SOME QUANTITATIVE PROPERTIES OF ANXIETY

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Anxiety has at least two defining characteristics: (1) it is an emotional state, somewhat resembling fear, and (2) the disturbing stimulus which is principally responsible does not precede or accompany the state but is 'anticipated' in the future.

Both characteristics need clarification, whether they are applied to the behavior of man or, as in the present study, to a lower organism. One difficulty lies in accounting for behavior which arises in 'anticipation' of a future event. Since a stimulus which has not yet occurred cannot act as a cause, we must look for a *current* variable. An analogy with the typical conditioning experiment, in which S_1, having in the past been followed by S_2, now leads to an 'anticipatory' response to S_2, puts the matter in good scientific order because it is a current stimulus S_1, not the future occurrence of S_2, which produces the reaction. Past instances of S_2 have played their part in bringing this about, but it is not S_2 which is currently responsible.

Although the temporal relationships of classical conditioning provide for an acceptable definition of anticipation, the analogy with anxiety is not complete. In anxiety, the response which is developed to S_1 need not be like the original response to S_2. In a broader sense, then, anticipation must be defined as a reaction to a current stimulus S_1 which arises from the fact that S_1 has in the past been followed by S_2, where the reaction is not necessarily that which was originally made to S_2. The magnitude of the reaction to S_1 at any moment during its presentation may depend upon the previous temporal relations of S_1 and S_2.

The concept of 'emotional state' also needs clarification in view of the experiments to be described. It has been suggested elsewhere (3) that in treating emotion purely as *reaction* (either of the autonomic effectors or of the skeletal musculature), a very important influence upon operant behavior is overlooked. In practice we are most often interested in the effect of a stimulus in altering the strength of behavior that is frequently otherwise unrelated to the emotion. A stimulus giving rise to 'fear,' for example, may lead to muscular reactions (including facial expression, startle, and so on) and a widespread autonomic reaction of the sort commonly emphasized in the study of emotion; but of greater importance in certain respects is the considerable change in the tendencies of the organism to react in

various other ways. Some responses in its current repertoire will be strengthened, others weakened, in varying degrees. Our concern is most often with anxiety observed in this way, as an effect upon the normal behavior of the organism, rather than with a specific supplementary *response* in the strict sense of the term.

The experiments to be described follow this interpretation. An emotional state is set up in 'anticipation' of a disturbing stimulus, and the magnitude of the emotion is measured by its effect upon the strength of certain hunger-motivated behavior, more specifically upon the rate with which a rat makes an arbitrary response which is periodically reinforced with food. Such a rate has been shown to be a very sensitive indicator of the strength of behavior under a variety of circumstances (1), and it is adapted here to the case of emotion. Mowrer's recent summary of techniques for measuring the 'expectation' of a stimulus does not include a comparable procedure (2).

In these experiments the disturbing stimulus to be "anticipated" was an electric shock delivered from a condenser through grids in the floor of the experimental box. The stimulus which characteristically preceded the disturbing stimulus and which therefore became the occasion for anxiety was a tone, produced by phones attached to a 60 cycle A.C. transformer.

The apparatus, which provided for the simultaneous investigation of twenty-four rats, has been described in detail elsewhere (1, 3). Each rat was enclosed during the experimental period in a light-proof and nearly sound-proof box containing a lever which could be easily depressed. A curve (number of responses vs. time) for each rat and mechanically averaged curves for the group and for certain sub-groups of six or twelve rats were recorded. Under the procedure of periodic reconditioning, the control clock was set to reinforce single responses to the lever every four minutes, intervening responses going unreinforced. The rats came to respond at a relatively constant rate during the one-hour experimental period, and the summated response curves tended to approximate straight lines, except for local cyclic effects resulting from a temporal discrimination based upon the four-minute period of reinforcement. Curves *A* and *C* in Fig. 4 are for groups of twenty-four rats and represent the sort of baseline available for the observation of the effect of anxiety.

The subjects were twenty-four male albino rats under six months of age, taken from an unselected laboratory stock. Records were taken for one hour daily during the entire experiment. After preliminary conditioning of the pressing response, two sub-groups were formed; one group of twelve rats was kept at a relatively high drive, while the other twelve were held at a drive which produced a very low rate of responding. The sound and shock were first introduced after two weeks of periodic reinforcement.

Conditioning of a State of Anxiety

The averaged periodic curve for twelve rats on a high drive on the occasion of the first presentations of the tone (*T*) and shock (*S*) is shown in Fig. 1. On this first presentation the tone was allowed to sound for three minutes. Each rat was then given a shock and the tone was stopped. It will be observed that neither the tone nor the shock (at the intensity used throughout the experiment) produced any disturbance in the mean periodic rate at either presentation. This orderly base-line made it possible to follow with ease the development of the 'anticipation' of the shock during subsequent repetitions of the situation.

The tone-shock combination was presented twice during each of six consecutive hourly periods. Then, in order to clarify any changes in the behavior, the period of the tone was lengthened to five minutes and the combination was given only once during each ensuing experimental hour.

The principal result of this part of the experiment was the conditioning of a state of anxiety to the tone, where the primary index was a reduction in strength of the hunger-motivated lever-pressing behavior. The ratio of the number of responses made during the period of the tone to the average number made during the same fraction of the hour in control experiments was 1.2 : 1.0 [1] for the first experimental hour; it had dropped to 0.3 : 1.0 by the eighth.

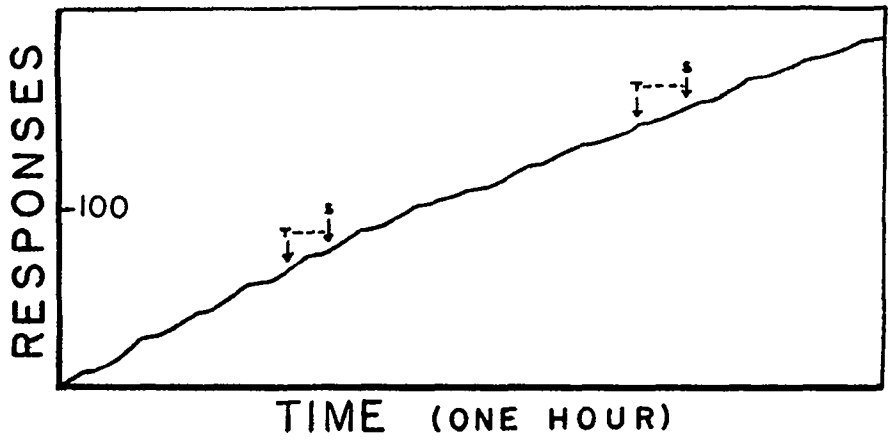

FIG. 1. First presentations of tone and shock. Mechanically averaged curves for twelve rats under periodic reinforcement. The tone was turned on at *T* and at *S* the shock was administered and the tone turned off. There is no noticeable effect of either tone or shock upon the rate of responding at this stage.

The changes in behavior accompanying anticipation of the shock are shown in Fig. 2, which gives the averaged curves for the group of six rats with the highest periodic rate during the first four days of the five-minute tone. A number of characteristics of these records should be noted. The progressively more marked reduction in periodic rate during the anticipatory period is obvious. The effect upon the rate is felt immediately after the presentation of the tone and remains at a constant value until the shock is given. (This constancy might not be maintained if the situation were repeated often enough to allow the rat to form a temporal discrimination.) Effects also appear

[1] The ratio is not expected to be exactly 1 : 1 since the number of responses made during a period of five minutes will depend upon where the period begins with respect to the four-minute interval of reinforcement.

after the shock, which were not present in Fig. 1 as the result of the shock alone. Especially in Curves *A* and *B* of Fig. 2, the shock is seen to be followed by a depression and irregularity of rate which are at least much greater than any effect in the control records. With continued repetition of the experiment, this disturbance tends to adapt out, although not completely. In Curves *C* and *D* of Fig. 2,

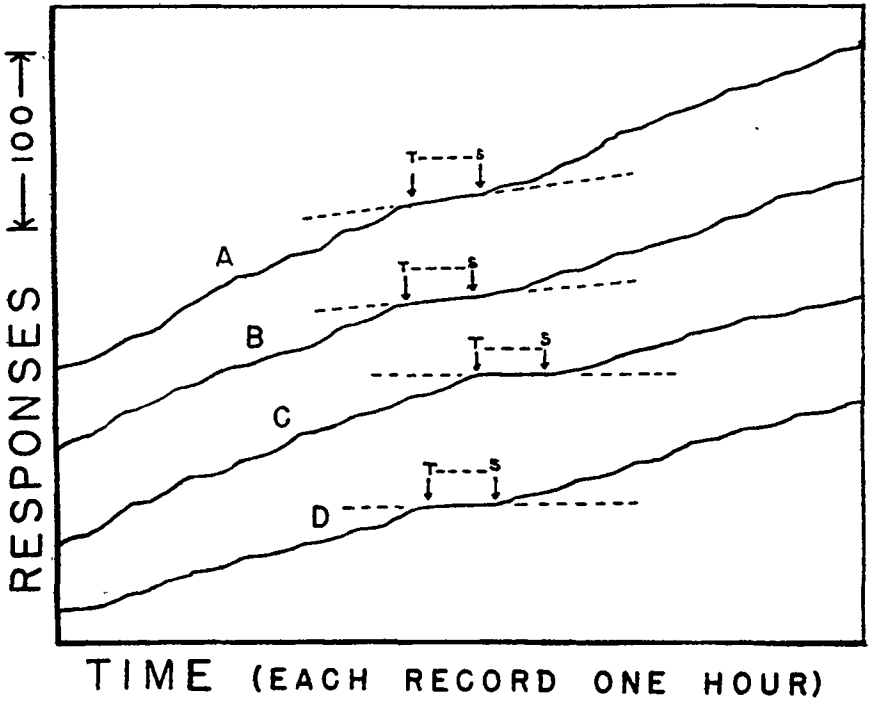

FIG. 2. Reduction in rate of responding during successive periods of anxiety. Averaged curves for six rats on four consecutive days. By the third or fourth day responding practically ceases during the presentation of the tone.

the distortion is much less marked. Curve *B* of Fig. 4 gives a similar example at a relatively late stage of conditioning.

The modification in behavior correlated with the anticipation of a disturbing stimulus cannot be attributed to a negative reinforcement of the response to the lever, since the shock was always given independently of the rat's behavior with respect to the lever. Only upon rare occasions could the shock have coincided with a response. This was especially true in the experiments upon the group at a lower drive, where a similar effect was obtained. Figure 3 shows averaged curves for a group of six rats which had been subjected to the procedure just described except that their drive was so low during condi-

tioning that the rate of responding was virtually zero. The lower curve in Fig. 3 is for the first day on which the five-minute rather than the three-minute period was given. Up to and including this record, no effect of the anticipation of the shock could be detected, since the animals were not responding at a significant rate. The drive was then raised, and the upper curve in Fig. 3 shows the performance of the same group on the following day. By sighting along the curve, one may observe a marked depression in the rate of responding during

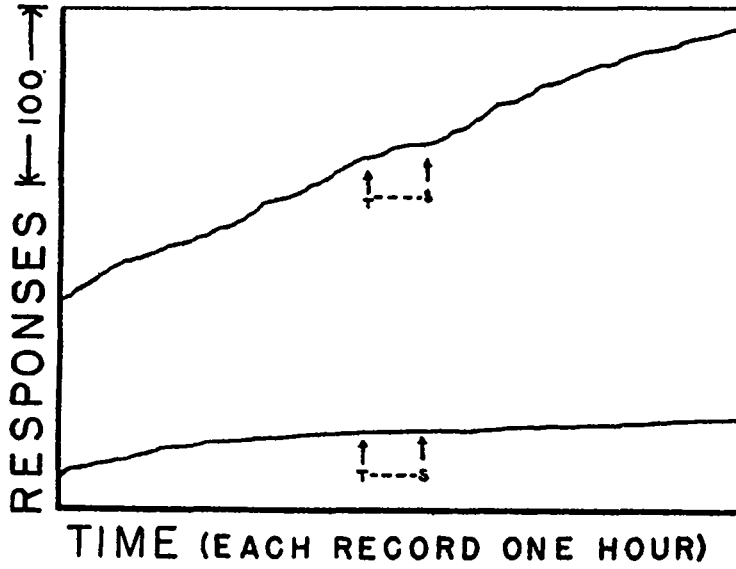

FIG. 3. Reduction in rate during anxiety following experiments at a very low drive. The lower record is a curve for six rats at a very low drive but otherwise comparable with the curves in Figs. 1 and 2. The upper curve is for the same group at a higher drive on the following day. The tone has an obvious effect, although all previous presentations have been made at a drive so low that no effect was observable.

the period of the tone. Comparison with Curve *B* in Fig. 2 shows that although the base line at the higher drive is more irregular, a depression of relatively the same magnitude is obtained. In this case, coincidental presentations of shock and response may safely be ignored, yet the tone has acquired the same depressing effect upon the behavior.

Another characteristic which deserves attention is the compensatory increase in periodic rate following the period of depression. This appears to some extent in all records obtained; but it may be seen most clearly in Curve *B* of Fig. 4, a periodic curve for all 24 rats after the emotional conditioning was quite complete. The curve was obtained about two weeks after the records in Fig. 2.

Curves *A* and *C* are controls taken (at a slightly higher drive) on adjacent days. By sighting along Curve *B*, one may observe a clear-cut increase in rate subsequent to the shock, which continues until the extrapolation of the curve preceding the break is reached. Evi-

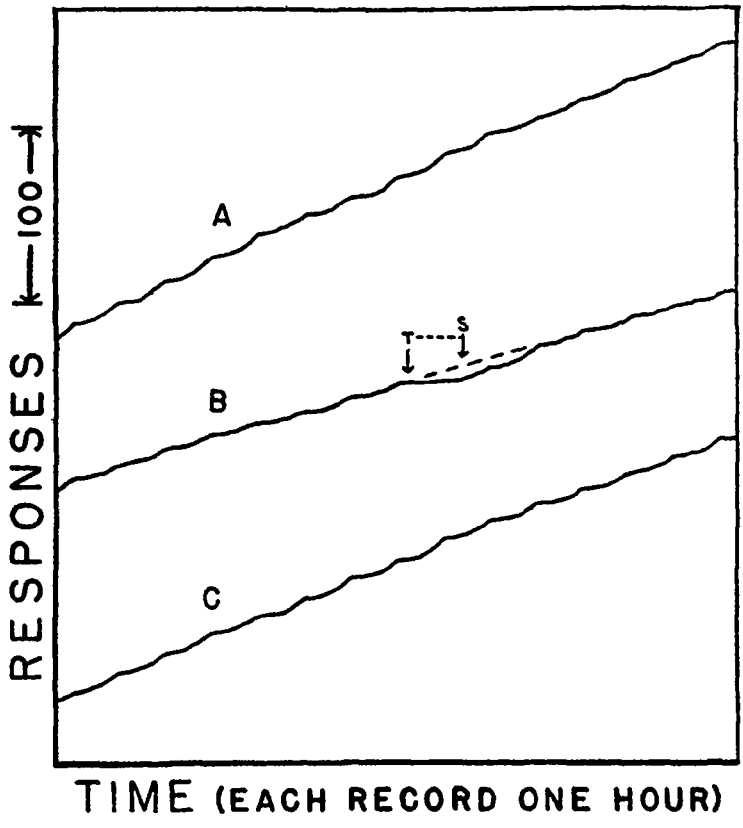

FIG. 4. Subsequent compensation for the reduction in rate during anxiety. The curves are averages for twenty-four rats taken on three consecutive days. *A* and *C* were taken under periodic reinforcement, while *B* shows the effect of the tone at a late stage in the experiment. The reduction in rate is followed by a compensatory increase, bringing the curve back to the extrapolation of the first part.

dently the effect of the emotional state is a temporary depression of the strength of the behavior, the total amount of responding during the experimental period (the 'reserve') remaining the same. Similar compensatory increases have been described under a number of circumstances, including physical restraint of the response (3).

EFFECTS OF ANXIETY UPON EXTINCTION

When reinforcement with food is withheld, the rat continues to respond, but with a declining rate, and describes the typical extinc-

tion curve. The effects of anxiety upon this curve have been investigated. The first hour of a typical extinction curve, during which the combination of tone and shock was presented, is shown in the group curves of Fig. 5 and the individual curves of Fig. 6. By sighting along either curve in Fig. 5, one may observe a distinct depression in rate during the period of the tone, and (following the shock) an equally distinct compensatory increase, which appears to be maintained until an extrapolation to the first part of the curve is approximated. Figure 6 contains sample records from four rats which showed different degrees of depression during the tone.

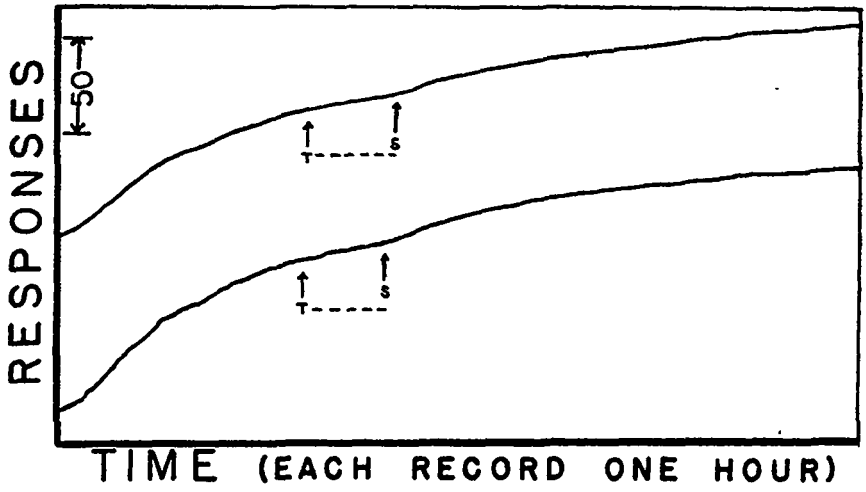

FIG. 5. Effects of anxiety upon extinction. The lower curve is an average for six rats, the upper for twelve. The tone, which had previously been followed by shock during periodic reinforcement, depresses the slope of the extinction curves, and a compensatory increase follows the administration of the shock.

During extinction, then, a state of anxiety produces a decrease in the rate of responding and the terminating stimulus is followed by such a compensatory increase in rate that the final height of the curve is probably not modified.

THE EXTINCTION OF A STATE OF ANXIETY

A further property of anxiety was investigated by presenting the tone for a prolonged period without the terminal shock. In one experiment, while the rats were responding under periodic reinforcement, the tone was turned on after twenty-seven minutes of the experimental period had elapsed and allowed to sound for the remainder of the hour. The result is shown in Figs. 7 and 8. It will be observed that the recovery of a normal periodic rate is delayed

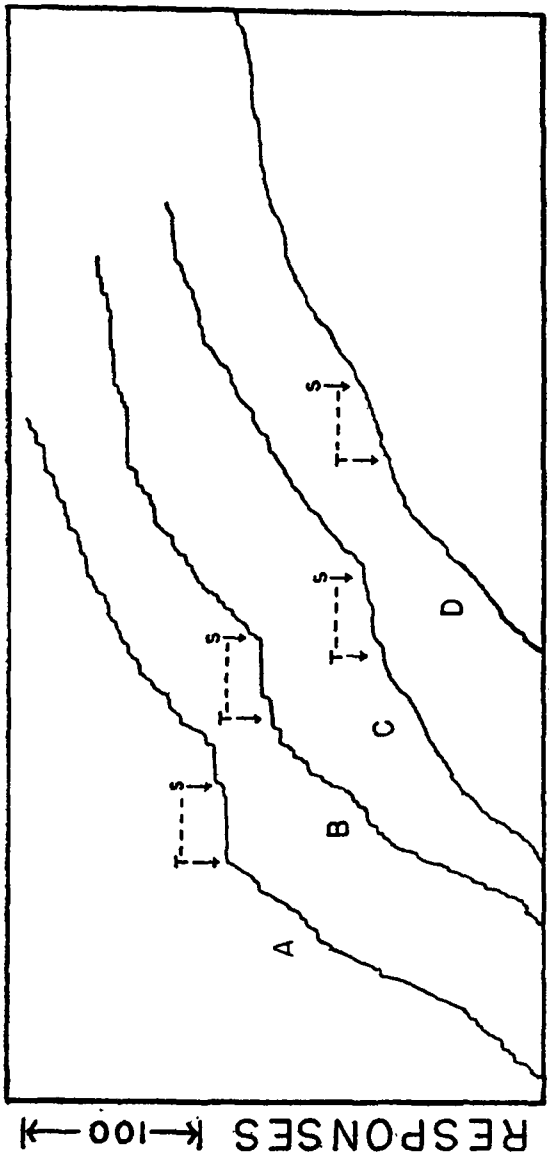

FIG. 6. Effects of anxiety upon extinction. Individual records from the experiment represented in Fig. 5.

considerably over the accustomed five-minute period of the tone. When the time is taken from the onset of the tone to the point at which the rat again reaches his previous periodic rate (measurements being made on individual curves), the mean period required for recovery is found to be 8.6 minutes. The group curve for twelve rats (the upper record in Fig. 7) shows a definite compensatory increase in rate later in the hour, although the extrapolation of the first part of the curve is not quite reached by the end of the period.

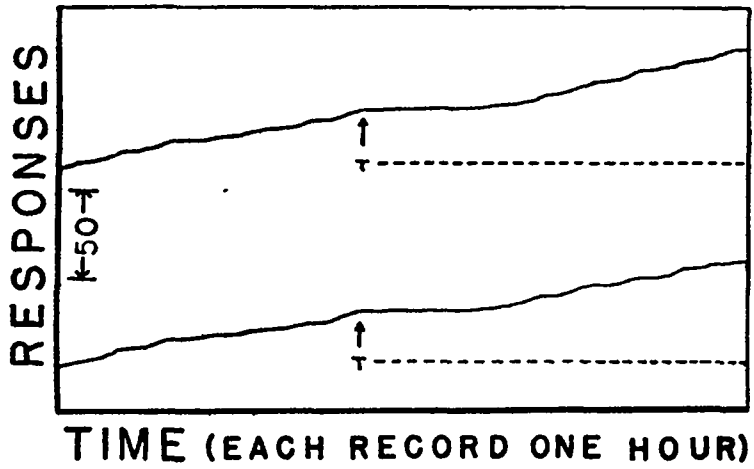

FIG. 7. Extinction of the effect of a tone when the terminating shock fails to appear. The upper record is the averaged curve for twelve rats under periodic reinforcement. The tone was turned on at *T* and continued to sound during the rest of the hour. No shock was given. The rate of responding returns to normal (and perhaps shows some compensatory increase) within ten minutes. The lower curve shows a repetition of the experiment ten days later.

The same experiment was repeated ten days later at a somewhat lower drive with the result shown in the lower curve in Fig. 7. The mean delay in recovery is here 9.1 minutes, and recovery is less complete. Except for the effects of the difference in motivation, the two records appear quite similar and exemplify the reproducibility of behavior of this sort.

Because the period of depressed activity varies among rats, individual records are needed in order to observe the course of the recovery of normal strength during the extinction of anxiety. Figure 8 shows a number of individual records with different periodic rates, the differences being attributable mainly to differences in hunger. The lag in recovery appears in nearly all records, and the compensatory increase in periodic rate in the majority. In some curves, notably *E*, *F*, and *G*, an extrapolation of the first part is reached before the end of the hour. It is not clear that this would have been

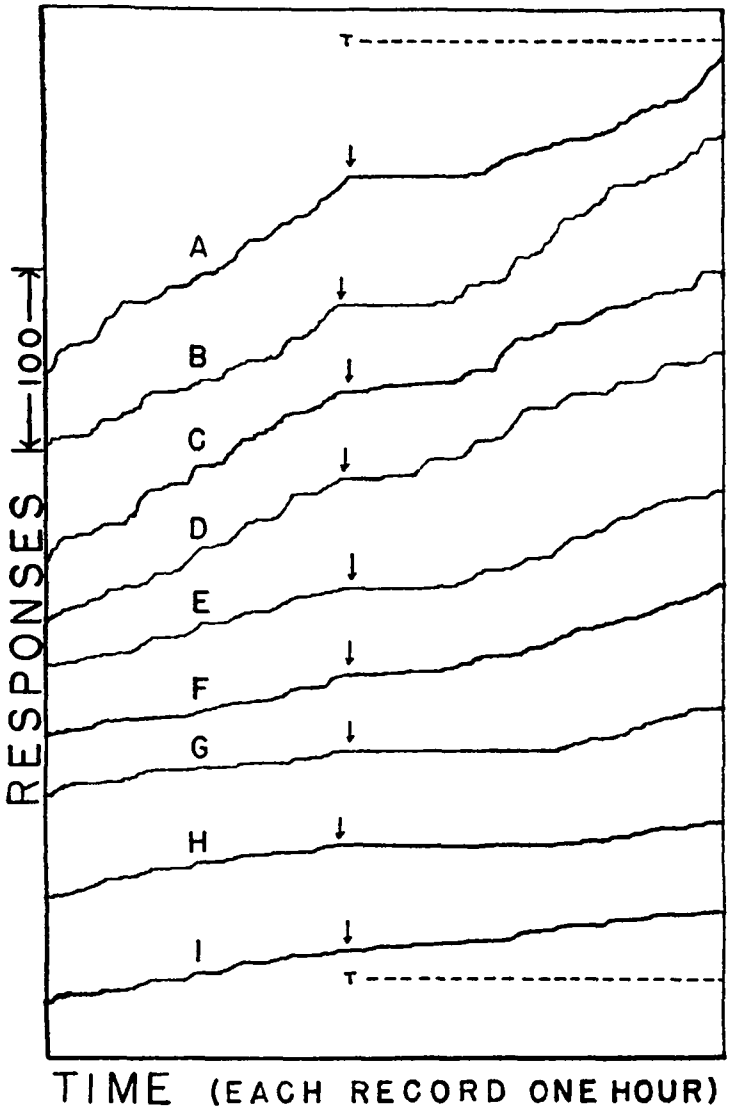

FIG. 8. Individual curves from the experiment described in Fig. 7.

the case with the other rats if the experimental period could have been prolonged, but the curves in general appear to be positively accelerated.

Spontaneous recovery from the extinction of the anxiety is fairly complete. The daily record which preceded the upper figure in Fig. 7 showed a ratio of 0.6 : 1.0 between the average periodic rate during the period of the tone and the normal rate for such an interval.

On the day following the figure, the ratio was 0.7 : 1.0 for a similar period, indicating that little or no effect of extinction survived.

Summary

Anxiety is here defined as an emotional state arising in response to some current stimulus which in the past has been followed by a disturbing stimulus. The magnitude of the state is measured by its effect upon the strength of hunger-motivated behavior, in this case the rate with which rats pressed a lever under periodic reinforcement with food. Repeated presentations of a tone terminated by an electric shock produced a state of anxiety in response to the tone, the primary index being a reduction in strength of the hunger-motivated behavior during the period of the tone. When the shock was thus preceded by a period of anxiety it produced a much more extensive disturbance in behavior than an 'unanticipated' shock. The depression of the rate of responding during anxiety was characteristically followed by a compensatory increase in rate.

During experimental extinction of the response to the lever the tone produced a decrease in the rate of responding, and the terminating shock was followed by a compensatory increase in rate which probably restored the original projected height of the extinction curve.

The conditioned anxiety state was extinguished when the tone was presented for a prolonged period without the terminating shock. Spontaneous recovery from this extinction was nearly complete on the following day.

(Manuscript received April 18, 1941)

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