STIMULUS ASPECTS OF AVERSIVE CONTROLS: LONG TERM EFFECTS OF SUPPRESSION PROCEDURES¹

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Five years ago, pigeons trained to peck a key for food were periodically presented with a 1000 cps tone which ended with electrical shock. They were then tested for the stimulus generalization of conditioned suppression. After an interruption of 2.5 yr, another series of generalization tests showed no loss of suppression. The present study was conducted 1.5 yr later to retest the effect of an extended interruption on retention of suppression. It was found, again, that suppression did not decline over time. The present paper, which summarizes the earlier data and reports the most recent findings, provides an overview of the extended behavioral consequences of the original aversive procedures administered five years ago.

The present experiment represents the last of a series of studies on the enduring consequences of conditioned suppression training. Approximately five years ago, pigeons trained to peck a key for food were periodically presented with a 1000 cps tone which ended with an electrical shock. When tone presentation consistently reduced the rate of ongoing key pecks (conditioned suppression) the shock at the end of tone was discontinued; over the years, the birds have been periodically tested for the lasting effects of this early procedure (Hoffman and Fleshler, 1961; Hoffman, Fleshler, and Jensen, 1963). The present paper reports the last of these tests and collates the older data to provide an overview of the effects generated by the original aversive training.

METHOD

Subjects

Four domestic White Carneaux pigeons, the surviving birds from the six used in the previous studies (Hoffman and Fleshler, 1961; Hoff-

man *et al.*, 1963) were used. They were approximately 2 yr old at the time of original training and about 8 yr old when the present study was conducted.

Procedure

The apparatus and procedure have been fully described in an earlier report (Hoffman and Fleshler, 1961). Briefly, the apparatus consisted of a pigeon chamber, equipment to program reinforcement and tones, a cumulative recorder and counters to assess key pecks, and a special purpose connector (Hoffman, 1960) to deliver electrical shock to the birds via a pair of permanently-worn wing bands. The training procedures involved the following sequence of stages:

1. Deprivation to 80% of free-feeding weight and adaptation to the apparatus and to the wing bands and shock connector.
2. Key peck training to establish a steady base rate of responses on a variable interval schedule of food reinforcement (mean interval -2 min).
3. Adaptation to the stimulus which was to be paired with electrical shock (a 1000 cps tone). In this phase the tone had a duration of 48 sec and an intensity of 80 db spl. Tone was periodically presented without shock with an average inter-tone-interval of 10 min.
4. Adaptation to the several tones to be employed in the tests for stimulus generalization. These tones were equated for intensity (80 db spl) and had the following frequencies: 300, 450, 670, 1000, 1500, 2250, and 3400 cps.

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As in the adaptation to the 1000 cps tone (stage 3) each tone lasted 48 sec. Tones were presented singly and in random order with an average inter-tone-interval of 10 min.

Stages 3 and 4 were included to mitigate any suppression of key pecks that might be produced by presenting novel stimuli (*i.e.*, the several test tones) during tests for stimulus generalization. In this respect it is noteworthy that, by the end of stage 3, presentation of the 1000 cps tone had no observable effect on key peck rate and that the effects of this adaptation generalized to all the other test tones. Thus, throughout stage 4, pecking behavior was unaffected by the presence or absence of tone, regardless of tone frequency.

5. The 1000 cps tone was again presented periodically while subjects pecked the key for food. In this phase, however, pulsing electrical shock was presented during the final 8 sec of each tone.

The procedures of stage 5 were continued until all birds pecked at a normal rate in the absence of tone and did not peck during tone. For most birds, stage 5 required approximately 600 tone-shock presentations distributed over approximately 70 sessions.

6. When suppression training was completed (stage 5), shock at the end of tone was discontinued and, without altering the schedule of positive reinforcement, tests for

stimulus generalization were conducted. These tests had the same format as the adaptation tests (stage 4) in that all seven tones were presented singly and in random order (without shock) while the bird pecked the key on the previously established schedule of positive reinforcement. In stage 6, however, tones had a duration of 40 sec (the duration of the pre-shock warning period).

Except for two extended interruptions (2.5 yr in an earlier study, and 1.5 yr in the present study) and for the interpolation of a shock stress condition during late tests, test sessions occurred approximately every other day and no shocks were ever delivered. During the interruptions subjects were maintained at full body weight and were not subjected to any experimental procedures. The shock stress condition consisted of eight test sessions in which a series of unsignaled electrical shocks was administered during a sequence of time-outs (periods of darkness) interspersed among tone presentations. Since all pecking ceased during time-outs, the administration of shock during these periods minimized the tendency for the birds to form a direct association between shock and either the tones or the pecking behavior itself. Moreover, since the time-outs with shock were distributed evenly throughout the test sessions, the relationship of tone to shock was uniform across tones.

Fig. 1. Successive tests for stimulus generalization during extinction of conditioned suppression. The large curve shows the mean suppression ratio (across four birds) for each presentation of the 1000 cps tone during the several test sessions. The insets at the top show successive gradients of stimulus generalization where each gradient is based on the data from the four sessions which the inset spans. Shock stress refers to a sequence of test sessions in which electrical shocks were presented during a series of interpolated periods of darkness.

RESULTS

Figure 1 collates the data from the earlier studies (Hoffman and Fleshler, 1961; Hoffman *et al.*, 1963) and also shows the results of the present test (sessions 49-52 in Fig. 1). In this figure, the measure of conditioned suppression is expressed arithmetically as a ratio:

$$\frac{\text{Pre-tone Rs} - \text{Tone Rs}}{\text{Pre-tone Rs}}$$

where Pre-tone Rs equals the number of key peck responses in the 40 sec before the onset of a given tone and Tone Rs equals the number of key peck responses during the 40-sec tone. This ratio is numerically equal to one when tone presentation causes responding to cease; it is equal to zero when tone fails to suppress responses. The use of a ratio controls for variations in baseline (non-tone) peck rate within and among sessions. It also provides a control for differences in the baseline rates among the several birds.

In general, different birds exhibited different baseline rates (slowest bird: approximately 50 responses per min; fastest bird: approximately 90 responses per min), but these rates were extremely stable over the years. Thus, neither the extended interruption nor any of the other conditions (suppression training, generalization tests, shock stress) changed a given bird's baseline rate by more than 5 responses per min (as measured by peck rate in the several pre-tone periods of a given condition). Moreover, such changes as did occur were never reliable.

The body of Fig. 1 shows the mean suppression ratio (across birds) for each presentation of the tone that had been previously paired with electrical shock (1000 cps). The insets at the top show successive gradients of stimulus generalization where each gradient is based upon the data from the four test sessions spanned by its inset.

Since in the initial test before the 2.5-yr interruption (Hoffman and Fleshler, 1961) different birds received different numbers of test sessions (12-25), only the last 12 sessions of these tests are shown. Thus, Fig. 1 summarizes the data from the last 12 sessions before the first interruption as well as the data obtained in the 40 test sessions administered thereafter. As can be seen, the behavioral effects of the original aversive procedures were extremely

inert. Suppression to the tone which had been paired with shock (the body of Fig. 1) extinguished very slowly, and in general the form of the extinction curve is ogival. Neither the earlier 2.5-yr interruption, nor the recent 1.5-yr interruption which preceded the present tests, yielded any loss in suppression. Indeed, suppression after the interruptions is, if anything, slightly higher than just before the interruptions.

As seen in the insets, as testing proceeded the slope of the gradient of stimulus generalization gradually increased despite the fact that the birds had never been subjected to discrimination training. By session 32, however, extinction of suppression had proceeded to the point where only the 1000 cps tone produced any suppression at all, and the degree of suppression it controlled was slight. Shock stress was introduced at this point and immediately increased the tendency for the several tones to suppress key pecks. In general, however, the birds continued to exhibit maximum suppression to the tone that had originally been paired with shock. Finally, suppression after the stress condition was slightly higher than just before it and remained higher across the most recent 1.5-yr interruption.

DISCUSSION

Razran (1939) and Wendt (1937) have found that classically conditioned responses are retained over interruptions as long as those employed here. Moreover, Thomas, Ost, and Thomas (1960) have found that the gradient of stimulus generalization of responses based on positive reinforcement exhibits negligible changes over a 21-day interruption in testing. The present results extend the implications of these earlier studies by simultaneously demonstrating the longevity and the specificity of the behavioral consequences of aversive procedures.

The overall picture that emerges from these data seems quite clear. When an initially neutral stimulus has consistently preceded a noxious event it acquires the capacity to suppress ongoing behavior, and stimuli which are similar to it also exhibit this capacity, but to a lesser degree.

This effect is remarkably resistant to change with the passage of time and, in the absence of specific experimental procedures, the stim-

uli retain their capacity to suppress behavior for a significant portion of the subject's life. (Pigeons live for approximately 15 yr. The interruptions in the present study totaled 4 yr.) Obviously time, in and of itself, does not contribute to the elimination of conditioned suppression, nor does it dull the subject's tendency to discriminate between the stimulus involved in the original conditioning and other similar stimuli. Rather, extinction occurs when stimulus presentation no longer leads to a noxious event, but even then the process is quite slow and the stimulus involved in the original conditioning is much more resistant to extinction than the stimuli on the wings of the generalization gradient. Finally, even when extinction is very nearly complete, a period of stress can lead to partial recovery of conditioned suppression and the effect can persist long after the stress has ended.

REFERENCES

- Hoffman, H. S. A flexible connector for delivering shock to pigeons. *J. exp. Anal. Behav.*, 1960, 3, 330.
- Hoffman, H. S. and Fleshler, M. Stimulus factors in aversive control: the generalization of conditioned suppression. *J. exp. Anal. Behav.*, 1961, 4, 371-378.
- Hoffman, H. S., Fleshler, M., and Jensen, P. Stimulus aspects of aversive controls: the retention of conditioned suppression. *J. exp. Anal. Behav.*, 1963, 6, 575-583.
- Razran, G. H. S. Studies in configural conditioning. VI. Comparative extinction and forgetting of pattern and of single-stimulus conditioning. *J. exp. Psychol.*, 1939, 24, 432-438.
- Thomas, D. R., Ost, J., and Thomas, D. Stimulus generalization as a function of the time between training and testing procedures. *J. exp. Anal. Behav.*, 1960, 3, 9-14.
- Wendt, G. R. Two-and-one-half year retention of a conditioned response. *J. gen. Psychol.*, 1937, 17, 178-180.

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