcement magnitude. Using hungry and thirsty rats, however, she found the same increases in local rate of responding as we did, namely that *local rate of responding increases as a function of reinforcement magnitude under the hunger and thirst drive of HT22½, and under the increased deprivation condition of HT22½, holding reinforcement magnitude constant at the amount which it had been under T22½*. With the increased deprivation schedule of HT46½, however, our data failed to show a corresponding increased local rate, thus contradicting Barakat's findings that local response rates increase as a function of deprivation time, at

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[110] *Ibid.*, P. 72.

least up to 46 hr. Possible reasons for these inconsistancies in results have already been discussed under overall rate of responding and may be applied here.

Decreasing local rate of responding was accomplished by 'zeroing' drive (Subjects 15, 16, and 19) and by employing the reinforcement schedule of Crf 10 min. FR12 20 min. (Subjects 13b and 19). We were not successful in reducing local response rates, however, by reducing reinforcement magnitude from a greater to a less concentration, from 32% sucrose to 16% (Subjects 15, 16, and 19), or by employing the phenomenon of experimental extinction (Subjects 13b and 19).

With zero drive it was expected that local rate of responding would be greater with 32% sucrose as reinforcing agent than with water reinforcement. In fact the reverse occurred as the local rates for all three Subjects under zero drive were greater with water than with 32% sucrose. Barakat, with two Subjects in a similar investigation of zero drive, also found a higher local response rate using 4% sucrose than 32%. Therefore tentative conclusions seem to be that Subjects under zero drive respond at faster local rates for less than for greater reinforcement magnitude. This is an interesting problem for further research.

With the reinforcement schedule of Crf 10 min. FR12 20 min. we were successful in breaking up local rate of responding. However, since this method appears rather clumsey for exact measurement and since it has been little used in an experimental situation of this sort, further research is necessary to prove or disprove its worth.

We were not able to reduce local rate of responding by decreasing the reinforcement magnitude from a greater to a less concentration, from 32% sucrose to 16%. Also we were unsuccessful in reducing local response rates under experimental extinction. These findings under experimental extinction are confirmed by Barakat[111]. Therefore tentative conclusions seem to be that once local rate of responding is stabilized, it does not decrease even by eliminating the reinforcement magnitude entirely.

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[111] *Ibid.*

SUMMARY

Overall and local response rates of 9 white rats of local stock reinforced on the reinforcement schedule of FR12 were examined as functions of reinforcement magnitude and drive in the Skinner box situation. Overall rates followed reinforcement concentrations when both thirsty rats and hungry and thirsty rats were reinforced with sucrose solutions, while local rates followed reinforcement concentrations only when hungry and thirsty rats were reinforced with sucrose solutions. Both overall and local rates of responding also increased as a function of the increased deprivation condition of HT22½ when reinforcement magnitude was held constant at the concentration employed under T22½.

Decreasing reinforcement magnitude from 32% to 16% sucrose failed to reduce stable overall or local response rates. Both measures, however, decreased when the reinforcement schedule of Crf 10 min. FR12 20 min. was employed and when drive was 'zeroed' with 32% sucrose and water as reinforcing agents, with the greatest decrease being with the 32% sucrose. With experimental extinction overall rates sharply decreased but local rates failed to decrease and even showed a slight increase with the absence of reinforcement. Further experimentation along the lines of this study is suggested for a better understanding and control of the rat's behavior in the experimental situation.

REFERENCES

1. Amsel, Abram. The role of frustrative nonreward in noncontinuous reward situations. Psychol. Bull., 1958, 55, 102-117.

2. Armus, H. L. Effect of magnitude of reinforcement on acquisition and extinction of a running response. J. exp. Psychol., 1959, 58, 61-63.

3. Barakat, Hind. The effects of schedules and magnitudes of reinforcement on behavior. Unpublished M.A. thesis. American University of Beirut, Beirut, Lebanon, 1962.

4. Butter, C. M., and Thomas, D. R. Secondary reinforcement as a function of the amount of primary reinforcement. J. comp. physiol. Psychol., 1958, 51, 346-348.

5. Cockrell, J. T. Operant behavior of white rats in relation to the concentration of a non-nutritive sweet substance used as reinforcement. Unpublished doctoral dissertation, University of Indiana, 1952. From Pubols, B. H. Jr. Incentive magnitude, learning, and performance. Psychol. Bull., 1960, 57, 89-115.

6. Collier, George, and Marx, M. H. Changes in performance as a function of shifts in the magnitude of reinforcement. J. exp. Psychol., 1959, 57, 305-309.

7. Collier, George and Myers, Leonhard. The loci of reinforcement. J. exp. Psychol., 1961, 61, 57-66.

8. Collier, George, and Siskel, M., Jr. Performance as a joint function of amount of reinforcement and inter-reinforcement interval. J. exp. Psychol., 1959, 57, 115-120.

9. Cotton, J. W. Running time as a function of amount of food deprivation. J. exp. Psychol., 1953, 46, 188-198.

10. Crespi, L. P. Quantitative variation of incentive and performance in the white rat. Amer. J. Psychol., 1942, 55, 467-517.

11. __________. Amount of reinforcement and level of performance. Psychol. Rev., 1944, 51, 341-357.

12. D'Amato, M. R. Secondary reinforcement and magnitude of primary reinforcement. J. comp. physiol. Psychol., 1955, 48, 378-380.

13. Davis, J. D., and Keehn, J. D. Magnitude of reinforcement and consummatory behavior. Science, 1959, 130, 269-271.

14. Dufort, R. H., and Kimble, G. A. Changes in response strength with changes in the amount of reinforcement. J. exp. Psychol., 1956, 51, 185-191.

15. Fehrer, Elizabeth. Effects of amount of reinforcement and of pre- and postreinforcement delays on learning and extinction. J. exp. Psychol., 1956, 52, 167-176.

16. Ferster, C. B., and Skinner, B. F. Schedules of reinforcement, New York: Appleton - Century - Crofts, 1957.

17. Furchtgott, E., and Rubin, R. D. The effect of magnitude of reward on maze learning in the white rat. J. comp. physiol. Psychol., 1953, 46, 9-12.

18. Gagne, R. M. The effect of spacing of trials on the acquisition and extinction of a conditioned operant response. J. exp. Psychol., 1941, 29, 201-216.

19. Gilbert, T. F. Fundamental dimensional properties of the operant. Psychol. Rev., 1958, 65, 272-282.

20. Goodrich, K. P. Performance in different segments of an instrumental response chain as a function of reinforcement schedule. J. exp. Psychol., 1959, 57, 57-63.

21. Greene, J. E. Magnitude of reward and acquisition of a black-white discrimination habit. J. exp. Psychol., 1953, 46, 113-119.

22. Grindley, G. C. Experiments on the influence of the amount of reward on learning in young chickens. Brit. J. Psychol., 1929, 20, 173-180.

23. Guttman, N. Operant conditioning, extinction, and periodic reinforcement in relation to concentration of sucrose used as reinforcing agent. J. exp. Psychol., 1953, 46, 213-224.

24. __________. Equal-reinforcement values for sucrose and glucose solutions compared with equal sweetness values. J. comp. physiol. Psychol., 1954, 47, 358-363.

25. Hopkins, C. O. Effectiveness of secondary reinforcing stimuli as a function of the quantity and quality of food reinforcement. J. exp. Psychol., 1955, 50, 339-342.

26. Hughes, L. H. Saccharine reinforcement in a T maze. J. comp. physiol. Psychol., 1957, 50, 431-435.

27. Hulse, S. H. Amount and percentage of reinforcement and duration of goal confinement in conditioning and extinction. J. exp. Psychol., 1958, 56, 48-57.

28. Hutt, P. J. Rate of bar pressing as a function of quality and quantity of food reward. J. comp. physiol. Psychol., 1954, 47, 235-239.

29. Jenkins, W. O. and Clayton, F. L. Rate of responding and amount of reinforcement. J. comp. physiol. Psychol., 1949, 42, 174-181.

30. Kagan, J. Differential reward value of incomplete and complete sexual behavior. J. comp. physiol. Psychol., 1955, 48, 59-64.

31. Kling, J. W. Speed of running as a function of goal-box behavior. J. comp. physiol. Psychol., 1956, 49, 474-476.

32. Kraeling, Doris. Analysis of amount of reward as a variable in learning. J. comp. physiol. Psychol., 1961, 54, 560-565.

33. Lawrence, D. H., and Miller, N. E. A positive relationship between reinforcement and resistance to extinction produced by removing a source of confusion from a technique that had produced opposite results. J. exp. Psychol., 1947, 37, 494-509.

34. Lawson, R. Amount of primary reward and strength of secondary reward. J. exp. Psychol., 1953, 46, 183-187.

35. ________. Brightness discrimination performance and secondary reward strength as a function of primary award amount. J. comp. physiol. Psychol., 1957, 50, 35-39.

36. Logan, F. A. Incentive. New Haven: Yale University Press, 1960.

37. Logan, F. A., Beier, Eileen M., and Ellis, R. A. Effect of varied reinforcement on speed of locomotion. J. exp. Psychol., 1955, 49, 260-266.

38. Logan, F. A., Beier, Eileen M., and Kincaid, W. D. Extinction following partial and varied reinforcement. J. exp. Psychol., 1956, 52, 65-70.

39. Maher, W. B. and Wickens, D. D. Effect of differential quantity of reward on acquisition and performance of a maze habit. J. comp. physiol. Psychol., 1954, 47, 44-46.

40. McKelvey, R. K. The relationship between training methods and reward variables in brightness discrimination learning. J. comp. physiol. Psychol., 1956, 49, 485-491.

41. Metzer, R., Cotton, J. W., and Lewis, D. J. Effect of reinforcement magnitude and order of presentation of different magnitudes on runway behavior. J. comp. physiol. Psychol., 1957, 50, 184-188.

42. Meyer, D. R. The effect of differential rewards on discrimination reversal learning by monkeys. J. exp. Psychol., 1951, 41, 268-274.

43. Myers, J. L. Secondary reinforcement: A review of recent experimentation. Psychol. Bull., 1958, 55, 284-301.

44. Pereboom, A. C., and Crawford, B. M. Instrumental and competing behavior as a function of trials and reward magnitude. J. exp. Psychol., 1958, 56, 82-85.

45. Pubols, B. H. Jr. Incentive magnitude, learning, and performance. Psychol. Bull., 1960, 57, 89-115.

46. Reynolds, B. The acquisition of a black-white discrimination habit under two levels of reinforcement. J. exp. Psychol., 1949, 39, 760-769.

47. __________. Acquisition of a simple spatial discrimination as a function of the amount of reinforcement. J. exp. Psychol., 1950, 40, 152-160.

48. __________. Resistance to extinction as a function of the amount of reinforcement present during acquisition. J. exp. Psychol., 1950, 40, 46-52.

49. Reynolds, B., Marx, H. H. and Henderson, R. L. Resistance to extinction as a function of drive-reward interaction. J. comp. physiol. Psychol., 1952, 45, 36-42.

50. Reynolds, W. F., and Pavlik, W. B. Running speed as a function of deprivation period and reward magnitude. J. comp. physiol. Psychol., 1960, 53, 615-618.

51. Saltzman, I. J. Maze learning in the absence of primary reinforcement: a study of secondary reinforcement. J. comp. physiol. Psychol., 1949, 42, 161-173.

52. Schrier, A. M. Amount of incentive and performance on a black-white discrimination problem. J. comp. physiol. Psychol., 1956, 49, 123-125.

53. Schrier, A. M. Effect of the method of presenting varied amounts of food incentive on performance by monkeys. Unpublished doctoral dissertation, University of Wisconsin, 1956. From Schrier, A. M. Comparison of two methods of investigating the effect of amount of reward on performance. J. comp. physiol. Psychol., 1958, 51, 725-731.

54. ____________. Comparison of two methods of investigating the effect of amount of reward on performance. J. comp. physiol. Psychol., 1958, 51, 725-731.

55. Seward, J. P., Shea, R. A., and Elkind, D. Evidence for the interaction of drive and reward. Amer. J. Psychol., 1958, 71, 404-407.

56. Sheffield, F. D., and Roby, T. B. Reward value of a non-nutritive sweet taste. J. comp. physiol. Psychol., 1950, 43, 471-481.

57. Sheffield, F. D., Roby, T. B., and Campbell, B. A. Drive reduction versus consummatory behavior as determinants of reinforcement. J. comp. physiol. Psychol., 1954, 47, 349-354.

58. Sheffield, F. D., Wulff, J. J., and Backer, R. Reward value of copulation without sex drive reduction. J. comp. physiol. Psychol., 1951, 44, 3-8.

59. Smith, M., and Duffy, M. Evidence for a dual reinforcing effect of sugar. J. comp. physiol. Psychol., 1957, 50, 242-247.

60. Smith, M., and Kinney, G. C. Sugar as a reward for hungry and nonhungry rats. J. exp. Psychol., 1956, 51, 348-352.

61. Spence, K. W. Behavior theory and conditioning. New Haven: Yale University Press, 1956.

62. Weiss, R. F. Deprivation and reward magnitude effects on speed throughout the goal gradient. J. exp. Psychol., 1960, 60, 384-390.

63. Wolfe, J. B., and Kaplon, M. D. Effect of amount of reward and consummative activity on learning in chickens. J. comp. physiol. Psychol., 1941, 31, 353-361.

64. Young, P. T., and Shuford, E. H. Intensity, duration, and repetition of hedonic processes as related to acquisition of motives. J. comp. physiol. Psychol., 1954, 47, 298-305.

65. Young, P. T., and Shuford, E. H. Quantitative control of motivation through sucrose solutions of different concentrations. *J. comp. physiol. Psychol.*, 1955, *48*, 114-118.

66. Zeaman, D. Response latency as a function of the amount of reinforcement. *J. exp. Psychol.*, 1949, *39*, 466-483.

SUMMARY

This experiment investigated local rates of responding (bursts of responses before each reinforcement) and overall response rates (total number of responses within each experimental session divided by total time of the session) of nine white rats of local stock reinforced on a fixed ratio (FR) schedule as functions of reinforcement magnitude and drive. (An FR or fixed ratio schedule means that a response is reinforced upon completion of a fixed number of responses counted from the preceding reinforcement.) Particularly the interest was to see how drive and reinforcement must be varied to increase or decrease overall rates of behavior, and how, if at all, local rates can be made to increase or decrease.

Water and various concentrations of sucrose solution were used as reinforcing agents in the bar-pressing situation, with shifts being made in drive conditions from a thirst-deprivation schedule to one of hunger-thirst deprivation. The absolute method of experimentation, whereby each subject experienced only one reinforcement value, was used in the stabilization phase of the experiment. The differential method, whereby each subject experienced more than one reinforcement value, was employed in the phases of reinforcement

changes and drive level changes.

The experiment consisted of four main phases: (a) stabilization, (b) changes in magnitude of reinforcement, (c) drive level changes, and (d) subsidiary procedures, in which the phenomena of zero drive and experimental extinction and the reinforcement schedule of Crf (continuous reinforcement) 10 min. FR12 20 min. were investigated to observe their effects on local and overall response rates.

The results of the experiment showed that overall rates followed reinforcement concentrations when both thirsty rats and hungry and thirsty rats were reinforced with sucrose solutions, while local rates followed reinforcement concentrations only when hungry and thirsty rats were reinforced with sucrose solutions. Both overall and local rates of responding also increased as a function of the increased deprivation condition of HT22½ when reinforcement magnitude was held constant at the concentration employed under T22½.

Decreasing reinforcement magnitude from 32% to 16% sucrose failed to reduce stable overall or local response rates. Both measures, however, decreased when the reinforcement schedule of Crf 10 min. FR12 20 min. was employed and when drive was 'zeroed' with 32% and water as reinforcing agents, with the greatest decrease being with the 32% sucrose. With experimental extinction overall rates of responding sharply decreased, but local response rates failed to decrease and even showed a slight increase with the absence of reinforcement. Therefore, it was concluded that local rates of responding, once stablized, did not decrease with decreases in reinforcement magnitude or with the absence of reinforcement, at least for a reasonable period of time.

Further experimentation along the lines of this study was suggested for a better understanding and control of the rat's behavior in the bar-pressing situation.