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COUNTERCONDITIONING OF CONDITIONED SUPPRESSION IN RATS[1]

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Summary.—Rats were trained to suppress lever-pressing for food during a 1-min. tone CS followed by shock on 5 of 10 trials per session. Six counterconditioning procedures were then carried out: (1) Regular Extinction; (2) Interference, in which extra food was delivered during the CS; (3) Toleration, in which a series of tones was employed starting at the lowest frequency and progressing to the original CS; (4) Toleration + Interference, a combination of the above procedures; (5) Flooding, in which a single 10-min. CS presentation was given each session; and (6) Flooding + Interference. Only Toleration + Interference significantly reduced the number of trials to a no-suppression criterion as compared with Regular Extinction. With respect to reducing the total amount of suppression during the counterconditioning period, Toleration + Interference was the most effective, followed in order by Toleration, Flooding, Interference, and Regular Extinction.

Fear can be considered a conditioned response to noxious stimuli. Fear is not itself an observable response but is an inference from other behavior, such as active or passive avoidance, autonomic reactivity, or inhibition of ongoing consummatory or exploratory behavior.

Since fear is a conditioned response, treatment therefore depends on principles of learning which weaken conditioned responses. Simple extinction, or the unreinforced presentation of the aversive conditioned stimulus (CS) is the most obvious of such learning principles. However, the resistance to extinction of active avoidance and the ease with which alternative avoidance behaviors are acquired are well documented laboratory phenomena (Solomon & Wynne, 1954; Miller, 1941; Miller, 1951) and serve as analogs to human clinical experience.

From the beginning of the conditioning approach to fear, procedures other than simple extinction have been tried (e.g., Jersild & Holmes, 1935; Jones, 1924). In a review of the literature on methods of extinguishing aversively controlled behavior (Poppen, 1968), it was found that the techniques used could be derived from the principles of counterconditioning originally formulated by Guthrie (1935; Hilgard, 1956). These principles may be listed as follows: (1) *Toleration*: Change the CS so that some response occurs other than the conditioned fear response. Then gradually change the CS to its original form, taking care that the fear response does not occur. (2) *Interference*: Combine

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the CS with another stimulus which specifically elicits a response antagonistic to fear. (3) *Flooding*: Present the CS in a massed or continuous fashion so that the fear response becomes refractory, allowing other responses to occur.

Perhaps the most germinal of the studies using counterconditioning procedures was the one by Joseph Wolpe (1952). Wolpe observed that conditioned fear interfered with eating in cats and reasoned that, if fear inhibited eating, eating could be used to inhibit fear. Wolpe fed his *Ss* by hand in the fear-eliciting chamber but had only limited success with this interference procedure by itself. He then devised the method of combining toleration and interference by feeding the animals in a series of rooms increasingly similar to the original chamber. However, he did not systematically compare the combined procedure with either of the components or with a simple extinction procedure. It was thus impossible to determine exactly the contribution of each of the counterconditioning principles or their advantage over regular extinction.

The aim of the present experiment was to investigate systematically counterconditioning principles in the elimination of conditioned fear. It is hypothesized that the use of these procedures will prove more effective than simple extinction and that their combination will be mutually facilitating.

METHOD

Subjects

Ss were 45 naive male albino rats of the Wistar strain, approximately 120 days old at the start of training. Final data are reported for 40 *Ss*, since one died and four failed to reach training criteria. They were housed in individual home cages with water freely available and the room light on continuously. Before training, they were reduced to 80% of their free-feeding weight. They were food deprived approximately 22 hr. before each session. Supplementary food was given after each session to maintain *Ss* at 80% bodyweight.

Apparatus

Four Gerbrands rat chambers (Model C) were employed. A 2-in. bar protruding ½ in. into the chamber was mounted on the front wall 3 in. from the floor. The food cup was below and to the left of the bar. The floor of the chamber was made of stainless steel rods spaced ½ in. apart.

Each chamber was enclosed in a larger sound-attenuated box made of layers of plywood, acoustic tile, and Fiberglas insulation. Illumination was provided by a 7½-w bulb mounted on the rear wall of each box. Each box was equipped with an exhaust blower which produced a low frequency hum. White noise was present in the room containing the chamber enclosures during all sessions.

Auditory stimuli were delivered through a 3-in. speaker (Jensen VK 350) mounted in the top of each rat chamber. The stimuli were provided by four audio oscillators (Hewlett Packard Model 200AB). Frequency output of each oscillator was calibrated with an electronic frequency counter (Hewlett Packard

Model 521 CR) to an accuracy range of ±1%. Sound pressure level of all tones inside the chambers was 90 db ±5% as measured on the C (flat) scale of a General Radio sound level meter with the microphone pointed toward the bar and all exhaust fans and masking noise turned off. Scrambled shock was delivered to the floor grids and the bar of all four chambers simultaneously by a single Grason Stadler shock generator. The shock duration was ½ sec. and the nominal intensity was 4 ma.

Standard relay programming equipment was contained in a room separate from the home cages and the experimental chambers. Bar presses were recorded on digital counters and cumulative recorders. Responses in each pre-CS and CS period were printed out separately on Sedeco print-out counters.

Procedure

In the first session, *S*s were shaped to press the bar for food (Noyes 45-mg. pellets) programmed on a continuous reinforcement schedule (CRF). After shaping, the session continued until *S* had received 100 pellets. In the second session, the CRF schedule was in effect until 50 pellets had been earned. For the remainder of an hour food was then programmed on a variable interval schedule with a mean value of 1 min. (VI 1). On all subsequent sessions, food was programmed on a VI 1 and the session length was 110 min.

On the ninth session the CS was introduced. The CS consisted of a 3500-Hz tone, 1 min. in duration, presented at 10-min. intervals for a total of 10 trials per session. This was done to determine that the tone alone did not suppress behavior. On the following session, conditioned suppression training was started. The offet of each CS was immediately followed by a ½-sec. shock. After several sessions in which shock followed every CS, an intermittent schedule was introduced in order to obtain maximum resistance to extinction (Sidman, 1960; Wagner, *et al.*, 1967). For the next 12 to 14 days, shock occurred on 5 randomly selected trials each session.

Suppression ratios were determined by the formula of Annau and Kamin (1961): Suppression $= B/(A + B)$, in which A is the number of responses in the 1-min. period preceding the CS, and B is the number of responses during the CS. Values thus vary from 0.50, no suppression, to 0.00, complete suppression. Over-all ratios for each session were calculated from the sum of responses in the A and B periods. Criterion for acquisition of suppression was an average over-all suppression ratio of .10 or less for the last 8 sessions of training.

After reaching acquisition criterion, *S*s were placed in one of six counterconditioning groups. Groups were made up so that they did not differ with respect to mean suppression ratio and number of *S*s trained in each chamber.

The criterion of no suppression for all *S*s was an average suppression ratio of at least .495 over 10 consecutive trials (not necessarily on the same day).

The conditions were the same for all animals during criterion run and were identical to the Regular Extinction procedure (see below).

The counterconditioning groups were as follows.

Regular Extinction ($N = 8$).—The procedure for this group was the same as acquisition except that the shock was turned off. That is, the 1-min. 3500-Hz tone CS was presented at 10-min. intervals for a total of 10 trials per session. Food was available on a VI 1 schedule throughout the session.

Interference ($N = 8$).—As above, the training CS was presented on each trial. In addition, during the CS period a free pellet was delivered every 15 sec. and a CRF schedule was in effect on the lever. CRF was scheduled so that more eating behavior would be present to interfere with fear and to strengthen lever pressing during the CS. Since response rate on CRF is less than on VI 1, this procedure would lead to spuriously low suppression ratios. Therefore, the VI 1 contingency, with a free pellet every 15 sec., was in effect if on the preceding trial *S* had made 5 or more responses on the CRF contingency or had a suppression ratio of .45 or greater. When *S* had a suppression ratio of at least .45 on two consecutive trials in the same session, the free pellets and the CRF contingency were stopped and *S* was placed on criterion run.

Toleration ($N = 8$).—Instead of a 3500-Hz tone, as in Regular Extinction, *S* was presented with a 400-Hz tone. When the suppression ratio on two successive trials was .45 or greater the tone was changed to 670 Hz on the next trial. *S*s progressed in this manner until they reached the training CS at which point they were on criterion run. The sequence of tones employed was 400, 670, 1000, 1500, 2280, and 3500 Hz. It has been shown that these tones produce generalization decrement in rats in the conditioned suppression situation (Desiderato, 1964). *S* started each session with the last tone on which he had reached criterion on the preceding day.

Toleration + Interference ($N = 8$).—This condition was essentially a conjunction of the two procedures just described. *S* progressed through the same series of tones, with the same criterion for change, as did the Toleration group. In addition, free pellets every 15 sec. and CRF on the lever were made available to *S* during the CS period. As in the Interference group, the CRF contingency was not in effect if on the preceding trial *S* had made 5 or more responses on CRF or had a suppression ratio of at least .45. The only difference was that CRF was in effect on every trial in which the tone frequency was increased although the ratio on the preceding trial was, necessarily, at least .45.

Flooding ($N = 4$).—In this condition the 3500-Hz CS was presented for 10 min. between the 50th and 60th min. of each session. Rate during this period was compared with rate during the 10 min. preceding the CS. When the suppression ratio for two consecutive sessions was at least .45, *S* was placed on criterion run.

Flooding + Interference ($N = 4$).—The CS was presented as in the pre-

vious group. In addition, every 15 sec. during the 10-min. CS a free pellet was delivered and the CRF contingency on the lever was in effect. If *S* made 50 or more responses during CRF he was placed on VI 1 with free pellets on the succeeding session. After seven sessions, CRF was discontinued.

RESULTS

The number of trials for the *S*s in each treatment group to reach the no suppression criterion is shown in Table 1. The Flooding groups were combined and a statistical analysis was performed which indicated that the variances of the groups differed ($F = 5.72$, $df = 4, 35$, $p < .01$). Selected contrasts based on the *F* test (McNemar, 1962) showed that the mean number of trials to no suppression was less for the Toleration + Inhibition group than for the Regular Extinction group ($t = 3.65$, $df = 35$, $p < .001$), the Inhibition group ($t = 3.00$, $df = 35$, $p < .01$), the Toleration group ($t = 2.68$, $df = 35$, $p < .02$), and the Flooding groups combined ($t = 4.48$, $df = 35$, $p < .001$). The mean number of trials to no suppression did not differ significantly between members of any other pairs of groups.

TABLE 1

NUMBER OF TRIALS FOR EACH *S* TO REACH CRITERION OF NO SUPPRESSION

	Group					
	a	b	c	d	e	f
S_1	43	46	47	22	50	70
S_2	60	69	52	28	102	90
S_3	93	70	53	30	109	105
S_4	96	70	76	37	138	106
S_5	96	79	76	46		
S_6	97	85	84	58		
S_7	103	87	87	64		
S_8	105	126	127	67		
M	86.62	79.00	75.25	44.00	99.75	92.75
SD	22.49	22.86	25.98	17.37	36.64	16.83

Note.—a = Regular Extinction, b = Interference, c = Toleration, d = Toleration + Interference, e = Flooding, f = Flooding + Interference.

The trial-by-trial course of the elimination of suppression for a "typical" *S* in each group is shown in Figs. 1, 2, and 4. Each "typical" *S* is one whose number of trials to criterion is closest to the mean of his group. Each dot represents a single trial on a given day. Except for the Flooding groups, 10 trials were given in each daily session. The criterion run of 10 trials for which the suppression ratio equals .495 or better is not shown.

Fig. 1A shows the course of extinction for a Regular Extinction *S*. He displayed virtually complete suppression for the first three sessions. He began to press the lever during the CS late in the fourth session but showed spon-

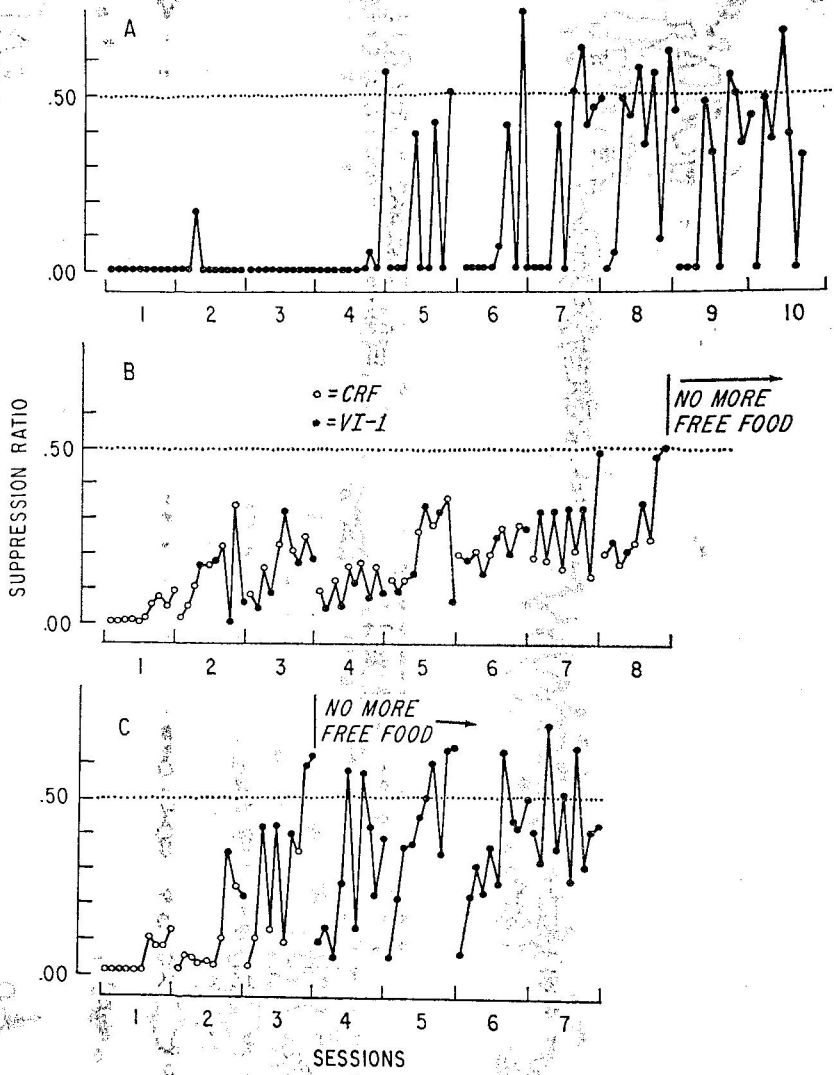

FIG. 1. Trial by trial suppression ratios for "typical" *Ss* during counterconditioning: A. Regular Extinction, B. Interference, C. Interference

taneous recovery of suppression by the start of the next session. The pattern of responding late in a session, with spontaneous recovery of suppression the next day, was common for animals in this group.

There were two counterconditioning patterns in the Interference group; 4 *Ss* displayed one pattern and 4 *Ss* displayed the other. The first pattern, shown in Fig. 1B, is characterized by immediate achievement of the criterion

after the extra food programs were withdrawn. (The criterion for terminating extra food was two successive trials with a ratio $> .450$.) Note that early in extinction there was less suppression on CRF trials (denoted by open circles) than on VI trials (denoted by closed circles). Later, VI rate increased over that on CRF trials. The second pattern is shown in Fig. 1C. It is characterized by rapid achievement of the criterion for withdrawal of extra food, followed by a prolonged period of regular extinction before the criterion is reached. The

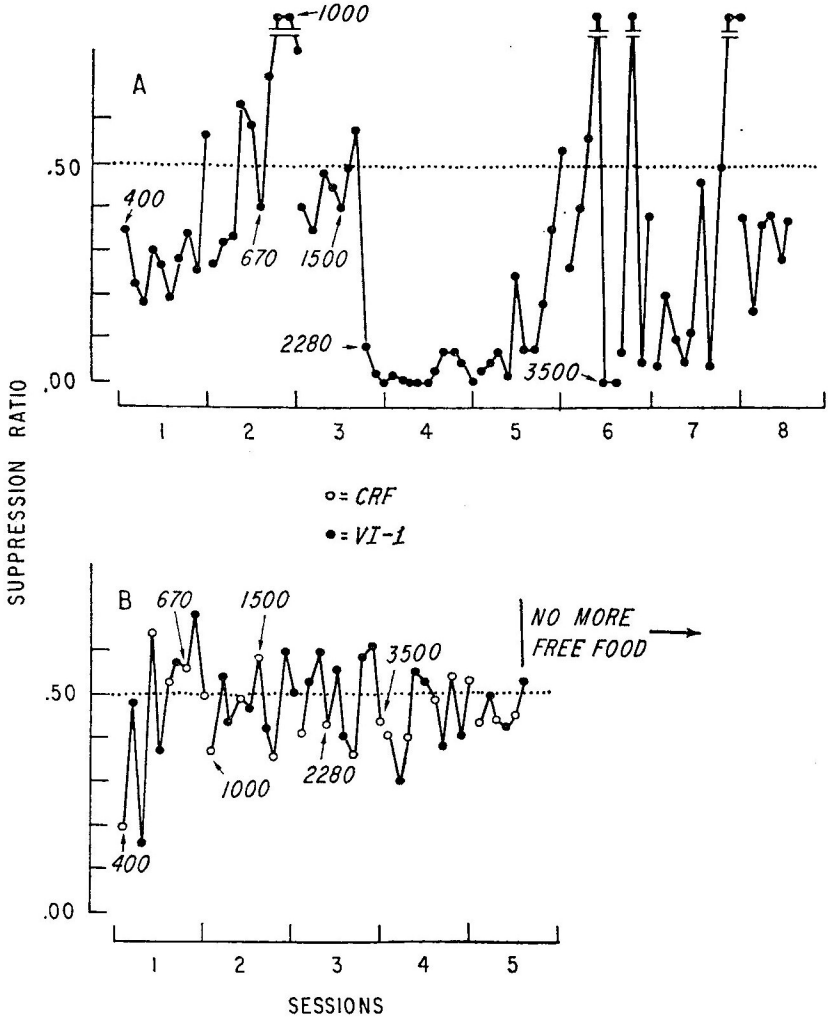

FIG. 2. Trial by trial suppression ratios for "typical" *S*s during counterconditioning: A. Toleration, B. Toleration + Interference. Arrows indicate change of tone frequency.

pattern of extinction late in a session, followed by recovery of suppression the next day, is similar to *Ss* in the Regular Extinction group.

Fig. 2A shows the pattern of counterconditioning for a Toleration *S*. There was usually an increase in suppression each time a new tone frequency was introduced. For 7 of 8 *Ss*, there was a marked and prolonged increase in suppression when tones of 2280 Hz, or 3500 Hz, or both, were introduced.

Fig. 2B shows the pattern of counterconditioning for a Toleration + Interference *S*. *Ss* in this group did not display the marked increase in suppression at the introduction of the training CS, or the tone closest to it, as did the *Ss* in the Toleration group. Fig. 3 shows the mean number of trials spent at each

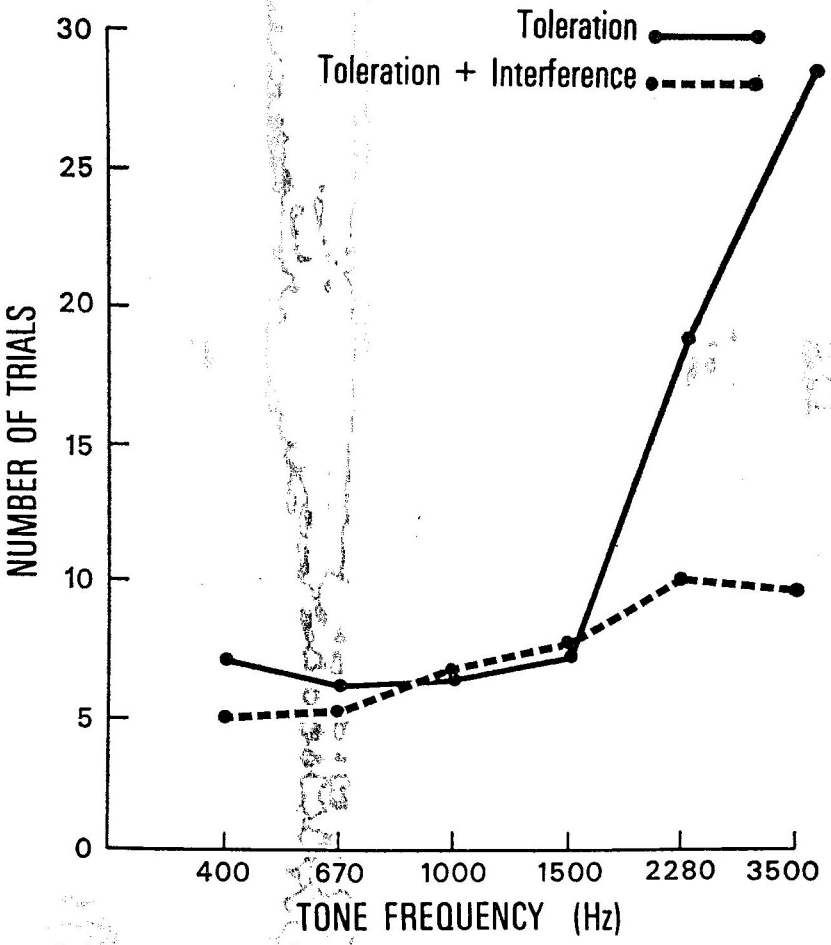

FIG. 3. Mean number of trials to criterion at each tone for Toleration and Toleration + Interference groups

tone before reaching the criterion for change for the Toleration and the Toleration + Interference groups. They did not differ at the lower values, but at 2280 Hz, and even more so at 3500 Hz, the Toleration *Ss* required significantly more trials to reach the no-suppression criterion. [Combining the total number of trials at 2280 Hz and 3500 Hz and comparing Toleration vs Toleration + Interference, $t = 3.14$ ($df = 14$, $p < .01$).]

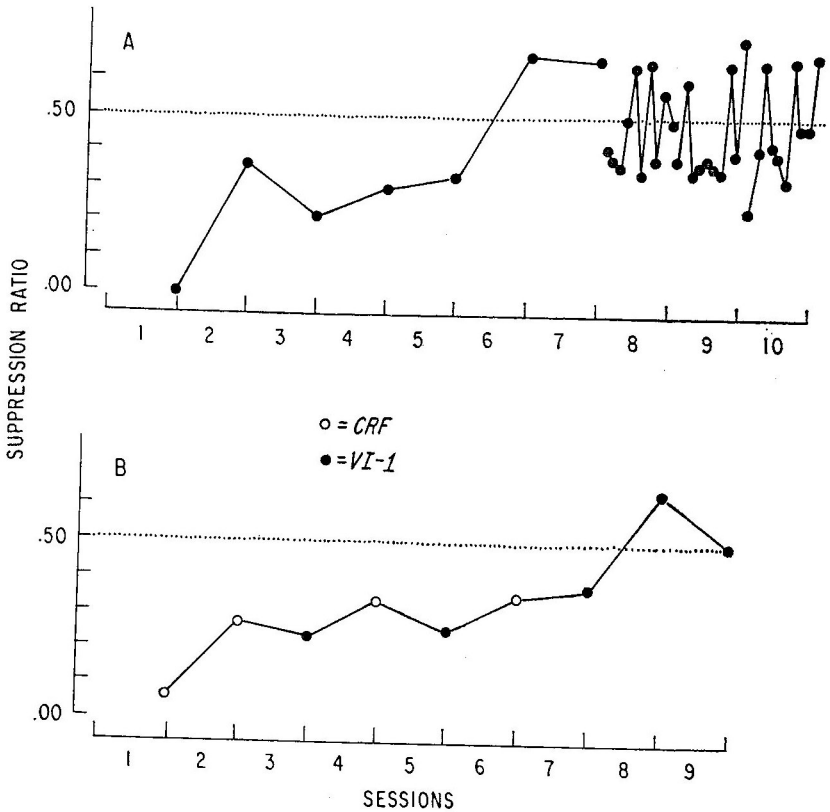

FIG. 4. Trial by trial suppression ratios for "typical" *Ss* during counterconditioning: A. Flooding, B. Flooding + Interference

The course of counterconditioning for a typical Flooding *S* is given in Fig. 4A. This *S* required 32 regular extinction trials after reaching the extinction criterion for the flooding procedure. Three *Ss* out of 4 in this group required additional regular extinction trials after reaching the flooding criterion.

Fig. 4B shows the course of counterconditioning of a Flooding + Interference *S*. This *S* achieved the no-suppression criterion on the first session that he was tested on the regular extinction procedure. Two *Ss* in this group reached

the no-suppression criterion immediately after the flooding criterion, and two required a few additional regular extinction trials.

The mean daily suppression ratios for each group for the first 10 sessions of counterconditioning are shown in Fig. 5. (When an individual *S* reached criterion in fewer than 10 sessions, a score of 0.50 was added to the group score for that *S* for the subsequent sessions.) This figure suggests that although the trials to no-suppression measure differentiated only the Toleration + Interference group, the course of counterconditioning for the groups was very different. Fig. 5, as well as the individual data, indicates that the groups differed with respect to amount of suppression during the counterconditioning period.

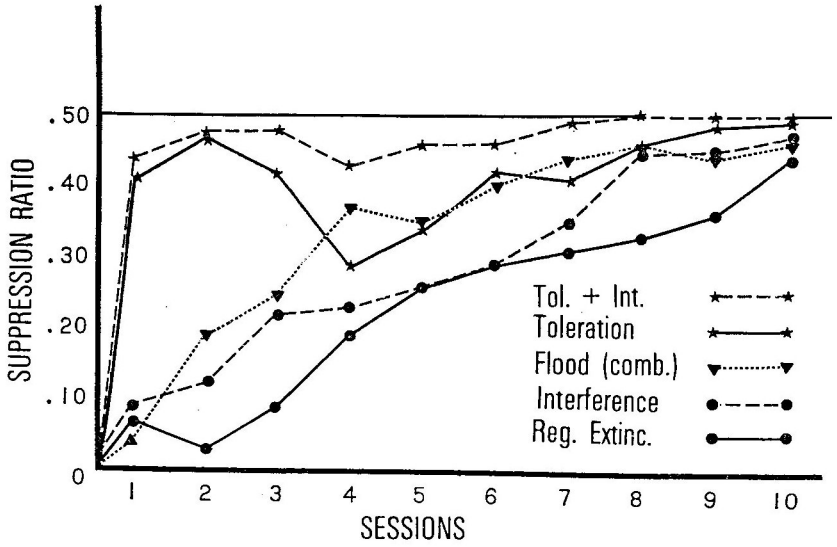

FIG. 5. Mean daily suppression ratio of each group for the first 10 counterconditioning sessions

In order to analyze the group differences suggested by Fig. 5, an "amount suppressed" score was determined for each *S* by subtracting his daily suppression ratio from 0.50 and summing these differences over the number of sessions that *S* took to reach the no-suppression criterion. These data were analyzed statistically in the same fashion as the trials to no-suppression criterion. A significant F was obtained ($F = 14.94$, $df = 4, 35$, $p < .001$) and the treatments were compared in a pair-wise fashion using the t test, in which the variance estimate and degrees of freedom are derived from the F. This analysis showed that the Toleration + Interference group showed less suppression during counterconditioning than the Toleration group ($t = 1.87$, $df = 35$, $p < .05$, one-tail test), the Interference group ($t = 5.28$, $df = 35$, $p < .001$), the Flooding groups

($t = 3.76$, $df = 35$, $p < .001$), and the Regular Extinction group ($t = 6.90$, $df = 35$, $p < .001$). The Toleration group, in turn, showed less suppression than the Interference group ($t = 3.46$, $df = 35$, $p < .01$), the Flooding groups ($t = 1.95$, $df = 35$, $p < .05$), and the Regular Extinction group ($t = 5.08$, $df = 35$, $p < .001$). Next, the Flooding groups showed only slightly less suppression than the Interference group during counterconditioning ($t = 1.51$, $df = 35$, $p < .20$) but showed significantly less suppression than the Regular Extinction group ($t = 3.31$, $df = 35$, $p < .01$). Finally, the Interference group showed only slightly less suppression than the Regular Extinction group ($t = 1.61$, $df = 35$, $p < .05$, one-tail test). In general, these findings lend statistical support to the differences pictured in Fig. 5.

Discussion

Response decrement with non-reinforcement is traditionally discussed in terms of two factors, interference and inhibition (Kimble, 1961). The former process refers to the replacement of the conditioned response by some other response, and the latter to the inherent decay of the conditioned response. The counterconditioning approach and the conditioned suppression technique emphasize interference, but inhibition may also be a factor.

In the Regular Extinction procedure employed in this study, the conditioned fear response was interfered with by positive arousal for food. The omission of shock at the end of the CS period, resulting in generalization decrement, might also have contributed to the interference, though this effect was minimized by employing a partial reinforcement procedure in the acquisition phase. The phenomenon of spontaneous recovery of suppression shown in Fig. 1A suggests that an inhibitory process was also at work. Repeated non-reinforced elicitation of the fear response resulted in a diminuation in that response and an increase in lever pressing during the CS toward the end of a session. Twenty-four hours later the inhibition had dissipated and complete suppression appeared in the early trials of the following session.

In the Interference group an attempt was made to enhance the positive arousal for food and thereby interfere with the fear response. This procedure thus differed only quantitatively from the Regular Extinction procedure and the results are highly similar. Some *Ss* showed no suppression late in a session and recovery the following day, with the result that they met the criterion for withdrawing the extra food early but still had to undergo many trials of regular extinction to meet the no-suppression criterion (Fig. 1C). Other *Ss* showed a low, but not zero, lever-pressing rate for many sessions before finally reaching the criterion for withdrawing extra food (Fig. 1B). This pattern may parallel the recent finding of Azrin and Hake (1969) that non-contingent food during a CS actually produces suppression. On the whole, the technique chosen to produce interference was not much more effective than regular extinction. A

more effective technique may be to provide a more preferred food during the CS. Geller (1960) has shown that suppression is more difficult to obtain and more easily extinguished in rats when they are working for milk than when working for water.

The Toleration procedure for eliminating response suppression can be regarded as the obverse of Terrace's method of errorless discrimination training (Terrace, 1963). The object of discrimination training is to eliminate responding to a particular stimulus (S—) which is on the same dimension as another stimulus (S+) to which an approach response has been trained. The method consists of starting with a stimulus of such intensity and duration that no response occurs and then by successive approximations changing it to the S—. The object of the present experiment was to eliminate not-responding to a stimulus associated with electric shock. The Toleration method starts with a stimulus to which responding does occur and progressively changes it to the aversive CS. This procedure worked well up to a point. When the stimulus closest to the CS, or the CS itself, was presented, a relapse of suppression suddenly recurred. This lends some support to the clinical notion that too large a step in the desensitization hierarchy will retard progress. However, an explicit experimental investigation of the size-of-step parameter remains to be carried out, both in the Terrace discrimination procedure and in the Toleration method described in this experiment. The results of this study suggest that logarithmic changes can be tolerated far from the critical stimulus but as the CS is more closely approximated, the stimulus-change steps must become smaller. The shape of the generalization gradients of the conditioned-fear response and of the antagonistic responses will determine the speed with which one can progress through the hierarchy of stimuli.

While the Toleration and Interference procedures singly were of only marginal effectiveness, their combination greatly reduced the number of trials to criterion and the amount of suppression during extinction. There was no evidence for spuriously low response rates due to non-contingent food as is a possibility in the Interference group. This may be due to the fact that the frequently changing CS did not allow such rates to be conditioned. That the Interference procedure did have some effect is shown by the fact that *Ss* in the Toleration + Interference group were able to make the transition to 2280 Hz and 3500 Hz without the relapse shown by *Ss* in the Toleration alone group. The results of this experimental procedure support Wolpe's (1952) contention that the most effective way to remove conditioned fear is to reduce the level of arousal by altering the stimulus conditions and then to elicit a specific antagonistic response. This study rules out the notions that the effects of "systematic desensitization" can be accounted for solely by interference, or by toleration, or by mere exposure to the fear generating cues.

The Flooding procedure makes use of the concept of inhibition. Prolonged

arousal of the fear response presumably causes it to become refractory. Individual records show that this did occur; in a given session *S*s began to press the lever in the latter part of the 10-min. CS interval. But on the following day *S*s again showed suppression during the first part of the CS presentation. The question may be raised as to whether different values of the flooding parameter would have been more effective. For example, would a 30-min. presentation be more effective than three 10-min. trials?

Addition of the extra food contingencies was not successful in getting *S*s in the Flooding + Interference group to start pressing lever earlier in the CS period. As in the Interference group, the non-contingent food may have lowered response rates during the CS for reasons other than conditioned fear. As suggested for that group, a better procedure might have been to use a more preferred food rather than CRF and non-contingent pellets.

REFERENCES

ANNAU, Z., & KAMIN, L. J. The conditioned emotional response as a function of the intensity of the US. *Journal of Comparative and Physiological Psychology*, 1961, 54, 428-432.

AZRIN, N., & HAKE, D. F. Positive conditioned suppression: conditioned suppression using positive reinforcers as the unconditioned stimuli. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 167-173.

DESIDERATO, O. Generalization of conditioned suppression. *Journal of Comparative and Physiological Psychology*, 1964, 57, 434-437.

GELLER, I. The acquisition and extinction of conditioned suppression as a function of the base-line reinforcer. *Journal of the Experimental Analysis of Behavior*, 1960, 3, 235-240.

GUTHRIE, E. R. *The psychology of learning.* New York: Harpers, 1935. (Rev., 1952)

HILGARD, E. R. *Theories of learning.* (2nd ed.) New York: Appleton-Century-Crofts, 1956.

JERSILD, A. T., & HOLMES, F. B. Methods of overcoming children's fears. *Journal of Psychology*, 1935, 1, 75-104.

JONES, M. C. A laboratory study of fear: the case of Peter. *Pedagogical Seminary*, 1924, 31, 308-315.

KIMBLE, G. A. *Hilgard and Marquis' 'Conditioning and learning.'* (2nd ed.) New York: Appleton-Century-Crofts, 1961.

MCNEMAR, Q. *Psychological statistics.* New York: Wiley, 1962.

MILLER, N. E. An experimental investigation of acquired drives. *Psychological Bulletin*, 1941, 38, 534-535.

MILLER, N. E. Learnable drives and rewards. In S. S. Stevens (Ed.), *Handbook of experimental psychology.* New York: Wiley, 1951. Ch. 5.

POPPEN, R. *Counterconditioning of conditioned suppression.* (Unpublished doctoral dissertation, Stanford Univer., 1968) Ann Arbor: University Microfilms, 1969. (No. 69-8241)

SIDMAN, M. Normal sources of pathological behavior. *Science*, 1960, 132, 61-68.

SOLOMON, R. L., & WYNNE, L. C. Traumatic avoidance learning: the principles of anxiety conservation and partial irreversibility. *Psychological Review*, 1954, 61, 353-358.

TERRACE, H. S. Discrimination learning with and without "errors." *Journal of the Experimental Analysis of Behavior*, 1963, 6, 1-27.

WAGNER, A. R., SIEGEL, L. S., & FEIN, G. G. Extinction of conditioned fear as a function of percentage reinforcement. *Journal of Comparative and Physiological Psychology*, 1967, 63, 160-164.

WOLPE, J. Experimental neurosis as learned behavior. *British Journal of Psychology*, 1952, 43, 243-268.

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