

*STIMULUS ASPECTS OF AVERSIVE CONTROLS:
THE RETENTION OF CONDITIONED SUPPRESSION¹*

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Three years ago a tone ending in unavoidable electrical shock was periodically presented to pigeons while they pecked a key for food. When pecking was disrupted by tone, shock was disconnected and the training tone as well as tones of different frequencies were presented. At first, all tones caused a reduction in the rate of pecking, but as testing proceeded, suppression began to extinguish and the gradient narrowed. In the present work, testing was resumed after a 2½-yr interruption. Analysis of the gradients obtained just before and just after the interruption yielded no evidence of changes with the passage of time. As testing proceeded, however, extinction of suppression continued and the gradient all but disappeared. In subsequent experiments with these subjects (Ss) it was found that the presentation of free shocks caused a reappearance of the gradient and that this effect persisted in reduced amount for several sessions after the shock condition was terminated.

When a stimulus has typically preceded an unavoidable noxious event, subsequent presentations of that stimulus will often cause a reduction in the rate of ongoing hunger-motivated responses. This phenomenon (conditioned suppression) was initially investigated by Estes and Skinner (1941) and because of its relevance to the broad problem of learned anxiety, it has since been the subject of many experiments. (See Brady and Hunt, 1955; Sidman, 1960.)

Previous work in this laboratory (Fleshler and Hoffman, 1961; Hoffman and Fleshler, 1961) was concerned with the degree to which conditioned suppression was mediated by stimuli which were like, but not identical to, the stimulus involved in the original training. This phenomenon, the stimulus generalization of conditioned suppression, commanded special attention because it represents one of the mechanisms by which aversive controls can affect large segments of an organism's behavior (Mednick, 1958).

This earlier work revealed that although conditioned suppression generalized broadly (all of the test stimuli yielded large amounts of suppression at first), the repeated presentation of the several stimuli, without an accompanying noxious event, led to extinction of suppression and in the course of extinction the gradient became quite steep. In the initial experiment of the present sequence, we wished to examine the relative permanency of these

effects; in particular, we wished to determine how the gradient changed with the passage of time. In the subsequent experiments with these Ss, we sought to examine the way in which the gradient was affected by emotional stress.

EXPERIMENT I

Subjects

Five domestic White Carneaux pigeons, the surviving birds from the six used in the previous study by Hoffman and Fleshler (1961), were used.

Apparatus

The experimental chamber and the associated equipment have been fully described in a previous paper (Hoffman and Fleshler, 1961). Briefly, they consisted of a Foringer pigeon chamber, equipment to program reinforcement and tones, cumulative recorders and counters to assess key pecking, and a special purpose connection (Hoffman, 1960)

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to deliver electrical shock to the birds via a pair of permanently-worn wing bands. The tones in the previous study, as well as in the present sequence of studies, were spaced at approximately equal intervals along a logarithmic scale (300, 450, 670, 1000, 1500, 2250, and 3400 cps). They were equated for intensity so that each produced a reading of 80 db spl on the C scale of a General Radio sound survey meter when the microphone was placed in the position typically occupied by the bird's head.

Procedure

In previous experiments (Hoffman and Fleshler, 1961), the pigeons had been trained in a series of stages: (1) deprivation to 80 per cent of free-feeding weight and adaptation to apparatus, (2) training to establish a base rate of pecking on a VI 2 schedule of reinforcement, (3) adaptation to the 1000 cps tone, (4) adaptation to the six other tones, (5) shock at the end of the 1000 cycle tone until all pecking ceased during the tone but the rate was normal in the absence of the tone, and (6) testing for generalization to all seven tones without shock. This last stage ended when extinction to the test tones (*i.e.*, tones with frequencies other than 1000 cps) was found to be substantial. Different birds received a total of from 14 to 25 test sessions. The only treatment difference between Ss was that two birds had their body weight lowered to 70 per cent during stage 5 and returned to 80 per cent after a few sessions of stage 6. Otherwise, the treatment was uniform.

At the conclusion of the previous work, the birds were returned to their loft for a period of approximately 2½ yr. At the beginning of the present study they were again adapted to individual cages and were thereafter maintained, by restricted feeding, at 80 per cent of their free-feeding weights. The birds were then run on a VI 2 for 10 sessions, each of which lasted approximately 2 hr. This was done to re-establish a stable base rate of pecking. No tones were presented during these sessions, and during these sessions as well as during the test sessions which followed, the shock connector was in place but no shocks were presented.

Tests for stimulus generalization were then begun. Each test session lasted approximately 1.5 hr and had the following pattern: the

pigeon was placed in the apparatus with all lights off and remained in this state for at least 30 sec. The session was started with the onset of the lights in the box. The bird was first given a 10-min period in which to develop a more or less stable rate of pecking. The seven stimuli were then presented sequentially and in random order. Each stimulus had a duration of 40 sec and a 9-min and 20-sec interval of silence occurred between the tones. The sequence of the tones was varied from day to day. Each tone was presented, once in each session, with its position determined by one row of a set of latin squares. The number of responses was recorded for each of the seven tone periods, and also for the seven 40-sec pre-tone periods that ended with tone onset. At the end of the session, all lights were turned off and the pigeon was removed. The tests were conducted daily for 20 sessions.

Results

Figure 1 shows the final portion of the results of stage 6 in the original experiment conducted almost 3 yr ago (the dotted lines) and also shows the results of Exp. I in the present sequence of studies (the solid lines). The curves in the inset show the data from a single S (No. 21) and serve to illustrate the degree to which functions based on means correspond to the data from the individual organism.

In Fig. 1 the measure of suppression is a ratio which is expressed arithmetically as

$$\frac{\text{Pre-tone R's} - \text{Tone R's}}{\text{Pre-tone R's}}$$

where Pre-tone R's equals the number of responses in the 40-sec period which ended with the tone onset, and Tone R's is the number of responses during the 40 sec of tone presentation. Each point in the main body of Fig. 1 represents the mean suppression ratio for all five birds over a four-day period of testing, while each point in the inset represents the mean suppression ratio for bird No. 21 over a four-day period of testing.

As seen in the first of the dotted lines, during the stage of extinction shown, the gradient was relatively sharp but still exhibited some suppression on both wings. As the extinction progressed, however, the suppression controlled by stimuli on the wings of the gradient extinguished at a higher rate than the suppression controlled by the tone that had been

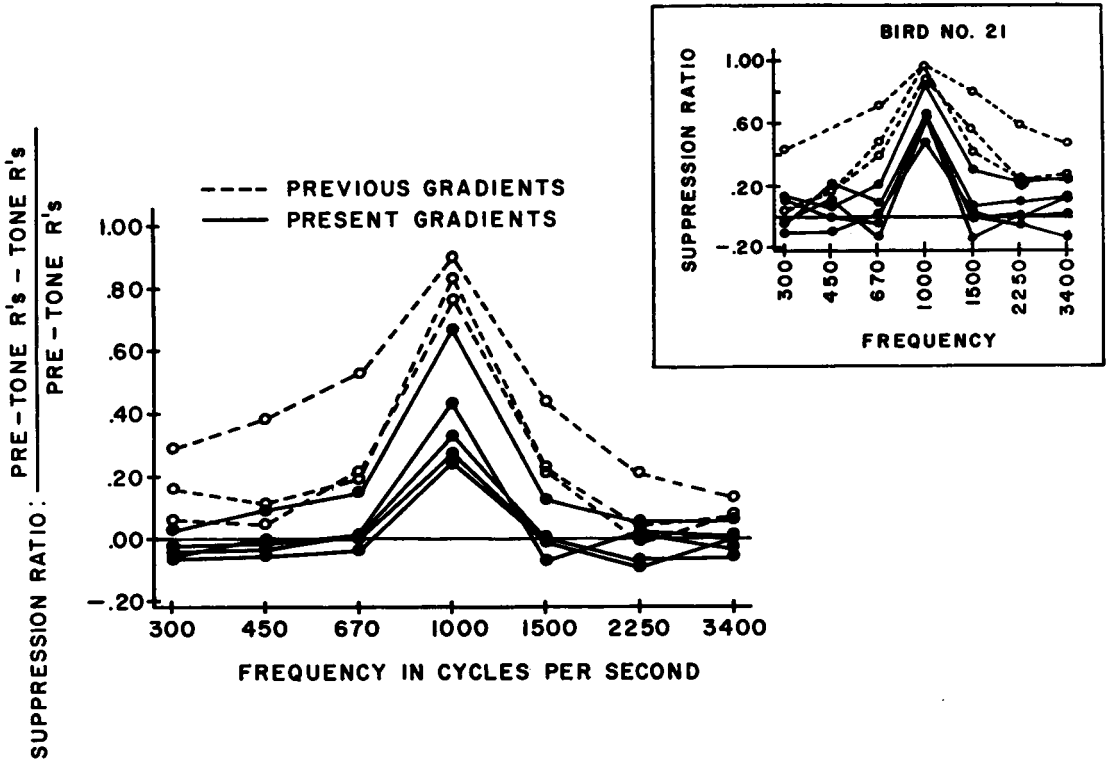


Fig. 1. Generalization gradients before and after the interpolated period. The solid lines show results of the present sequence of tests, whereas the dashed lines show the terminal gradients obtained more than 2 yr previously. Each gradient represents data averaged across four successive sessions for the five birds, and the sequence of gradients shows successive blocks of sessions in descending order. (The inset shows the comparable results from S No. 21.)

used in training (1000 cps). The result was a further sharpening of the gradient.

In general, the 2½-yr interruption had little, if any, observable effects. By the end of the earlier experiment, the extinction of the 1000 cycle tone had progressed to the point where the mean suppression ratio for this stimulus was .68. The decrement of .09 which was found when 2 yr intervened between blocks of trials is only slightly larger than the previous decrement of .07, obtained just prior to the interruption. By the end of the earlier experiment, the extinction of the stimuli on the wings of the gradient had advanced to the point where the mean suppression ratio for each of these tones was below .22. In the present study, this trend continued through the first block of trials. By the second block, the stimuli on the wings of the gradient exhibited almost no tendency to suppress pecking, *i.e.*, no point showed a suppression ratio of over .02.

We were surprised to note that during later stages of this study, a large number of negative ratios were obtained for stimuli on the wings of the gradient. These reflect a condition in which the rate of response is increased during the presentation of a tone. It was decided to test this effect separately for each of the five Ss. In general, the negative ratios tended to occur only toward the end of extinction. For this reason, each S's record was divided into two sections. The dividing point used was the first session which, when averaged with the following three sessions, would yield a suppression ratio of below .50 for the 1000 cycle tone. All trials beyond this point were included in the test of significance. For each occurrence of a 300, 450, 2250, and 3400 cycle tone the difference between the number of responses in the tone and pre-tone periods was found. On the basis of these differences a *t* test for related samples was run for each bird.

The results are found in Table 1. Four of the five *Ss* showed a significant increase in response rate when tones on the wing of the

Table 1

Tests of significance for differences between number of responses in pre-tone versus tone periods for the four extreme stimuli during the late stages of extinction. In these tests a negative value of *t* indicates that response rate during tone exceeded the response rate in the pre-tone period.

Bird No.	<i>t</i> value	<i>df</i>
10	.134	59
11	-3.06 **	43
21	-3.66 **	15
5	-2.72 **	71
9	-2.51 *	67

**P* < .05 for a two-tailed test.

***P* < .01 for a two-tailed test.

gradient were present during this section of extinction. The one *S* which did not show this effect never dropped much below .45 for the 1000 cycle tone at any time during extinction. It is possible to combine these separate *t* tests by the formula Chi Square = $-\sum 2 \log_e P$ (Winer, 1962, pp. 43-45). This yields an overall Chi Square with 10 *df* of 59.94, *P* < .001.

Discussion

The facilitation observed during the late stages of testing is puzzling and at present, attempts at an explanation must be largely speculative. Ray and Stein (1959) have observed a similar phenomenon in the course of discrimination training on conditioned suppression. Toward the end of their training procedure the *S^A* (a stimulus never paired with shock) tended to cause an elevation in response rate. They suggested that during discrimination training, the period in the absence of the warning signal is frequently terminated by the onset of the *S^D* (a stimulus consistently paired with shock). As a result, this period becomes somewhat aversive relative to the *S^A* period, which is never terminated by the onset of the *S^D*. Although no discrimination training was employed in the present study, the sharpening of the gradient is similar to the effects of such training and it seems possible that during the period of a sharpened gradient, a mechanism such as that described by Ray and Stein might have been operating.

A second possibility is that during the late stages of the extinction procedure, the tones were to some extent energizing the positively-reinforced behavior. A facilitation of this sort is consistent with the proposition that mild levels of anxiety may augment the effects of deprivation to produce an increase in the rate of hunger-motivated responses (Brown, 1961, chap. 5).

A third possibility is that the speed-up was a product of an interaction between the testing procedure and the baseline schedule. During the present study, key pecking was maintained on a variable interval schedule of reinforcement, and it is a property of this schedule that it locks up when a predetermined time has elapsed since a given reinforcement. Once the schedule locks up, however, the next peck, regardless of its time of occurrence, will yield an *rf*. When the bird suppresses to a given tone, the rate of response is low, but because of the lock-up feature of the schedule, the probability of reinforcement per response is elevated. In general, this condition would tend to cause an increase in rate of response, and it seems possible that exposure to this condition during the extinction of suppression might have facilitating effects which persist after the Conditioned Emotional Response to the warning signal has ceased to cause suppression.

The broad features of the retention data are perfectly clear. When testing was resumed after a 2½-yr interruption, the tones continued to cause suppression and the level of suppression for a given tone was inversely proportional to the frequency difference between that tone and the tone that had been used in training. Moreover, the level of suppression for each tone was approximately that expected, had testing proceeded without interruption. In short, the original aversive experience left effects which persisted (essentially without distortion) over a time span which encompassed approximately one-fifth of the life of the organism.

This finding is consistent with the results of Razran (1939) and Wendt (1937) which revealed that conditioned responses are retained over long periods. They are also consistent with those of Thomas, Ost, and Thomas (1960). Their work revealed that the gradient of stimulus generalization for behavior maintained under positive reinforcement exhibits

negligible changes during a 21-day interpolated interval. In general, the present results extend the implications of previous work by simultaneously demonstrating the longevity and the specificity of the behavioral consequences of aversive controls.

EXPERIMENT II

By the end of Exp. I, the extinction process had progressed to a stage where the negative effects of the original aversive training were scarcely discernible in the behavior of the *Ss*. Only the 1000 cycle tone caused any suppression at all, and the degree of suppression associated with this tone was not very substantial. It seemed possible, however, that in part these effects were deceptive. What, for example, would happen if the *Ss* were placed under emotional stress? Would the tones again cause substantial suppression and if so, how would the effects of the stress be distributed among them? The answers to these questions were of particular interest because of their relevance to problems associated with the clinical management of anxiety.

Method

The plan was to create a stressful situation by periodically administering electrical shock throughout an additional sequence of tests. The initial step was to establish an appropriate shock level for each bird. This was accomplished in a single short session (about 5 min per bird), conducted on the day following the completion of Exp. I of the present sequence. Each *S* was placed in a specially constructed plexiglass chamber and a series of brief shocks of increasing intensity were presented until a level was found which produced a marked, but not violent, reaction. The plexiglass chamber was used to preclude the formation of a direct association between shock and the normal testing situation. In this session, and in the test sessions which followed, shock was generated by an Applegate constant current stimulator. The levels established in the above fashion varied from bird to bird with a range of 1.25 ma to 3.0 ma.

The tests for stimulus generalization were begun on the day following the determination of shock levels. These tests were similar to those in Exp. I except that periods of darkness (Time Out) occurred in the interval between

presentations of tone and that a brief electrical shock was presented during each Time Out (TO). Since it is known that all pecking ceases during periods of darkness (Ferster and Skinner, 1957), the technique of administering shock during TOs would minimize the tendency for the birds to associate the shock with either the tones or the pecking behavior itself. Moreover, since the TOs with their associated shocks were to be evenly distributed throughout the sessions, the relationship of tone to shock would be uniform across tones.

The sequence of events in each session was as follows: the *S* was placed in the chamber and the lights were turned on. After a 10-min period to stabilize its response rate, the box was placed in a condition of TO. During the TO the house lights and key light were turned off and reinforcement was not available. The TO lasted 2 min. Forty seconds from the beginning of the TO, the *S* was administered a brief electrical shock (2 sec) at the previously-established level. Six minutes and 40 sec after the end of the TO, one of the seven tones was presented (without shock). As in Exp. I, the tone lasted 40 sec. Two minutes and 40 sec following the termination of tone, another TO with associated shock occurred. This pattern was repeated until the full series of seven stimuli had been presented. Then, after 2 min and 40 sec the session ended. The sequence of stimuli was determined in the same manner as in the first experiment. The *Ss* were run for eight sessions of testing on the shock condition.

Results

The effect of the introduction of shock on the baseline behavior varied somewhat from *S* to *S*. For several *Ss*, it caused a temporary reduction in rate during the first minute or so following each TO. For other *Ss* it produced a slight speed-up during this period. In almost every instance, however, the rate returned to a nearly normal level by the time each tone was introduced. For example, during the final four sessions of Exp. I, the average key pecking rate across all birds in the several pre-tone periods was 74 responses per min. During the first four sessions of Exp. II, the comparable average rate was 77 responses per min.

Although the shocks did not cause a marked change in the base rate of pecking, they did produce a dramatic modification in the *Ss*'

response to the tones. Figure 2 shows the two gradients obtained during the eight shock sessions and for purposes of comparison also shows the final gradient from Exp. I of the present sequence. The inset shows the data from bird No. 21. As seen in Fig. 2 there was a sudden and marked increase in the level of suppression to all seven stimuli. The rise was complete after two sessions in the shock condition and showed little change in the next six sessions. For the 1000 cycle tone the mean suppression ratio across all Ss increased from .24 to .65. Since all 40 of the suppression ratios obtained to the 1000 cycle tone under this condition were higher than the last pre-shock ratios of the respective birds, it is obvious that the effect for this tone is statistically significant.

The effects of the shocks on the rest of the stimuli were analyzed in two separate tests. As seen in Fig. 2 the suppression to stimuli other than the 1000 cycle tone was in general higher during the shock condition sessions than during the four sessions which preceded the introduction of shock. To evaluate the statistical significance of this effect, a non-parametric rank test for related groups was

employed (Jonckheere, 1954). It contrasted the responses (suppression ratios) of a given S to a given tone in the eight shock condition sessions with those of the eight sessions prior to shock. The results for the six tones (the test tones exclusive of the training tone) and the five Ss were pooled. The test was highly significant, $Z = 6.52$, $P < .0001$.

It can also be seen in Fig. 2 that the effects of the stress condition were not evenly distributed among the tones, and more specifically, that the suppression produced by a test stimulus was a function of the similarity of that stimulus to the training stimulus. To assess the significance of this finding, a non-parametric rank test for an ordered hypothesis involving related groups was conducted. A related group consisted of the responses to the three stimuli, on a given side of the gradient (e.g., 300, 450, 670) and the ordered hypothesis was that tones closer in frequency to the 1000 cycle tone produce greater suppression (e.g., $670 > 450 > 300$). For a given animal there are two comparison groups per session and thus 16 comparison groups for the eight shock condition sessions. The results for the five Ss were all in the predicted direction,

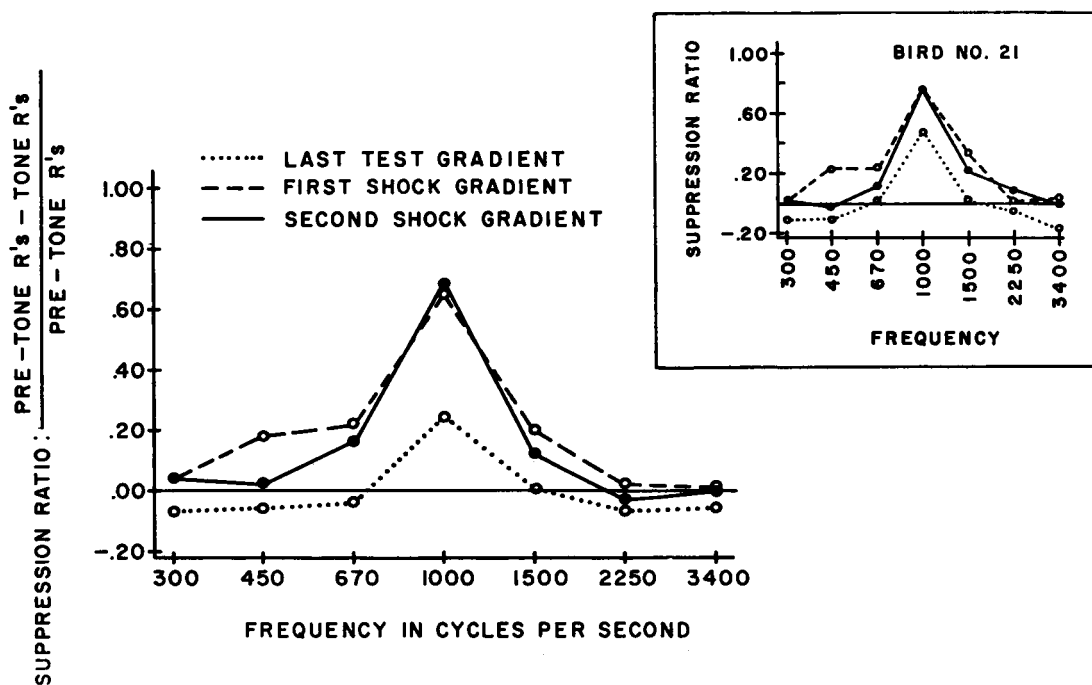


Fig. 2. The effects of emotional stress. The dotted line shows the final gradient from Exp. I of the present sequence. The solid and dashed lines show the gradients obtained during subsequent stress conditions. (The inset shows the comparable data from S No. 21.)

and a test combining these results was significant, $Z = 4.61$, $P < .0001$.

Discussion

The results of Exp. II provide an answer to the question of whether the negative effects of the aversive training administered 3 yr previously were, in fact, permanently eliminated during the extinction procedures. They were not. When the Ss were placed under emotional stress, the tones again caused substantial suppression, and, moreover, the degree of suppression for a given tone was largely determined by the similarity between that tone and the one that had been employed in the original aversive training.

In an earlier study with two of the present Ss (Hoffman and Fleshler, 1961), it was found that the degree to which suppression generalized was in part determined by variables which affect the ongoing behavior. In general, an increase in the motivation for the ongoing behavior produced a reduction in the breadth of the gradient. The present results supplement those of the earlier study by revealing that the breadth of the gradient is increased by variables which enhance the emotional state of the S.

EXPERIMENT III

In Exp. II, the occurrence of shocks during the sessions led to an amplification of the suppression produced by the several tones. Experiment III was conducted to determine whether this amplification, once initiated, would persist when shocks were no longer present.

Method

The use of TOs with shock was discontinued and beginning on the day following the termination of Exp. II, the birds were run for eight additional sessions under the procedures employed in Exp. I of the present sequence.

Results

The baseline behavior was insensitive to the removal of the TOs with shock. During Exp. III the mean rate in the several pre-tone periods was 77 responses per min, a value almost identical to the rates observed in Exp. I and II.

Figure 3 shows the two gradients obtained in Exp. III, and for purposes of comparison also shows the final gradients obtained in Experiment I and II. The insets show the

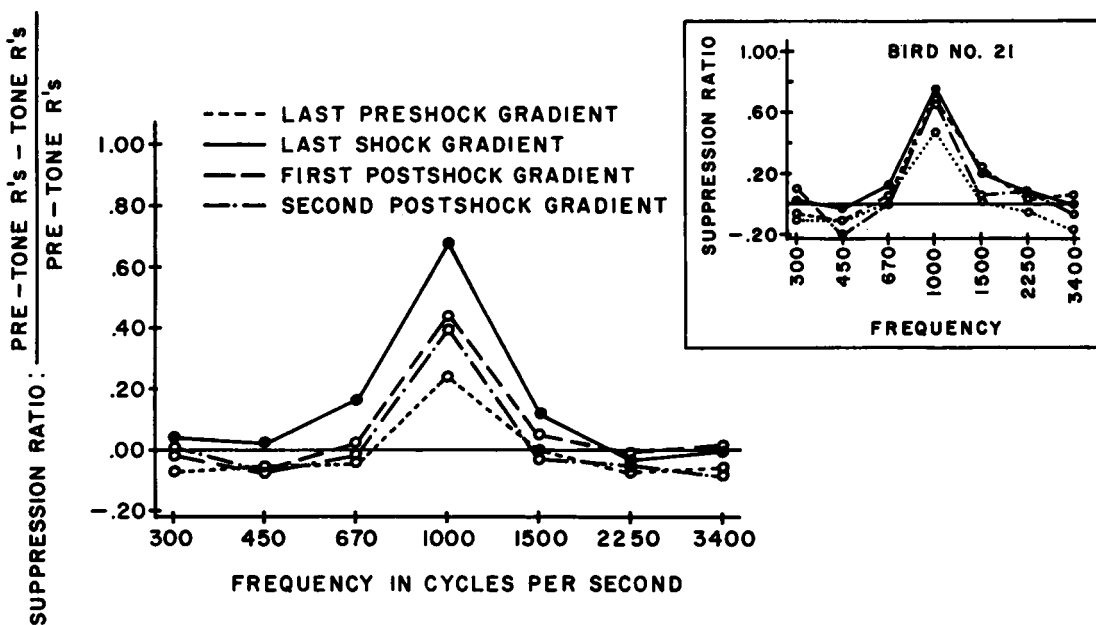


Fig. 3. The after-effects of emotional stress. The solid line shows the final gradient from the stress condition. The dashed lines show the gradients obtained in the sessions following the termination of the stress condition. The dotted line shows the final gradient obtained prior to the initiation of the stress condition. (The inset shows the comparable data from S No. 21.)

data from bird No. 21. When the TOs with shocks were removed and normal testing conditions were reinstated, the suppression controlled by the tones showed an immediate drop; yet, even after several sessions, suppression to the 1000 cps tone did not drop to the level exhibited at the end of Exp. I.

Non-parametric rank tests were employed to evaluate the reliability of the observed differences between the results of Exp. III and the other two levels of performance, *i.e.*, Exp. II and the final level of Exp. I. The first of these tests (a related groups analysis) concerned the effect of the removal of shock on the suppression to the 1000 cycle tone. For each *S* the suppression ratios produced by the 1000 cycle tone during the eight sessions of Exp. III were compared with the comparable data from Exp. II. The result for *Ss* combined was significant, $Z = 4.34$, $P < .0001$. The same test was used for the comparison of the suppression to the 1000 cps tone between Exp. III and the final eight sessions of Exp. I. The result was again significant, $Z = 2.677$, $P < .01$.

Two tests were conducted on the six other tones. Their format was similar to the first of the tests reported in Exp. II. For a given *S*, the eight suppression ratios to a given tone for either the eight final sessions of Exp. I or the eight sessions of Exp. II were contrasted with the comparable data from Exp. III. It was found that the drop from Exp. II to Exp. III was significant, $Z = 5.667$, $P < .0001$; but that the small observed difference between the levels in Exp. III and Exp. I was not statistically significant, $Z = 1.33$, $P > .05$.

Apparently, with the removal of the stress condition, all tones showed a reduction in their capacity to produce suppression. For tones other than 1000 cps, this reduction was complete. For the 1000 cycle tone, however, the reduction was less than complete.

Discussion

The decline in suppression with the removal of the stress condition is consistent with expectations. The finding that all tendencies toward suppression did not immediately return to the pre-stress level, however, is surprising and it appears that its explanation will require a far deeper understanding of aversive controls than currently exists. Perhaps this result depended upon some form of condition-

ing during the stress period. If so, it is difficult to specify just what was conditioned and to see why the after-effects of the stress were not distributed uniformly among the several tones. Perhaps the emotional byproducts of the stress remained after the conditions which produced them were removed. If so, why did the baseline behavior fail to reflect these effects and why did the effects persist throughout the eight sessions of Exp. III? Finally, it may be asked whether or not the occurrence of tone, during the stress condition was a critical factor in producing the result. Clearly, much more work will be necessary if these and related questions are to be answered.

For the present, however, we can only note that these results seem to have numerous implications for comprehension of problems associated with the clinical management of anxiety and its symptomatic manifestations. Not only does stress amplify the emotional response to stimuli with an aversive history, but once amplified, these responses can continue to produce their negative effects (conditioned suppression) long after the source of stress has been removed.

GENERAL CONCLUSIONS

When viewed in the context of the previous history of these *Ss*, the present results make it clear that aversive training can produce a profound effect upon behavior and, moreover, that the effect can persist through a significant portion of the *S's* life. Exposure to a noxious event which is consistently preceded by a neutral stimulus endows that stimulus with the capacity to suppress behavior, and stimuli which are similar to it also exhibit this capacity. In general, the degree to which the suppression generalizes is an inverse function of the motivation for the ongoing behavior and a direct function of the concurrent emotional state of the *S*. The behavioral consequences of aversive training tend to disappear with extended extinction procedures and the rate of extinction for a given stimulus is an inverse function of the physical similarity between that stimulus and the one involved in the original aversive training. The mere passage of time plays little, if any, role in these processes. Finally, when stimuli which have been employed in extinction procedures are presented during a period of emotional stress,

they regain a part of their former capacity to suppress behavior and the effect may persist long after the stress period has ended.

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